ECOLOGICAL VALUES of
DIKED HISTORIC BAYLANDS

By

Madrone Associates, Environmental Consultants

Philip Williams and Associates, Consultants in Hydrology

Jennifer R. Cherniss and Nancy Wakeman,
Staff of the
San Francisco Bay Conservation
and Development Commission

Revised FEBRUARY 1983

A Technical Report Prepared for
SAN FRANCISCO BAY CONSERVATION AND DEVELOPMENT COMMISSION

SAN FRANCISCO BAY CONSERVATION AND DEVELOPMENT COMMISSION
Thirty Van Ness Avenue, San Francisco 94102 557 - 3686

November 26, 1986

INFORMATION REGARDING OFFICE OF ADMINISTRATIVE LAW DETERMINATION CONCERNING THE COMMISSION'S DIKED HISTORIC BAYLANDS REPORT

On September 3, 1986, the Office of Administrative Law (OAL) ruled that with two minor exceptions, the Commission's Diked Historic Baylands of San Francisco Bay.....Findings, Policies, and Maps (October 21, 1982) (Diked Historic Baylands Plan) does not constitute a regulation under the Administrative Procedures Act (APA). The decision responded to a request from the Bay Planning Coalition to determine if the Commission had acted illegally when it had adopted the Diked Historic Baylands Plan without following the APA.

The two minor exceptions concern the two policies located at the bottom of page six of the Diked Historic Baylands Plan, which deal with development within diked historic baylands that are located partly within the Commission's permit jurisdiction. These two policies essentially indicate that such development should be permitted only if it is consistent with all applicable policies contained in the McAteer-Petris Act and the San Francisco Bay Plan and only if all wildlife values lost or threatened by such development will be fully mitigated. OAL concluded that unlike all the other policies contained in the Diked Historic Baylands Plan, which are only advisory because they apply only to areas outside the Commission's permit jurisdiction, these two policies are regulations because they deal with activities located within the Commission's permit jurisdiction and are therefore enforceable through the Commission's permit process. OAL further concluded that the existence of separate Commission mitigation policies in the San Francisco Bay Plan does not render the possible use and application of the mitigation policies in the Diked Historic Baylands Plan moot.

The Commission acknowledges that the language of the the mitigation policies contained in the Diked Historic Baylands Plan differs from the language of the mitigation policies contained in the Bay Plan. Nevertheless, the Commission believes that the existence of the mitigation policies in the Diked Historic Baylands Plan is irrelevant because the application of either sets of mitigation policies would result in the application of identical mitigation conditions to any given set of facts. Moreover, the Commission believes and fully acknowledges that the Commission must use only the mitigation policies contained in the San Francisco Bay Plan when it reviews permit applications for projects within its McAteer-Petris Act jurisdiction.

ECOLOGICAL VALUES

OF

DIKED HISTORIC BAYLANDS

A Technical Report

by

Madrone Associates, Environmental Consultants
Philip Williams and Associates, Consultants in Hydrology
Jennifer Cherniss and Nancy Wakeman, Staff of the San
Francisco Bay Conservation and Development Commission

This publication was prepared with financial assistance from the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, under the provisions of the Federal Coastal Zone Management Act of 1972, as amended.

Prepared for the San Francisco Bay Conservation
and Development Commission
as part of the BCDC Diked Historic Baylands Study

April, 1982

This technical report, by Madrone Associates
and Phillips Williams and Associates, was prepared as part of the Diked
Historic Baylands Study. The purpose of the consultants' report is
to document the biological and related values of diked baylands
and to explain their relationship to San Francisco Bay.
The technical report should be read in conjunction with the staff
report entitled "Diked Historic Baylands of San Francisco Bay."

C O N T E N T S

FIGURES

INTRODUCTION

A primary value of the diked historic baylands is the extensive and diverse wildlife habitat they provide around the periphery of San Francisco Bay. Though isolation from tidewater has modified diked areas, the wide variety of water regimes and vegetation adds greatly to the total habitat diversity of the Bay Area. Diked lands serve as buffers between urban and tidal areas, reducing the impact of development on wildlife. Many historic baylands serve as corridors for wildlife movement, connecting otherwise separated wetlands areas.

Diked baylands also contribute to improved water quality of the Bay by trapping pollutants from runoff and wastewater. Diked historic baylands act as interim storage basins for stormwater runoff that coincides with high tides, thus providing flood control benefits. Thus, even though the diked areas have no tidal interaction with San Francisco Bay, they function as an integral part of the estuarine ecosystem.

These ecologic values should be appreciated in addition to the diked historic bayland's high social value; these lands provide many recreational, research, and educational opportunities. Some diked lands are used for growing hay and oats, providing the North Bay dairies with essential forage.

The following report is divided into two sections. The first characterizes diked baylands according to their physical and biological attributes and current land use. The second section discusses the values and sensitivities of diked baylands, and the probable future condition of these lands were they to remain diked.

Appendix A describes some specific tidal marshes and types of diked areas around San Francisco Bay that were not included in the inventory. This discussion offers a basis for comparing the study sites and their conditions with natural and modified tidal conditions on the one hand, and with fully or partially developed conditions on the other.

PHYSICAL AND BIOLOGICAL ATTRIBUTES OF DIKED HISTORIC BAYLANDS

Physical Effects of Diking Tidal Areas

The major hydrologic effect of diking off an area from tidal action is to block both tidal exchange and freshwater drainage between the marsh and the Bay.

The effect on the Bay itself is to curtail the volume of water typically conveyed by the major channels and sloughs in and out of the tidal marsh system and to change local currents and water circulation. These changes in turn alter locations and rates of sedimentation around the Bay margin. More drastic changes occur inside the dike. An interruption of the hydraulic connection can indirectly alter substrate density and texture, soil and water chemistry, and land elevations. A diked area receives and traps both pollutants and sediments (including nutrients) from upland sources. And finally, the levee itself can influence land elevations within the diked area.

When a levee is constructed the former marsh becomes part of the upland watershed, representing a low point in the local drainage system. Freshwater runoff, collecting during the rainy season, either is prevented by the dike from being discharged to the Bay, or is partially discharged through tidegates or by pumping. An extreme submergence/evaporation regime often results. For example, a diked area may remain flooded through the wet season and become totally dry in the summer and early fall, creating conditions that are inimical to all but a few plant species. An unusually dry winter may subject a diked area to prolonged drought conditions, or a wet year subject it to a depth of flooding which precludes the establishment of new vegetation.

Freshwater inflow from uplands into diked areas often carries a variety of pollutants from urban and agricultural activities. Typical urban runoff includes suspended solids (sediment), nutrients, petrochemical residues from automobiles, and trace amounts of heavy metals. Typical agricultural pollutants are fertilizers, animal wastes, pesticides, and defoliants. These pollutants accumulate and concentrate in the diked wetlands.

Diked areas are also subject to extremes in soil salinity levels. Salts accumulate in some cases because diking prevents periodic flushing; salts remaining in the soil concentrate at the surface during annual summer evaporation. Winter rainfall and ponding leach salts from the soil, but if leachate cannot drain from the diked area, salts continue to build up in top layers, reaching levels as high as 60 to 70 parts per thousand (ppt). This level may be compared to San Francisco Bay waters which have an average of 25 to 30 ppt salinity, and to the Pacific Ocean waters which have about 35 ppt.

Salts may also have accumulated in local topographic depressions. Where these "pans" occur in higher marsh elevations (i.e., about four feet above NGVD*), infrequent tidal inundation and subsequent evaporation concentrates salts at levels that, along with poorly drained soil, inhibit vegetation growth. These areas often persist and may be common features in some diked-off areas, resisting revegetation by invading plants.

Diked former bayland soils are also occasionally very acid (pH as low as five), especially where dredge materials have been recently deposited, partially filling the area and exposing typically anaerobic muds to oxidation. Leaching of acid by winter rains is slowed by impermeability, by the inability of the leachate to drain away, and by the absence of tidal flushing.

Diking can also lead to subsidence, the lowering of the natural land elevation. Bay sediments are usually composed of fine clay particles, separated by moisture. Saturated clay particles occupy greater volume than dry clay particles. With diking, the resulting absence of moisture causes the clay particles to dry out, compact, and consolidate, forming surface crusts with deep cracks. Because dry clay soils do not reabsorb moisture readily, once dried the soils remain compacted. The elevation of the diked area may thus become considerably lower than before the diking occurred.

Consolidation and compaction, when accompanied by oxidation of exposed organic material, may cause surface subsidence greater than that which occurs through normal geologic processes. For example, diked farm lands in north

---

* A variety of elevation standards are used by people involved in wetlands restoration. The following definitions are some of the more common encountered in the marsh business:

Datum is a base elevation used as a reference from which to reckon heights and depths. It is called a tidal datum when defined by a certain plane of the tide.

Mean Sea Level (MSL) is a tidal datum: the arithmatic mean of hourly water elevations observed over a specific 19-year cycle.

The National Geodetic Vertical Datum 1929 (NGVD), formerly known as the Sea Level Datum of 1929, is a reference adopted as a standard geodetic datum for heights. The geodetic datum is fixed and does not take into account the changing standard of sea level.

Points on land can be referenced to a mean sea level, in which case the datum assumes zero elevation. To avoid confusion, when referring to restoration projects, heights should be identified on NGVD. Usually points are referenced to a local Mean Lower Low Water (MLLW) based on the National Geodetic Vertical Datum.

Marin County, Napa Marsh, and many other areas have subsided three to five feet from evaporative consolidation, oxidation, and other related surface factors caused by diking alone. Diked baylands along the Alameda County shoreline demonstrate similar surface subsidence. In contrast, in the Palo Alto Baylands, subsidence due to groundwater withdrawal alone lowered land elevations by three feet between 1930 and 1960 (J. E. Poland in Atwater, et. al. 1979).

Elevation does not always change in a uniform manner. Marsh soils often settle differentially, especially under the random placement of fill or dredge spoils. Thus, surface topography can be quite irregular, creating distinct wetland microenvironments within a superficially homogeneous area.

Irregular elevations may also be created by the weight of a levee structure itself or by subsequent loading of fill. The low shear strength (resistance to lateral displacement) of Bay sediments requires that levees have gradual side slopes, typically resulting in an elevated section with a wide base. The resulting mass of material may exceed the foundation strength of the underlying sediments, causing subsidence and mud heaving (mud "waves") in adjacent areas. As consolidation under loading occurs over a period of time, mud waves may appear many years after the initial diking and filling.

Effects of Diking on Vegetation

These same physical effects behind dikes also influence whether vegetation will be present and the composition and distribution of marsh plant species that do occur. Some plants recolonize or persist in diked areas, providing some habitat resources for wildlife. Certain conditions preclude any vegetation from surviving or readily reestablishing after diking. Other conditions may lead to patchy distributions and a mosaic in lieu of the more typical zonation of tidal marsh vegetation. Finally, there are several species which "exploit" disturbed marshes and serve as useful indicators of change in the growing conditions.

In typical tidal salt marshes, lower elevations are dominated by cordgrass (*Spartina foliosa*), while higher elevations are dominated by pickleweed (*Salicornia pacifica*). In most diked San Francisco Bay marshes, the primary vegetation species is pickleweed. Cordgrass is eliminated when regular tidal action is eliminated, but is a common colonizer outside new dikes where shoaling reaches the appropriate elevation. Most other halophytes (plants associated with saline soils) and hydrophytes (water loving plants) which are common in the Bay Area can survive to some extent under the limiting conditions imposed by diking, although extreme conditions of prolonged submergence or drought, acidity, and hypersalinity can eliminate vegetation entirely or selectively. Diversity of plants is thus usually curtailed.

The change from tidal salt water to freshwater runoff as the primary water supply, in itself, has little direct effect on typical salt marsh plants in a diked wetland, most of which can germinate and survive in a freshwater environment. Residual soil salinity is the more important influence. However, as the environment becomes progressively brackish-to-fresh, other species, which were unable to compete with halophytes in a saline environment, may compete successfully and begin to replace salt marsh species. The amount, frequency, and drainage of freshwater determines the composition and extent of this vegetation.

In diked salt marshes in which accidental or sporadic tidal waters enter--as seepage, for example--cordgrass may persist along channel margins or in areas where water enters and drains with sufficient frequency and salinity is not excessive. Persistant standing water, i.e., prolonged submergence of the root zone, will eliminate cordgrass. Since circulation is blocked in most diked wetlands, cordgrass may remain for a period of time following diking but eventually dies out.

Most perennial pickleweed species (e.g., S. pacifica) are also eliminated where water remains ponded, although annual species (e.g., S. bigelovii) appear to tolerate slightly longer submergence and frequently exploit the wet margins of ponds in diked marshes. Algae and widgeon grass (Ruppia maritima) are often the only plants evident in such ponds.

Prolonged drought in summer months typically follows prolonged winter submergence in diked areas. Since seasonal evaporation also concentrates salts in the soil, the growing environment supports a limited number of salt tolerant species. In addition to pickleweed, tolerant species include those common in high marsh and on peripheral lands and dikes around the Bay, e.g., alkali heath (Frankenia grandifolia) and salt grass (Distichlis spicata). Brass buttons (Cotula coronopifolia) is a notable invader of diked and otherwise disturbed wetlands, seeding profusely and germinating in the receding spring water line of evaporating ponds. Fat hen (Atriplex patula var. hastata) also colonizes disturbed marshes where water is sufficient for annual germination.

The most stressful conditions of drought, soil compaction, and salinity on the periphery or on high spots within diked historic baylands are tolerated by such species as spurrey (Spergularia ssp.), plantain (Plantago juncoides), and the "sickle" grasses (Monerma cylindrica and Parapholis incurva). These areas, which occur in the form of dried dredge spoils, levees, or otherwise partially filled diked lands, also support coyote brush (Baccharis pilularis), toyon (Heteromeles arbutifolia), salt bush (Atriplex semibaccata), and a number of exotics such as pampas grass, acacia species, escaped garden shrubs, and "weedy" annuals and grasses. The "ruderal" habitat thus formed is useful for terrestrial wildlife. Newly exposed dredge spoils, especially hydraulic slurry, can remain barren for a number of years in the absence of sufficient freshwater leaching and drainage or tidal flushing. High acidity, together with a hard surface crust that forms in a recently diked and drying marsh or on dredged spoils inhibit both germination and root penetration and establishment of new plants, unless some plant fragments, such as roots, remain from the prior tidal marsh. Clamshell dredging retains soil structure, vegetative plant parts, and seeds. This dredging method allows recolonization much more rapidly than hydraulic slurry dredging. There is abundant evidence around the Bay of spoils piles and levees produced in this manner which have revegetated naturally (e.g. Bair Island, Redwood City).

Condition and Wildlife Use of Diked Historic Baylands

Although diking has altered, and in many cases drastically or partially reduced, the habitat value of historic baylands, these areas still support many species and significant populations of wildlife that feed, reproduce, rest, and take cover in the diked areas. The following section discusses in detail the diverse habitat conditions found in San Francisco Bay diked historic baylands, and their extensive use by water-dependent wildlife.

For discussion purposes, diked historic baylands are grouped into three major habitats: (1) marshes (areas which are predominantly wet, seasonally or year-round); (2) non-wetlands, such as agricultural lands (areas which are predominantly dry); and 3) ponds. BCDC study sites generally fall into one of these categories. In reality, many study sites display characteristics of more than one type, reflecting the original purpose of diking, the length of time that the area has been diked, the subsequent use of the land, and management practices (or lack thereof) which have been applied since diking. It should be noted that the use and management of diked lands has not necessarily been consistent over time.

The following habitat groups, and habitat types within those groups, represent the current and predominant condition of study sites.

Diked Marshes

BCDC classified diked marshes into four habitat types:* salt marsh, brackish marsh, freshwater marsh, and seasonal wetland with pickleweed (or other hydrophytes). This last type is a hybrid class that includes either salt or brackish marsh, depending on water regime.

Modified or diked marshes add to the Bay ecosystem diversified habitat for wintering and migratory puddle ducks, for wading birds, rails, raptors, and a variety of perching birds (salt marsh yellowthroat, long-billed marsh wren, blackbirds) that feed, nest, and take cover in marsh vegetation. Mammals, reptiles, and (in freshwater wetlands) amphibians are common. Fish and aquatic invertebrates inhabit the channels of diked marshes; their diversity and abundance is dependent on the amount of water entering and circulating in the marsh.

---

* BCDC staff chose to classify habitats into these very broad categories. The environmental consultants did not participate in this initial classification.

One important feature of many diked historic baylands is the seasonal water that collects after rains. Even though this water remains for a relatively brief portion of the year, the wet period coincides with periods of maximum concentration of waterfowl and shorebirds in the Bay Area. Rain triggers soil dwellers to move to the surface, where birds feed on them. Life cycles of many insects and (in freshwater areas) amphibians are also timed to rainfall. This food resource attracts waterfowl and shorebirds to seasonal wetlands. Because food-producing wetland habitat has diminished in the Bay Area, diked wetlands have increased in importance as a food source.

1. Diked Salt Marsh

Some historic baylands in San Francisco Bay have been enclosed by dikes but have not been otherwise substantially altered. Examples occur along the San Leandro and Hayward shoreline. Sources and amounts of fresh and salt water entering these diked lands vary. In all cases, winter rainwater that falls directly onto the area is the principal source of freshwater that ponds throughout winter and spring and evaporates gradually in summer. The typical impermeability of underlying Bay muds precludes any percolation of the ponded water. Freshwater may also enter diked areas through conduits carrying stormwater runoff from adjacent uplands.

Saltwater occasionally enters when high tides overtop levees, when seepage passes through poorly maintained levees, and when tide gates originally placed for stormwater discharge malfunction.

In all of these situations, portions of the marsh are more or less wet year round, even though the area is effectively cut off from regular hydraulic connection with the Bay. Salinity levels in the soil are typically high. In the absence of tidal flushing, such marshes undergo gradual physical and chemical changes, but historic meanders and surface features may remain relatively intact. Within the relatively homogeneous habitat, topographic variations account for different surface water ponding and salinity conditions. Vegetation reflects these physical variants. As with the majority of fully tidal salt marshes around the Bay, vegetation is dominated by species of pickleweed growing in continuous or dispersed stands, depending on the presence and average depth of surface water. The extent of total plant cover varies greatly with individual site conditions.

Conditions in the aquatic habitats of diked salt marshes are similar to those occurring in high tidal marsh pools and channels that are isolated from tidal flushing except during extreme high tides. These areas usually have bottoms of soft mud. Throughout much of the year, filamentous green algae (*Enteromorpha clathrata*) occur in open, sunny areas. Waterboatman beetles (*Trichocorixa reticulata*), and amphipods (*Anisogammarus confervicolus*, a crustacean) are generally abundant. Three species of fish are fairly common where standing water is maintained year-round: mosquitofish (*Gambusia affinis*), threespine stickleback (*Gasterosteus aculeatus*), and rainwater kill fish (*Lucania parva*). However, fish diversity and abundance is lower in diked ponded areas than in tidal marshes because tidewater is restricted (Balling *et al.*, 1980).

A great variety of wildlife species inhabit diked salt marshes; their use is similar to that described for salt marshes with restricted tidal access, or those that receive only occasional extreme high tides (see Appendix). Marshes that receive sufficient periodic water (such as former, now inactive, salt ponds) or year-round water sustain enough vegetation to provide food and/or cover for many wading birds, sparrows, and raptors. Avocet and black-necked stilt are particularly evident in sparsely vegetated inactive salt ponds. These species along with song sparrow, marsh hawk, and a few puddle duck species nest in the vegetation. Diked salt marsh provides habitat for the endangered salt marsh harvest mouse and a number of other small mammals and reptiles. Seasonal salt marshes with pickleweed are a variant of this habitat type; they have a more limited water supply, and correspondingly less vegetation cover and more selective wildlife use.

Diked salt marshes which are sufficiently wet year-round to have the characteristics described above are found in San Leandro and Hayward, Alameda County. On Bair Island, San Mateo County, former salt evaporation ponds also display the typical microtopography of a diked salt marsh. Small seasonal pickleweed marshes are scattered throughout the Bay shoreline.

Several diked areas which were operated as salt ponds in the late 19th and early 20th centuries have largely returned naturally to salt marsh habitat. Evidence of their past use remains in the surrounding deteriorated dikes and the systems of drainage meanders developed during salt evaporation in response to drainage from dikes and borrow channels. Pickleweed grows around the remaining segments of old dikes. Central pond areas sustain stands of cordgrass. Fish and wildlife use is much the same as in unmodified tidal salt marshes. Abandoned salt ponds are found at Mt. Eden Creek and the Coyote Hills Flood Control Channel (Old Alameda Creek) in Alameda County.

Typical examples of diked salt marsh habitats in the BCDC inventory are described below.

Example: San Leandro Bayfront. (Nielsen and Josselyn, 1979) Many of the diked wetlands which ring the Bay display a combination of salt marsh and ruderal/upland vegetation. Marshes bordering the Alameda Transportation Corridor (Alameda County) represent this combination of habitat types. These sites are located along the San Leandro bayfront and border the San Lorenzo Creek Flood Control Channel, extending northward to the Ashland-Washington Flood Control Channel. Most of the area does not receive tidal inflows; some bay water over-tops the northeastern levee during storms. Several ponds and old slough channels remain on the San Leandro bayfront site and collect stormwater during winter months.

Vegetation on this site forms indistinct zones from the bayfront to the interior edge. Seasonal ponds are confined to low elevation lands bordering the sandy Bay edge. These ponds are lined with pickleweed that forms lush monotypic stands. On higher areas of the marshland and intermixed with pickleweed are several species of halophytes including alkali heath and brass buttons. Ruderal vegetation occupies a strip along the interior portion of the San Leandro bayfront site. This zone is at a higher elevation and has no seasonal ponds. Coyote brush, sweet fennel, and curly dock are distributed among a cover of annual grasses forming a thick vegetation cover.

Between these two strips is a transition zone containing species of both ruderal and wetland communities. Transitional areas such as this are common in both diked and tidal baylands that are progressively changing from salt marsh to upland habitat.

Wildlife use on this site reflects the mixed conditions; there is an evident separation between those species that use the salt marsh primarily and those that prefer ruderal areas. Wintering waterfowl and migratory shorebirds feed on invertebrates and vegetation in the seasonal ponds. Black-necked stilt and American avocet also use these ponds, nesting in the pickleweed. The most common shorebirds on the site are marbled godwit, dowitcher, dunlin, and western sandpiper. Wading birds, such as great and snowy egret and great blue heron, feed along the edges of ponds and channels. Waterfowl take refuge from Bay storms on the seasonal ponds and adjacent vegetation during winter months. Pintail are very abundant on the site as are cinnamon teal, American widgeon, and northern shoveler. Nevertheless, the lack of permanent water bodies in the marsh limits its year-around use by shorebirds and waterfowl compared to a tidal situation.

The ruderal and adjacent transition zone vegetation add useful variety to this bayside habitat complex. Areas of tall, dense coyote brush and fennel provide cover for many perching birds. Annual grasses mixed among these bushes are a food source for sparrows, finches, and other species. Small mammals such as the California vole, house mouse, black-tail jackrabbit, and ground squirrel inhabit ruderal vegetation. This variety of small birds and mammals provides a food source to the larger raptor species including white-tailed kite, burrowing owl, short-eared owl, marsh hawk, and red-tailed hawk. The transition area, while serving as habitat for many ruderal species, also acts as a buffer from disturbance for the salt marsh zone. In addition, some waterfowl and shorebirds nest in the transitional wetlands bordering ponds. Waterfowl and shorebirds, as part of their daily activities, need an area to "haul out"--sun, preen, and rest.

<u>Example: Fremont Bayfront</u> (Environmental Science Associates, 1981). A 552-acre diked marshland borders both Mud Slough and Coyote Creek on the Fremont bayfront in Alameda County. The area is adjacent to a parcel of San Francisco Bay National Wildlife Refuge and north of the Fremont airport. The site demonstrates transition from diked salt marsh along the Bay edge to upland vegetation lining the interior area. The diked salt marsh (approximately 300 acres) is partially covered by a mixture of pickleweed, alkali heath, and fat hen. The salt marsh area is separated from the tidal water of Mud Slough and Coyote Creek by a levee, but saline water may overtop and intrude into the marsh. Rainwater collects in old tidal channels and low depressions on the marsh surface.

Along the interior edge of the salt marsh is a transitional area, in which upland grasses and halophytic species are intermixed. An exact separation line between the two vegetation types is not readily apparent to the observer, although zonation studies have made such determinations based on transect surveys (Harvey, et al., n.d.).

The interior portion of this Fremont bayfront site contains upland grass species including farmer's foxtail, ripgut, soft chess, and Italian ryegrass. Other weedy species such as mallow and thistle are scattered over this area.

Located in the upland zone of this parcel is a farming operation. Small farm structures and a barn housing farm animals are centered in the upland area. Cattle graze over the entire site.

Shorebirds, including curlew, killdeer and black-necked stilt, feed on insects and invertebrates in the seasonal ponds, adjoining mudflats, and ruderal areas, and rest in higher marsh areas during high tide. Resident birds of the upland area include western meadowlark, burrowing owl, mourning dove, several species of sparrows, and finches. Small mice, black-tail jackrabbit, and ground squirrels comprise the mammalian residents. The endangered salt marsh harvest mouse may inhabit pickleweed stands on the site. Wildlife use of this diked historic bayland site is restricted by human disturbance of the habitat. Not only do farming operations disturb nesting birds and normal feeding habits of wildlife, but poachers and packs of feral dogs kill animals. Both domestic and wildfowl have been shot on the site and in the adjacent National Wildlife Refuge.

2. Brackish Marsh: Unmanaged

Formerly a common habitat around the Bay, this category now consists of a few diked areas which receive sufficient storm runoff to remain relatively fresh or are located in the northernmost extremity of the Bay where local salinities are strongly influenced by freshwater inflow from the Delta. In spring and summer, brackish marshes either slowly dry by evaporation or are sustained by high groundwater or other sources of fresh or brackish water inflow. Residual soil salinity depends on the amount of freshwater input, the period during which the wetland has been maintained, and the extent to which water is able to drain. Marshes which drain year-round are not as saline as those with only seasonal drainage. Under natural conditions, in the past, brackish-to-fresh wetlands developed where streams entered Bay marshes and obstacles such as sediment and vegetation formed, separating fresh from saline lowlands. They also developed as tidal marshes in San Pablo Bay and on both shorelines of Suisun Bay.

The plant species composition and wildlife use of brackish marshes are best described in the context of an example.

Example: Moffett Field Marsh (Environ and Madrone Associates, 1981). The Moffett Field Naval Air Station marsh in the South Bay is maintained by both stormwater runoff and cooling water discharge. It demonstrates the interaction of saline soils with freshwater inflow and infrequent tidal inflow over surrounding levees, to produce a brackish-to-fresh marsh. The stormwater retention pond and its bordering lands exemplify a diked brackish marshland. Located within the historic marsh margin, the marsh was diked off from tidewater during construction of the air station. The pond now receives storm waters draining from the west side of Moffett Field. Water is pumped out of the pond and into Stevens Creek, an adjacent tidal channel.

Many varieties of wildlife favor this combination of a year-round open water habitat and adjacent brackish marshland. Freshwater vegetation composed of cattails, sedges and rushes, as well as salt marsh species (pickleweed and heath) are found in distinct groupings along the borders of the pond. Differences in the amount of water inflow, salinity, and drainage patterns account for the presence of these two distinct vegetation types within the pond of the Moffett Field marsh.

Migratory waterfowl such as ruddy duck, canvasback, lesser and greater scaup, and American widgeon rest on the open water of this pond. During winter storms when Bay waters become turbulent, the storm retention pond and adjacent salt ponds serve as a refuge for the ducks. In addition, a small freshwater marsh at the southeastern portion of the pond, provides both cover and limited nesting sites for mallard, gadwall, pintail, northern shoveler and cinnamon teal. Freshwater marshes are uncommon in the South Bay, though they provide an important habitat to nesting waterfowl. The use of the Moffett site as a stormwater retention pond has allowed establishment of this marsh.

Ruderal vegetation provides additional habitat on the Moffett Field site. Composed of grasses and weedy plant species, the narrow borders of ruderal vegetation cover the peripheral levees of the pond. This strip is inhabited by birds (white-crowned and song sparrows, western meadow lark, burrowing owl) and mammals (ground squirrels, grey fox, black-tail jackrabbit). Several types of shorebirds (stilts and avocets) and terns (least and Forester) use such minimally disturbed levee areas as nesting sites.

A 25-acre diked salt marsh located in the southwestern corner of the Moffett Field site is habitat for wintering and resident shorebirds. Black-necked stilt, killdeer, least sandpiper, and American avocet feed on small insects in the seasonal ponds within the marsh. This salt marsh is composed almost entirely of pickleweed and receives no direct tidal inundation. Immediately adjacent is Stevens Creek, a tidal channel with well developed corridors of both cordgrass and pickleweed.

3. Brackish Marsh: Managed

Many brackish tidal marshes in San Francisco Bay were diked in the late 19th century and have since been operated as duck hunting clubs. The marshes are managed with the goal of providing optimum habitat for selected species of waterfowl through management of water levels and salinity for preferred food plant species. Brackish water is removed from the marsh and freshwater redirected from sloughs into the marsh to create growing conditions that favor certain native and introduced food plants. Water is also added and drained to maximize seed production. Water levels maintained at eight to 12 inches in depth from September to January sustain a food supply which encourages use by particular migrating and wintering waterfowl species favored by hunters.

These habitat manipulations encourage growth of alkali bulrush (*Scirpus robustus*), smart weed (*Polygonum lapathifolium*), brass buttons, and marsh timothy (*Heleochloa schoenoides*). Certain plants are deliberately discouraged by water depth control, timing of salinity levels, and burning. These plants, including cattails (*Typha* sp.), tule (*Scirpus acutus* and *S. californicus*), and Baltic rush (*Juncus balticus*), provide cover but not food for waterfowl. Managed brackish marshes favor dabbling ducks; mainly pintail shoveler, wigeons and mallard. Many small crustaceans, such as amphipods, are common in the ponds. Small fish, such as mosquitofish (*Gambusia* sp.), are often stocked for mosquito control.

4. Freshwater Marsh: Unmanaged

There are relatively few natural freshwater marshes around the Bay in former tidal areas, although small freshwater marshes were once a common feature where streams entered the Bay and were blocked by sediments or other obstacles (see Brackish Marshes, above). The areas which do remain are largely dependent on seasonal rainwater and sufficient ponding or high ground water to sustain vegetation through the summer dry season.

The plants colonizing these marshes are mainly cattails, with a few scattered stands of tules or hard stem bulrush, and, on higher ground, willows. Cattail spreads by rhizomes (rather than seed), which explains its typical dominance in freshwater marshes. Water plantain (*Alisma plantago-aquatica*) is also found.

Diked freshwater marshes are heavily used by birds and mammals, even though, in the San Francisco Bay Area, many of these areas are small and in close proximity to human activities and disturbances. For example, it is not uncommon to find nesting black-crowned night heron, or courting and nesting red-winged blackbird, song sparrow, white and golden-crowned sparrows, house finch, brown towhee, robin, scrub jay, mourning dove, yellow-rumped warbler, violetgreen and barn swallows, chestnut-backed chickadee, and American and lesser goldfinches, as well as large numbers of feeding puddle ducks, shorebirds, and wading birds (Madrone Associates, 1975). At least 50 species of birds could be expected to use this type of marsh, with a number of aquatic species occurring in ponded areas (Burns, 1972).

Examples of freshwater wetlands--largely seasonal, former baylands--are found in ponds and marshes near Highway 101 and Roseland Boulevard in Novato, Marin County; in the large fresh-to-brackish flood retention area at Moffett Field, Santa Clara County; and other pockets of freshwater marsh in Alameda and Contra Costa Counties.

5. Freshwater Marsh: Managed

At least two diked former salt marshes in San Francisco Bay are now managed as freshwater marshes for fish and wildlife purposes, providing habitat that is no longer common in the Bay Area. Management involves control of water level and salinity, with limited vegetation manipulation. Prior to their management as freshwater wetlands, both of these diked areas collected storm runoff from surrounding hills. The East Bay Regional Park District's (EBRPD) Coyote Hills Regional Park (Alameda County) freshwater marsh is sustained by well water during dry seasons. At Bel Marin Keys in Marin County a recently enlarged pond falls into this category but does not yet sustain vegetation.

Example: Coyote Hills Marsh. (Madrone Associates, 1979-80) The perimeter of the Coyote Hills marsh is approximately five feet above mean sea level. Plants dominating this area are cattails (Typha latifolia, T. angustifolia, T. domingensis and hybrids), tules (Scirpus acutus), spike rush (Eleocharis sp.), nut grass (Cyperus esculentus), bur-reed (Sparganium sp.), and water plantain. According to Southworth (pers. comm.), 188 species of birds have been observed in the freshwater habitat of Coyote Hills. The marsh and associated ponds contain the largest known nesting site of tri-colored blackbird in the South Bay area. Salt marsh yellowthroat and long-billed marsh wren breed in good numbers at Coyote Hills. Snowy egret and great blue heron also use the marsh for feeding and resting. The area provides habitat for many mammals including the muskrat, gray fox, long-tailed weasel, raccoon, striped skunk and beechy ground squirrel. The water supports at least five species of fish, and approximately ten species of amphibians and reptiles also occur at Coyote Hills.

Other Managed Habitats in Diked Historic Baylands

Diking of historic baylands has generally been undertaken to create and manage land for a specific purpose, typically to create dry land. Thus, many tidal wetlands were diked in the 19th and early 20th century and are continually pumped to create farmland.

Both deliberately and fortuitously, some historic baylands have been diked by their owners to remain as full or partial wetlands, in some cases for interim uses (assuming eventual filling) and in some cases for long term uses. The brackish marshes managed for waterfowl exemplify the latter case (see above), as do a few situations in which grazing has been found to be compatible with seasonal wetland. In other cases, already diked lands have been put to use as seasonal flood control basins and to create marsh using secondarily treated municipal wastewater.

1. Diked Salt Marsh Used for Grazing

Several small tracts of diked marsh in the Bay area are used to graze cattle. Vegetation on these lands is limited to sparse natural and largely introduced vegetation. Direct human interference varies from site to site. Some such areas have undergone subsidence due to gradual loss of groundwater as well as diking.

Pickleweed and nonnative annual grasses cover these sites, limited primarily by selective grazing. Grazed areas are used primarily by the small perching birds common in fields and disturbed areas (e.g. blackbirds, sparrows, house finch, meadowlark, and mourning dove), and raptors.

Examples of this habitat exist along the San Francisco Bay shoreline south of San Lorenzo and west of the Hayward Air Terminal in Alameda County; and areas south of the intersection of Highway 121 and Highway 37 (Sears Point Road) in Sonoma County, and east of the Napa River in Napa County. The Stanley Ranch, along the west side of the Napa River, just south of the new Highway 121 southern crossing, is another diked salt marsh used for grazing. Elevation in the Alameda County areas has dropped to 2.5 feet below MHHW. The Sonoma and Napa County sites are four to five feet below MHHW.

2. Diked Salt Marsh Used for Flood Control

As substantial areas of the Bay tidal and flood plains have been diked and developed, the need for flood protection for surrounding low lying areas has become more apparent. Diked lands which are not yet filled act as interim storage basins for stormwater runoff that coincides with high tide. Because the land elevation in the basin is several feet lower than external tide levels, storm drains can discharge freely from the surrounding areas until the basin fills. Water is discharged from the basin to the Bay either by pumps or through tide gates that open when the tide goes down.

Flood basin use of diked wetlands can partially restore some salt marsh values. Prolonged rainstorms produce large volumes of runoff in the winter months from November to March when much of the salt marsh vegetation is dormant. Tidal action can be introduced through tide gates from April to October and shut off during the flood season. Freshwater inflow to the marsh can be beneficial in creating a range of brackish water conditions at the salt marsh edge.

In some cases, as in the Palo Alto Flood Basin (see below), the maximum tidal elevation that is allowed to enter must be restricted because of overall subsidence of the marsh plain. The tidal in- and outflows, therefore, have to be closely controlled.

Salt marshes used as flood control areas are vegetated by pickleweed, salt grass, dock (Rumex sp.), and annual grasses or hay. Egrets and herons frequent the small seasonal ponds and marshes, and puddle ducks are abundant in the extensive winter ponds. Some aquatic species are present, such as aquatic insects and small fish (sticklebacks).

The Novato, Marin County, floodplain contains areas of seasonal marsh/pastureland drained by Rush, Basalt and Novato Creeks. Other examples of diked marshes used specifically for flood control are the Palo Alto Flood

Control Basin in Santa Clara County, and Alameda County Flood Control Basin adjacent to Coyote Creek in Alameda County.

3. Waste Assimilation and Treatment in Diked Basins

Use of the wetlands as a stormwater retention basin during the winter can be integrated with "treatment" of stormwater and/or wastewater, removing by biological means some of the pollutant load, while still providing fish and wildlife habitat.

Wetlands are known to remove a number of pollutants from urban runoff or partially treated wastewater effluent; they are sometimes referred to as a natural "tertiary" wastewater treatment process because the specific pollutants they remove most effectively, nutrients and heavy metals, are not effectively removed in a conventional secondary level sewage treatment plant. (A more detailed discussion appears on pages 28-30).

Example: Palo Alto Flood Basin. (Association of Bay Area Governments, 1979). The only flood basin in the Bay Area whose effectiveness in assimilating pollutants in stormwater runoff has been studied is the Palo Alto Flood Basin.

The diked 600-acre Palo Alto Flood Basin was formerly an extensive natural tidal salt marsh. The basin is supplied with water from two sources: freshwater storm runoff from Matadero, Barron and Adobe Creeks, and controlled tidewater which enters through a tidegate at the Bay entrance to Mayfield Slough. Tidewater inflows are regulated through an electronically controlled tidegate installed and maintained by the City of Palo Alto Public Works Department. Outflows of both fresh and saline water occur through a series of 16 flap gates adjacent to the tidegate. The basin is managed to achieve several goals. Its primary function is as a stormwater retention area. In addition, five habitat types--brackish marsh, freshwater marsh, tidal marsh, upland (on levee), and grassland--occur in and around the basin. The combination of these habitats, in association with adjacent tidal habitats, provides unusual diversity in the Palo Alto Baylands.

The freshwater edge of the basin supports typical freshwater marsh plants, such as species of cattails, common rush, bulrush, and sedge. Other "weedy" plants typical of wet depressions include water plantain, horseweed, wild radish, alkali mallow, and willow, all of which provide cover for coot, marsh wrens, puddle ducks and redwinged blackbird. The brackish and saline portions of the basin support vegetation and wildlife that are typical of diked salt and brackish marshes.

Levees of the Palo Alto Flood Basin are vegetated by weedy species which provide marginal habitat at high tides for a number of marsh wildlife species, among them the endangered salt marsh harvest mouse. Common plant species include Australian saltbush, fat hen, coyote brush, thistles and annual grasses, marsh grindelia, curly dock, and others. Levee habitats are used by ground squirrels, willet, sandpipers, plovers, gulls, mourning dove, and other birds and small mammals.

Grasslands are represented in the Palo Alto Flood Basin by a diverse mixture of annual grasses and forbs. In the saltier soils and in wet depressions subject to evaporation and salt deposition, pickleweed predominates, along with fat hen, salt grass, alkali ryegrass and alkali heath. These areas are heavily used by wildlife. For example, the short-eared owl breeds in the Palo Alto Baylands and is abundant in the flood basin. Pheasant breed in the flood basin, and other seed eaters and raptors are characteristic bird fauna. White-tailed kite, red-tailed hawk, and short-eared owls feed on abundant small rodents in the basin; burrowing owls feed on insects there.

Example: Mountain View Sanitation District, Contra Costa County. There is only one case in the Bay Area (Mountain View) in which a freshwater pond is used for treating municipal wastewater. The concept has been tested in other areas and is becoming more prevalent.

Although the condition of the wastewater and the particulars of site management vary with different treatment projects, water from waste sources is typically high in nutrients, especially phosphates and nitrogen. Relatively untreated sewage contains nitrogen in organic compounds and as ammonia. In secondary effluent, nitrogen exists primarily as nitrates. High nutrient levels encourage lush algal growth, which binds nitrates into organic "food" compounds, used by higher life forms. However, when large quantities of algae "bloom" and die, the process of decay seriously depletes oxygen in the water. Decreased oxygen levels can result in fish kills and other biomass dieoffs. It also contributes to conditions that are conducive to growth of wildfowl botulism and other potentially harmful bacteria.

A managed wastewater marsh is operated by the Mountain View Sanitation District in Contra Costa County. This marsh removes some of the nutrient load from the wastewater effluent, and also provides useful wetland and pond habitat.* More than 100 species of birds have been observed in the Mountain View marsh (Demgem, pers. comm.). Muskrats are one of the most common mammals inhabiting the marsh. These furbearers sometimes cause maintenance problems by burrowing into the dikes. Cattails (*Typha* sp.) and tules (*Scirpus acutus*) thrive in the nutrient rich waters. These plants do not supply much food for wildlife but do provide important cover and nesting sites. Other vegetation includes sago pondweed (*Potamogeton pectinatus*) and planktonic and filamentous algae.

Numerous invertebrates, including amphipods, mayfly nymphs, dragonfly nymphs, waterboatman beetles, and snails, inhabit the water. The ponds are stocked with mosquitofish, which eat invertebrates and control mosquito populations. Fish and invertebrates inhabiting the waters provide food for terrestrial mammals and wading and diving birds.

---

* Habitat enhancement, as opposed to waste treatment, is the primary function of of this project.

Non-wetlands

Terrestrial areas supporting non-wetland vegetation can be of great importance to wildlife, particularly if they act as a buffer between developed land and nearby wetland habitats. A number of diked historic tideland areas have been filled or managed as dry land and, if left undeveloped, will remain terrestrial habitats resembling native uplands.

Upland areas adjacent to freshwater are the preferred nesting habitat of puddle ducks. Eucalyptus windrows serve as wildlife corridors, perches, and breeding habitat for birds and mammals that use the wetlands. Shorebirds occasionally flock on high patches of barren ground near the Bay when forced out of other habitats by high tides. Dikes are also used by many species of breeding birds. Dikes covered with sand and broken shells attract nesting least tern, an endangered species. Perching birds, raptors, and small mammals commonly inhabit upland, ruderal, and agricultural habitats.

Cultivated areas generally support a limited number of wildlife species (especially breeding animals) because they lack vegetation diversity and undergo frequent disturbance. However at certain times of the year (e. g., during plowing or with seasonal flooding) they may draw large feeding flocks of a few bird species.

1. Diked Historic Baylands Used for Dry Land Farming.

In the late 19th century, broad expanses of marsh in rural Marin, Sonoma, and Napa Counties were diked, ditched, and drained for dry land farming. Some of these marshes were long established when diked, others were formed relatively recently. The age of the marsh when diked is a major factor determining its eventual elevation, which in turn affects ecological properties.

The more recent marshes were created by deposition of sediment from hydraulic mining in watersheds of the Sacramento River and other Delta rivers. Marsh fronts in the North San Pablo Bay advanced at a rate greater than 30 feet per year during the period of heavy sedimentation that followed the hydraulic mining era. Marshes created by this rapid siltation had not yet settled and consolidated when diking and draining occurred. These "leading edge" marshes have consolidated more since diking. Thus, surface subsidence has been greater in former "young" marshes than in "older" marshes, lowering surface elevations from four to nine feet below MHHW, depending on the age of the marsh when diked and the time elapsed since diking.

Because of their low elevation relative to both Bay and upland, these low fields collect rainwater and function as seasonal wetlands unless regularly pumped to maintain their dry condition. In addition, seepage through levees is common from the adjacent Bay. Vegetation and wildlife use are thus directly dependent on the way in which surface water is managed. Areas maintained as dry land support terrestrial species. Those which are seasonally wet support wintering and migrating waterfowl and some shorebirds.

A relatively homogenous area of dry crops can show distinct heterogeneity of habitat if water stands in parts of it and some parts are left uncultivated. Crops now consist largely of cultivated grasses, mainly oats, intended for use as hay.

Some peripheral areas have escaped cultivation or have been cultivated then abandoned. Ruderal ("weedy") vegetation at these sites includes annual grasses, forbs, and shrubs such as coyote brush (*Baccharis pilularis* var. *consanguinea*).

Birds that feed in the fields include several species of finches and sparrows, blackbirds, mourning dove, horned lark, meadowlark, great-horned owl, marsh hawk, red-tailed hawk and white-tailed kite. The perching birds feed on seeds and insects while the raptors feed on rodents, snakes, lizards, and smaller birds. Ruderal areas are used by a greater diversity of bird species.

Example: Bel Marin Keys Fields (Madrone Associates, 1980-81). Several types of non-wetland habitat are represented on the cultivated fields surrounding the Bel Marin Keys development in Novato. These fields, which border San Pablo Bay, were reclaimed from marshland during the 1800's. Hay and forage crops are still grown and provide food for the dairy cattle of Marin and Sonoma Counties. Within these agricultural fields differences in vegetation cover and hydrologic conditions create three habitat types: seasonally flooded field, dry field, and ruderal field.

The seasonally flooded field is low in elevation (-4.5 ft. NGVD) and collects storm waters during winter months. The field is nearly barren of vegetation and covered with large ponds. These seasonal ponds are visited by wintering waterfowl and small passerine birds. Puddle ducks feed on the germinating seeds remaining from the previous harvest. Ponded cultivated fields provide substitute feeding habitat for waterfowl dependent on wetland habitats, and are breeding grounds for amphibians. Shorebirds also use these ponds to rest and feed when high tides cover the adjacent mud flats.

During spring the ponds dry, and a succession of annual plants proceeds. Fiddlenecks, covering the field until April, are replaced by thick stands of rye grass intermixed with bristly ox tongue, mayweed and winter vetch. The fields are not re-seeded each year; forage grasses resprout and are harvested in summer. As the ponds dry, bird use in the area declines. A few songbirds remain in the grasses and raptors continue to hunt for rodents over the fields.

A dry field adjacent to the flooded areas lies at two feet NGVD. This field is separated from the Bay and tidal marsh by a levee. Wild oats cover the field in near monotypic stands and are cut in the spring as forage crop. After harvesting, star thistle, Italian rye grass, winter and spring vetch, bristly ox tongue, and mayweed invade the stubble covered field. Ruderal plants cover the levee and a row of eucalyptus trees serves as a windbreak.

Before the oats are harvested, songbird numbers in the field are high. Doves, upland game birds and raptors are also present. Red-winged blackbird, an abundant visitor, might nest in the grasses if the field was not cut. The dry field, due to limitations in cover and food sources, does not receive as much use by birds as the seasonally flooded fields.

The ruderal habitat abuts the Bel Marin Keys Lagoon and Novato Creek and is bounded by a levee on two sides. This area is former agricultural land which has been invaded by weedy plant species. Annual forbs such as winter vetch, sow-thistle, wild oats, mustard and barley are interspersed amongst the tall, thick stands of Italian rye grass which cover most of the site. Coyote brush is scattered along the southern periphery.

Levees bordering the Bel Marin Keys diked land will occasionally leak causing salt water to collect in low depressions. Pickleweed and salt grass colonize these wet areas. The diversity of plants furnishes food, nesting area, cover and perches for bird and small mammal species. Songbirds use the ruderal habitat on this site in great numbers. House finches, blackbirds, sparrows and meadowlark feed and nest in the brushy herbage. Several swallow species forage for insects above this site and return to other areas to nest. Mammal species are common residents including black-tail jackrabbit, grey fox and meadow mice. A variety of reptiles also populate this area, eating insects and supplying food for some of the mammals.

A wide apron of farmland around the southern slope of Sonoma Mountain from Hogg Island to Skaggs Island, north to Schellville and east toward the Napa River is also former marsh. The hay-producing farmland between Novato Creek and Hamilton Air Force Base best exemplifies this habitat type.

2. Windrows Planted on Dikes

Windrows are landscape features created by trees planted, either in rows or in groups, along the dikes. They protect agricultural fields from wind.

By far, the favored tree for windrow planting has been Eucalyptus spp. This genus, native to Australia, grows rapidly, some species to great height. It has relatively high tolerance to local insect foragers and to salt in the soil. Planted windrows provide habitat diversity and shelter for migrating and resident birds and small mammals. For example, on the east side of Knight Island, Napa County, a dead eucalytus windrow serves as a rookery for cormorants. In Marin County, great horned owl roost in a group of eucalyptus on the diked salt marsh of Novato.

Windrows are common in the Napa Marsh, in some cases adjacent to BCDC study sites, but are less common in other bayfront areas.

3. Diked Historic Baylands Used for Row Crops

The history of this modified wetland type is similar to that of dry land farms on former marshes. In addition to diking and draining, these areas were further altered with freshwater irrigation supplied by local wells. In the first half of this century peas were grown on what is now Hamilton Air Force Base. The Patterson Ranch Area in Fremont near Coyote Hills historically was used for agriculture and some sections are still used for row crops such as cauliflower. Elevations of these farms vary and are subject to change from continued modifications. Subsidence has lowered surfaces from four to five feet below MHHW.

There are only limited diked historic baylands in which row crops are still grown, notably small areas at Tubbs Island.

Ponds, Ditches, and Lagoons (See also Appendix A)

The habitat value of ponds and lagoons to various wildlife species is influenced by the depth, salinity, and circulation of the water; steepness and substrate of the banks; and amount of cover along the shoreline. Deeper, more saline water bodies with steep, unvegetated shorelines include some lagoons and ditches. These areas are used primarily by diving birds (grebes, cormorants, diving ducks) which do some limited feeding. Large numbers of waterfowl may rest on these inboard open water areas during heavy weather on the Bay. Flocks of wintering and migratory puddle ducks, shorebirds, and wading birds feed and rest on the shallow waters and exposed mud of seasonally wet agricultural fields and flood control areas, active salt ponds, and shallower portions of lagoons and permanent ponds. Dabbling ducks prefer to feed in the areas of fresher water while shorebirds and wading birds feed in shallow waters of varying salinities. Large flocks of shorebirds may loaf in the shallow waters when Bay mudflats are covered by high tides. Wastewater oxidation ponds draw many feeding phalaropes and gulls. Numerous perching birds such as blackbirds and swallows also feed over shallower waters.

Aquatic conditions in ponds and ditches are extremely variable. However, limited tidal exchange and poor circulation are generally responsible for poor water quality which is not favorable to most aquatic organisms. Filamentous algae often thrive in ponds, due to high nutrient concentrations, high water temperatures, and fairly stagnant conditions. Insect larvae or adults such as midges, flies, and beetles, and small crustaceans such as amphipods and copepods, are generally abundant. Certain species of fish (sticklebacks and mosquitofish) do well in ponds. Ponds and ditches with good circulation, gently sloping shorelines, and some surrounding vegetation cover generally provide the highest habitat value.

1. Inactive Salt Ponds

The San Francisco Bay Area contains an unknown number of inactive salt ponds which were once part of salt works but are no longer used for that purpose. The BCDC inventory grouped them with pond habitats since a ponded condition prevails throughout winter and spring. The length of seasonal saturations and standing water, soil salinity, organic material content, and dissolved oxygen of the waters of these ponds vary considerably. For this reason, they can also be considered either diked salt marsh or diked seasonal wetland with pickleweed.

Bottoms of those ponds once used as late stage evaporation or crystallization ponds are covered with layers of precipitates. These precipitates (e.g., calcium sulfate, calcium carbonate and magnesium sulfate) developed over a period of several years, creating a crusty surface. The ponds are prevented from leaching by the impermeability of underlying clays.

Flora in the former late stage evaporation ponds and crystallization ponds consists almost exclusively of red photosynthetic bacteria. Some salt tolerant plants have been planted on surrounding dikes, including the San Diego glasswort (Salicornia depressa) and ice plant (Mesembryanthemum cyrstallium). Inactive early stage evaporation ponds now support dispersed stands of pickleweed. Killdeer, black-necked stilt, and avocet nest in and around these old salt ponds, and many migrating birds use them for resting. Native mice, including the endangered salt marsh harvest mouse, are found in more vegetated areas. Some of the aquatic species in presently active salt ponds may be found also in inactive ponds, particularly insects and stickleback fish.

Example: Bair Island (Madrone Associates, 1975). The salt ponds of Bair Island on the Redwood City bayfront have been inoperative for many years. The dry ponds are relatively barren; stands of pickleweed are scattered over the surface. The high salinity level of the soil restricts plant colonization in large open ponds. During winter months rainwater collects in the shallow ponds and Bay water overtops levees during storms.

Avian wildlife use the ponds as resting areas during winter months and as nesting sites in summer. The proximity of Bair Island to large mud flats and the open Bay makes the ponds easily accessible to many wintering bird species. Both waterfowl and shorebirds rest on the water-filled ponds and levees during winter storms and high tides.

During summer, the dry ponds and levees are used by several nesting bird species. The endangered California least tern nests in the center of the dried ponds. In 1981, Bair Island supported 20-25 least tern nests. A larger nesting population (50-60 pairs) were present in 1980. This larger number is attributed to migration from the Alameda Naval Air Station colony where predation and disturbances caused nesting pairs to leave. This species prefers nesting in open areas with loose dirt or sand, or dried mud near lagoons or open water. The tern excavates a shallow depression in the substrate; natural or artificial depressions in hard soil are also used. In addition to least terns, 1,000 pairs of Caspian terns nested on a levee along the northern border of the ponds. These birds are aggressive defenders of their nesting grounds and act to protect the nearby least tern colony as well.

Along the northeast edge of the island is an area of ruderal vegetation and dried salt marsh. Both herons and egrets nest in the coyote brush and forage in nearby tidal sloughs. To the southwest, along Redwood

Creek, dredge spoil piles have become "upland" and also support a heron and egret rookery in coyote brush.

Restoration of the Bair Island salt ponds to tidal action would displace the nesting grounds of the least tern. Destruction of nesting habitat has reduced least tern populations to their present low numbers. The salt ponds receive special use by this species and restoration to salt marsh would be inimical to continued use.

Inactive salt ponds can also be found at Jarvis Landing in Alameda County.

2. Nontidal Lagoons

Many artificial lagoons around the Bay have been constructed with locks (tide gates) to control the water level in the lagoon. A few lagoons are landlocked, with no tidal access. Controlled tidal lagoons do not have regular tidal exchange and suffer from poor water quality. The lagoon waters are less saline than Bay waters during the winter as freshwater storm runoff collects. In fact, many of these lagoons are specifically designed as flood storage basins. Nutrients, sediments, and pollutants, carried into the lagoon by runoff tend to accumulate in the water column or bottom sediments. Most artificial lagoons experience excessive algal growth during spring and summer, due to a nutrient surplus, warm temperatures, and minimal circulation. Controlled tidal lagoons can be periodically flushed with Bay water to alleviate water quality problems.

Vegetation and wildlife use is similar to that described for tidal lagoons (see Appendix A). However, the water level in nontidal lagoons is maintained at a constant point for long periods. The absence of normal tidal fluctuations and the typical structural treatment of banks prevent the establishment of most native plant species. Fish and invertebrate use of nontidal lagoons is similar to that described for marshes with limited tidal access (see Appendix A).

Example: Spinnaker Point Lagoon (Madrone Associates, 1974-75). Spinnaker Point Lagoon is a landlocked 20.5-acre nontidal brackish lagoon on the east San Rafael bayfront. This area was diked and partially filled in the early 1960's. The southeastern portion of dike includes a former island known as South Marin Island or San Rafael Rock. The lagoon was formed by a combination of dredging and deposition of spoils along lagoon edges and the interior region to form three islands.

The lagoon receives stormwater runoff from the nearby area. Residual salt in surrounding lands make the water brackish; the lagoon receives no tidal inflows. Permanent water in the lagoon isolates the three small islands from man and other predators.

The lagoon is ringed by a narrow band of pickleweed. Upland vegetation covers the islands and major portions of the area surrounding the lagoon. Ruderal grasses and weedy plants predominate. Waterfowl species such as cinnamon teal, American widgeon, lesser scaup, and ruddy duck use the open water throughout the year. Herons and egrets feed along the shoreline. The islands, owing to their isolation and upland cover, are attractive to ground nesting birds like mallard and killdeer. A variety of shorebirds including willet, greater yellowleg, marbled godwit, and three species of sandpipers feed along the lagoon borders and rest there when high tides immerse nearby mud flats.

The steep banks and hard-packed substrate of the lagoon tend to limit the aquatic habitat for insects. A field survey completed in 1974 (Madrone Associates, 1974-75) identified fourteen types of aquatic insects from the ponds and observed a capacity threshold in insect numbers could be reached.

Example: Marina Lagoon (Environmental Science Associates, 1981). The City of San Mateo owns and maintains Marina Lagoon, a relatively large controlled tidal body of water on the San Mateo bayfront. Formerly Seal Slough, the lagoon was separated from the Bay in 1952 with the construction of dikes. The lagoon now serves as both a stormwater retention pond and a recreational facility.

Water levels are controlled in the lagoon by pumping and restricting tidal inflows with flap gates along the bayside dike. Three tributary streams (actually street drainage ditches: Central Creek, Borel Creek, and Laurel Creek) flow into the lagoon. In anticipation of the winter rainy season, water level is lowered to two feet by pumping and opening flap gates to allow drainage of water into the Bay. Stormwaters refill the lagoon and excess water is pumped out. The lagoon is drained and refilled to a six-foot depth during the spring and summer with salt water pumped in from Belmont Slough. Although the flap gates, which allow drainage of the lagoon, can also opened for tidal exchange, they are not used for this purpose. The emergency outfall of the San Mateo sewage treatment plant lies adjacent to the mouth of the lagoon; lagoon water could be contaminated if inflows were allowed.

The lagoon is filled with nearly freshwater in winter and brackish water in summer creating a broad range of aquatic conditions. Few aquatic organisms can withstand this range; some benthic worms and molluscs have colonized the northern shoreline. In addition, the fluctuating waterline prohibits the establishments of emergent vegetation around lagoon edges. Despite this lack of aquatic organisms, the lagoon is used by migratory shorebirds and winter waterfowl. Scaups, phalaropes, grebes, canvasback, and coot are common in winter, resting on the open water.

During summer, some Bay fish, as well as crago shrimp, enter the lagoon with tidal water from Belmont Slough. The lagoon frequently has water quality problems during summer months. Warm water temperatures and light penetration allow for massive algal blooms and a thick growth of aquatic plants. The City of San Mateo usually adds herbicides to the lagoon each year to control plant growth. Although water outflows during summer are stopped, some leakage occurs through the flap gates and the herbicides enter Bay waters. California Department of Fish and Game has expressed some concern over contamination of Bay shellfish by these chemicals.

Nontidal lagoons have also been constructed at Bel Marin Keys, Belvedere Lagoon, and Greenbrae Marina in Marin County; and at Foster City Lagoon and Redwood Shores Lagoon in San Mateo County.

3. Oxidation Ponds

During one step of a sewage treatment process, large ponds store primary-treated sewage. These ponds are relatively shallow, with an expansive area providing a good exchange surface for oxygen. This enables bacteria and other organisms to reduce the biochemical oxygen demand (BOD) of the water. Planktonic algae also grow in these ponds, increasing the amount of dissolved oxygen during the spring and summer.

The algae and flagellates most abundant in oxidation ponds are *Chlorella*, *Ankistrodemus*, *Scenedesmus*, *Euglena*, *Chlamydomonas* and *Oscillatoria*. Midge larvae thrive in the ponds and northern phalarope and ring-billed gull have been observed in large numbers swimming and feeding in the ponds.

Oxidation ponds have been constructed in the Hayward shoreline and are operated by the Hayward Sanitary District in Alameda County. The elevation of these ponds, measured at surrounding dikes, is approximately six feet above MHHW.

VALUES AND SENSITIVITIES OF DIKED HISTORIC BAYLANDS

While wetlands are regarded primarily as valuable habitat for wildlife, particularly migratory birds, the basis for current protection and regulation of wetlands is recognition that they provide other ecological and physical functions that are also of general importance to public health, safety, and welfare.

The diked historic baylands surrounding San Francisco Bay have retained many of the values associated with tidal marshes. Although most of these wetlands have no more than a tenuous hydraulic connection with the Bay, they all contribute in varying degrees to the the Bay ecosystem as well as to the urban areas that surround many of them. These lands have diverse functions and values. Their resources are of biological importance in that they provide major wildlife habitat and contribute nutrients to the Bay regional ecosystem. The wide variety of water regimes and vegetation, even in modified form within the diked areas, contributes greatly to the habitat extent and diversity of the Bay. Diked lands act as a buffer between remaining natural tidelands and serve as protected corridors for wildlife movement in and out of the wetland areas, and as nesting, denning, or breeding areas for some species.

Diked historic baylands perform other important functions to residents of San Francisco Bay Area, such as retaining storm runoff and flood waters, contributing to water quality by assimilating wastes (i.e. trapping and/or removing pollutants from runoff), and buffering land areas from storms and erosion. In addition, they have high social value, providing visual, recreational, research and educational opportunities. And, finally, extensive diked historic baylands in the north Bay, in agricultural use for many decades, continue to provide opportunity for local grazing and production of forage. These latter functions are treated in two separate reports. (See Recreation Values of Diked Historic Baylands and Agricultural Values of Diked Historic Baylands).

Value of Diked Historic Baylands for Wildlife

The diked historic baylands' complex of habitats provides their principal ecological value. Significant losses of tidal marsh have reduced the regional carrying capacity for wildlife species and populations. In spite of that loss, large areas of undeveloped diked historic bayland continue to support many of the "original" wildlife species using the Bay and offer diversified habitat not often recognized. The wildlife values of the habitat complex thus include:

1. Diversity. Fresh, brackish, and saline wetlands, native uplands, and ruderal lands--all with varying types of vegetation--exist within diked historic baylands. Some of these are degraded by past and present uses, but still offer secondary habitat for water dependent birds as well as primary habitat for terrestrial species.

2. <u>Extent of Habitat</u>. The large expanses of diked inactive salt ponds, hay fields, and the brackish marshes of the Contra Costa shore of Suisun Bay fulfill in part the wildlife functions of the large tidal marsh systems (e.g. Alviso, Napa, and Suisun Marshes) that once existed.

   Some of the smaller parcels of diked historic baylands serve as "wildlife oases" within urbanized areas. Animals tolerant of human activities can use these habitat islands when forced out of other areas.

   Still other diked parcels, while not extensive in acreage by themselves, are located where they add considerably to tidal or upland habitat acreage.

3. <u>Buffers, Transitions Areas, and Corridors for Water-Dependent Wildlife</u>. One of the principal losses due to development is the transitional lands that (in nature) separate tidal habitats from terrestrial ones. During high tides, birds and mammals that feed on tidal flats and in marshes take refuge on high ground, within vegetative cover. Supplementary food supply is also available on higher ground. Similarly, terrestrial species which feed in the shallow waters of the shoreline use the vegetation of transition areas for cover. Those diked areas that remain as separators, or buffers, between the Bay and development or open uplands are important remnants of the historic condition.

   Transitional zones, also demonstrate an "edge effect;" that is they support organisms from each of the bordering habitats--say, salt marsh and grassland--plus plant and animal species that thrive in a mixed or broken habitat. Many diked historic baylands act as substitutes for natural transition zones which have been replaced by development.

   Many resident wild animals migrate locally within the Bay region during diurnal movements or in various seasons or stages of their life cycles. Access to traditional breeding, feeding, or wintering grounds may be interrupted by expanding urban development. Some diked historic baylands provide corridors, connecting undeveloped areas with the Bay shoreline, through which wildlife can migrate. Raccoons, for example, move from uplands to feed on tide flat organisms.

4. <u>Rare and Endangered Species</u>. The transition areas afforded by diked historic baylands provide essential habitat for the rare and endangered salt marsh harvest mouse, whose natural high marsh pickleweed habitat has been severely reduced around the Bay. The least tern nests in at least one site in the BCDC inventory (Bair Island) and the San Francisco Garter Snake has

been recorded on one freshwater site (near the San Francisco airport). The black rail and clapper rail, endangered birds inhabiting tidal marshes, may find habitat in restored historic baylands. Subspecies of salt marsh yellowthroat and salt marsh song sparrow, which biologists consider rare (but which are not currently listed), have been studied in diked wetlands. Again, the loss of natural transition areas contributes to reductions of populations of these species.

5. Productivity. Primary productivity can be defined as the amount of plant biomass available to consumers. In San Francisco Bay, mudflat algae are a principal component. Invertebrates--insects, worms, snails, etc.--that eat the plants provide a secondary level of productivity. These in turn serve as food sources to small birds and mammals (of course, many vertebrates feed on plants, also) and so on, along the various food webs.

   The productivity of wetlands in general and San Francisco Bay tidal marshes and mudflats in particular has been speculated and discussed in many previous reports, although few actual biomass measurements have ever been made in San Francisco Bay. Cordgrass is well known from Atlantic Coast studies as a productive species, and, while pickleweed has been less studied, limited research indicates that this species also is productive. Daily flushing of tidal wetlands circulates organic material (decaying and aquatic organisms) into the Bay on a regular basis. While they do not contribute to the Bay through the same mechanism, diked historic baylands are productive to varying degrees. The numerous wildlife consumers of plants and small animals that move in and out of diked areas demonstrate one way this productivity passes to undiked areas. The net productivity of diked areas thus can be viewed as the net energy produced, used, and in a sense "exported" into adjacent habitats through the movements of these wildlife consumers.

Value of Diked Historic Baylands in Flood Control

Diked unfilled historic baylands are particularly important for retaining stormwater during coincident heavy runoff and high winter tides. As Bay Area floodplains have been filled and developed and storm discharge creeks channelized (thus increasing the rate of runoff) the ability of the Bay plain to accommodate floods and high tides has diminished. Some diked areas must remain in open space to compensate for the "mistakes" of previous decades which resulted in inappropriate fill and urban development on the natural tidal flats of the Bay.

The reputed value of a tidal marsh to function as a sponge, literally absorbing flood waters, is generally fallacious, in that soils subject to regular inundation are already saturated. Diked former tidelands may function as partial sponges, however, since they are "drier" on the surface than a tidal marsh, but this does little to alter their net capacity.

The most practical way to view the flood control function of diked historic baylands is to regard them as basins with a measurable capacity available to detain runoff from surrounding uplands following rains, as well as that part of the tidal prism of the Bay that occasionally exceeds the limit of the functioning tidal plain. In the absence of such "overflow" lands, massive levees requiring large amounts of Bay fill would continue to be built and maintained to protect the shoreline developments.

Value of Diked Historic Baylands in Waste Assimilation

The value of tidal wetlands in water quality maintenance has been recognized and studied for a number of years. This waste assimilation capacity extends also to diked wetlands, which may serve as tertiary treatment systems, removing pollutants from both storm runoff and partially treated municipal sewage.

The mechanisms of pollutant removal in wetlands can be summarized as follows:

-physical removal of sediment, as a result of settling, trapping, and filtering by wetland vegetation;

-utilization and transformation of compounds by soil micro-organisms in the wetland environment;

-uptake and utilization or storage of pollutants of by wetland plants; and

-other chemical interactions such as precipitation, formation of complexes, and chemical degradation.

Although a substantial amount of research has been conducted demonstrating that wetland vegetation does improve water quality, little of this work is directly applicable to situations encountered in the San Francisco Bay wetlands. The Association of Bay Area Governments (ABAG) is conducting a number of studies including literature review, field investigation on the effectiveness of the Palo Alto Flood Basin in stormwater treatment, and a demonstration project on a tidal marsh in Fremont. It is hoped that when these studies are complete, they will provide design information and reasonable estimates of the level of pollutant removal which marshes can accomplish with urban runoff.

The pollutants and water quality characteristics which are of principal interest in these studies are:

1. Nitrogen. Nitrogen may be present in a number of forms including ammonia (NH_3), nitrite (NO_2), and nitrate (NO_3). The first three of the previously mentioned removal processes are important in removing nitrogen from water. A certain amount of incoming nitrogen is absorbed on suspended particles which settle out in marshes, becoming incorporated into the upper

soil layers. Micro-organisms utilize nitrogen for metabolic processes and release nitrogen gas to the atmosphere through the process of denitrification. Plants also remove nitrogen for growth and development. In previous marsh studies, total nitrogen removal has ranged from 50 to 90 percent (ABAG, 1979).

2. Phosphorous. The general removal mechanisms for phosphorous are similar to those for nitrogen, except that there is no process analagous to denitrification (the direct removal of the nutrient from the system). Unless phosphorous is fixed in marsh sediments, it will be released into the system when the plant dies. Consequently, treatment efficiency of phosphorous removal is lower than that of nitrogen. Reported phosphorous removal rates range from 13 to 90 percent (ABAG, 1979).

3. Heavy Metals. The fate of heavy metals (lead, zinc, chromium, cadmium, copper) in natural wetlands has received little study. What data is available suggests that plant uptake of heavy metals is low, in the range of two to ten percent; about half of this may be released when the plant dies. Most of the "removal" capacity results from the absorption of these elements onto the clay surfaces of marsh soil particles. One prior study indicated removals of 23 to 94 percent for various heavy metals in a combination meadow, marsh and pond system (Small and Wurm, 1977).

4. Biochemical Oxygen Demand. Levels of the five-day biochemical oxygen demand (BOD) are a commonly used indicator of water quality. Virtually all prior studies show a significant reduction of BOD by marshes. In the Palo Alto Flood Basin study, these range from two to 71 percent (ABAG, 1979). Mechanisms of BOD reduction include:

- production of oxygen through photosynthesis;
- physical trapping of organic compounds by plant structures; and
- uptake of nutrients that would otherwise support oxygen-depleting organisms.

5. Suspended Solids. Actual plant structures and calm water pools slow the movement of incoming water allowing the heavier soil particles to settle out and become trapped at the base of the plants. Since these particles often contain organic compounds, macro-nutrients and trace heavy metals absorbed to the particle surface, this physical settling provides significant pollutant removal. In the Palo Alto study, suspended solids removal ranged from 34 to 66 percent.

This process of physical trapping may also reduce oil and grease; however, these often form a thin layer on the water surface and would tend to be transported through the marsh to the open water.

In assessing the treatment efficiency of marshes, it is important to distinguish between the following processes:

- temporary storage of a pollutant in marsh vegetation;
- permanent storage/immobilization of pollutants within the system; and
- transformation of pollutants to forms with changed chemical reactivity or to elemental forms.

For example, nitrogen or phosphorous may be incorporated into plant tissue during the growing season, representing a temporary removal of the nutrient. However, when the plant dies and decays, the nitrogen may be re-introduced into the water. The denitrification process in which ammonia is oxidized to nitrogen gas and released to the atmosphere, represents a removal of nitrogen from the system. Likewise, the absorption of cadmium onto the surface of a clay particle in the marsh soil may permanently remove it from the water system.

Sensitivities of Diked Historic Baylands

The traditional view that for many decades prompted San Francisco Bay wetlands to be "reclaimed" for more intensive use and to be used as sinks for urban waste of all kinds has given way to a more enlightened recognition of the values of these lands, which were so easily overlooked or regarded as cheaply developable. By the time the McAteer-Petris Act and other forms of wetland regulations were enacted in the mid-60's and early 70's, thousands of acres had already been lost from the Bay. This direct loss of tidal habitat, resulting from diking, filling, and irretrievable commitment to developed uses, represents the single impact to which both tidal and nontidal lands have been most vulnerable and continue to be susceptible.

In addition to direct loss, the hundreds of acres of remaining undeveloped diked historic baylands have been exposed to a variety of conscious and inadvertent land uses and abuses. Many tidal areas had been diked by the mid-60's merely to preserve the option of future development rather than for a specific purpose. Once diked, these areas were subject to a predictable sequence that involved dumping debris, excavated soils from construction sites, dredge spoils, and finally engineered fill in preparation for eventual construction. The condition of many diked sites around the Bay now reveals a midpoint--partial fill or dredge "spoiling"--in this somewhat random process. Other diked areas that were not carried into the process toward ultimate development, or were diked for a specific purpose such as salt evaporation and later withdrawn from this use, have been the victims of benign neglect. The fact that they have retained significant albeit modified habitat value for wildlife and some fish is testament to the resilience of the wetlands themselves and of the wildlife that continue to use them. In short, while we must regard diked historic baylands as vulnerable, they are also resilient as habitats, if granted protection from major physical conversion.

Most of the diked lands--both wetland and functionally "dryland"--provide wildlife habitats that, while persistent, are sensitive to human activities on and near them. Their sensitivities must be recognized when placing permit conditions on adjacent developments and when prescribing programs for protecting and enhancing their present value. These sensitivities are summarized below.

1. Sediments from upstream sources or adjacent development hastens the natural filling and aging process of wetlands. Tidal marshes that receive freshwater inflow from upland sources typically act as partial sediment filters for water mixing with the tide and entering the Bay. In a diked wetland, all sediments entering from upland sources are trapped and deposited behind dikes, filling remnant channels as well as vegetated areas and subjecting the receiving wetland to relatively rapid changes in topography and water relations. Changes in topography and water availability have a direct influence on vegetation, typically detrimental relative to the natural condition.

2. Mud waves can be induced by displacement of substrate. In diked lands this occurs from overloading deformable bay muds on adjacent sites in the process of filling, constructing dikes, placing heavy equipment, or constructing buildings whose weight exceeds the load bearing capacity of the underlying soils. Mud "heaves" are generally subtle, evidenced by changes in microtopography, drainage, and eventually vegetation. Proper fill and foundation engineering ordinarily can prevent this uncontrolled consolidation from happening, but past practices are reflected in examples of mud waves in various locations around the Bay. These waves continue to occur long after the initial loading.

3. Diked areas typically are recipients of both controlled and uncontrolled dumping of domestic refuse, construction debris, cut material from upland excavations, etc. Controlled dumps (sanitary landfills) are now subject to rigorous regulations, but the residue from overflow and past practices can still be found in the form of glass, metal, lumber, and other miscellaneous substances and leachate which still emanates from some of them. Debris can become a permanent part of diked wetlands as a pier, piling, or dock becomes part of a tidal wetland, providing substrate for attachment of organisms or only minimially disturbing wildlife inhabitants. The accumulation of debris imparts an appearance of neglect and misuse that invites further misuse, with the possibility of increased damage to vegetation and resident organisms (e.g., the Emeryville Crescent "gallery" of junk sculpture).

4. Pollution and stagnation can result from failure to manage or monitor the source and quality of water entering or leaving diked historic baylands. The most consistent, and often only, concern expressed over conditions of poor water quality in diked areas is from mosquito abatement districts, whose mandate leads them to investigate otherwise neglected wetlands and apply abatement techniques. Evidence of poor water quality is the decline of wildlife food organisms in both species and numbers within the diked areas.

5. Undesirable exotic plant species are introduced into diked areas along with construction debris and domestic trash. Thus, the San Francisco Bay shoreline is dotted with concentrations of pampas grass, weedy acacias, Russian thistle, and other invading exotics that may be aesthetically offensive and difficult to eradicate once established.

6. Human activity. It is difficult to measure impact of development adjacent to diked historic baylands. Some wildlife species have demonstrated their ability to become accustomed to constant, predictable sights and sounds, such as freeway traffic, and in fact some continue to exist in close proximity to urban environments. However, uncontrolled recreational use of diked wetlands disturbs vegetation and reduces or eliminates use by many wildlife species. Feral pets prey on wildlife, and grazing animals alter the vegetation cover and natural habitat value of these areas. No studies have been conducted over time on the Bay shoreline which document these impacts conclusively. Many informal observations generally bear out the adverse relationship between human encroachment and wildlife use of these habitats.

In conclusion, distance, vegetation, barriers, or other means that separate wetland habitats visually and/or spatially from human activity are a necessary and conservative measure to insure continued use by sensitive species.

Public Uses Compatible with Ecological Values

Some public access to diked historic baylands is essential. These areas provide a variety of educational, research, and recreational opportunities. Access to wildlife areas increases public awareness of the importance of wildlife habitat. Yet access must be controlled to avoid undue habitat destruction and disturbance to wildlife species and populations which are known to be sensitive to human encroachment, e.g. the nesting herons and egrets on Bair Island, or nesting California least terns on salt pond levees.

Damage to diked historic bayland areas can be minimized by controlling the types of activities allowed in these areas, prohibiting access in sensitive portions of the habitat, and appropriately designing the means of access (such as trails or boardwalks) to avoid trampling vegetation and compacting soils. Activities such as birdwatching, hiking, picnicking, and fishing can provide enjoyment to many people with minimal impact on the habitat. Trails around perimeters of large ponds or boardwalks in marshes can be designed to allow animals to escape into inaccessible portions of the habitat. Rows of native trees around sensitive areas can add to habitat value and screen these areas and species from disturbance. Water channels parallel to boardwalks and trails separate the activities of animals from those of people and their domestic pets. Islands within channels and ponds provide sanctuaries for wildlife. During breeding season of certain species it may be necessary to limit some activities or prohibit access to their habitats.

Educational and scientific activities in diked historic bayland areas can actually benefit wildlife. Monitoring of the fish and wildlife populations of these areas, for example before and after restoration, can lead to improved methods of enhancing and restoring wildlife habitat and a better understanding of the rate of colonization of a new marsh habitat by plant, bird, mammal, invertebrate, and fish species.

APPENDIX A

HISTORY AND CONDITIONS OF WETLAND FORMATION AND EXAMPLES OF MODIFICATION IN SAN FRANCISCO BAY

Introduction

The present conditions of modified baylands in the Bay Area are more easily appreciated by examining their history of land formation and land use in relation to the formation and condition of the unmodified, or natural tidal, marshlands from which they are derived.

This section of the report provides a description of the morphology of San Francisco Bay tidal marshes and their zonation and vegetation to provide a "baseline" for understanding the extent and types of modification which have occurred. Following this description, the report characterizes modified tidal wetlands and non-tidal developed former tidelands.

A summary of resource values for each modified habitat type is included. These resource descriptions enable comparison of natural and developed tidal areas with the BCDC diked historic bayland study sites. Habitat richness and diversity in tidal wetlands are an indication that restored former baylands may yield similar value. Likewise, the loss of resource value apparent in filled and developed areas is an indication of what can result from further degradation of the diked sites under investigation.

Physical Development of Tidal Marsh Formation in San Francisco Bay

Until about 8,000 years ago, rising sea levels associated with worldwide glacial melting prevented the development of extensive marsh systems in San Francisco Bay. The rate of rise gradually slowed to between four and eight inches per 100 years. At this rate, sedimentation in a salt marsh can counterbalance submergence. The vertical development of Bay marshes through alluviation has proceeded at approximately the same rate as submergence during the past 4,000 to 6,000 years, creating extensive flat areas of marshland around the margin of the Bay, roughly at the high tide level (Atwater et al., 1979).

Before the Gold Rush period in California (1850's), sediment entering the Bay was derived primarily from natural erosion in the Sierra Nevada and surrounding Bay watersheds, which continue to be a natural source of sediment entering the Bay. Sierra Nevada sediment discharges into the Bay system through the Delta and Suisun Bay, where most of the coarser sediments are retained. Consequently, the sediment entering San Pablo and San Francisco Bay consists almost entirely of fine silty and flocculated clays. Between 1853 and 1884, hydraulic gold mining in the Sierras caused the discharge of massive quantities of sediment to the Sacramento River and its tributaries, which ultimately reached the Bay system and has continued to be redistributed, particularly in San Pablo Bay. Since the end of hydraulic mining in 1884, and with the construction of dams on the major rivers, sediment input to the Bay has gradually decreased (Krone, 1979). Currently, the Sacramento River accounts for approximately 75 percent of the total sediment entering the Bay, with local streams supplying the remainder. Based on projected freshwater diversions, it has been estimated that by the year 2020, total sediment will decrease to about half of the present value, with the Sacramento River contribution representing about 54 percent of the total (Krone, 1979).

Bay sediment is extremely fine-grained, about 85 percent clay and 15 percent silt, and uniform in texture. It settles out wherever water velocities are low at slack tide. Typically, sedimentation occurs until the areas of deposition, e.g., mud flats, reach a level where they are periodically exposed during low tides. At the same time drainage channels develop and, as emergence time of mud flats increases with elevation, marsh plants become established. The first colonizing plants trap additional sediment, and the elevation of the marsh sediments continues to rise with vertical accretion and expanding plant colonization until it reaches the approximate level of mean higher high water (MHHW). The roots of the colonizing marsh plants stabilize the banks of the drainage channels to such an extent that nearly vertical sides result. Lateral migration of these channels proceeds by undercutting of the banks by tidal erosion and the subsequent slumping of blocks of marsh soil and vegetation. The hydraulic geometry of the larger drainage sloughs is controlled by both the ebb and flow of tidal movements, whereas the shape of the myriad intricate smaller channels is controlled primarily by the high velocity ebb movement. Drainage channel development is also influenced by the growth of cordgrass, which typically occurs within channels, and pickleweed, which typically colonizes the upper banks and produces extensive root systems, and by other biological factors such as colonies of clams and mussels, which reduce erosion by lining the sides and bottoms of channels, acting as a living "rip rap" (Pestrong, 1972). This quasi-structural support has also been called "bioconstruct."

Despite the difference in hydrologic regime between drainage channels formed in tidal marsh areas and those formed in a typical terrestrial environment, the hydraulic geometry of the two is generally similar (Pestrong, 1965). The tree-like branching of numerous smaller drainages to fewer and larger channels, the amount and rate of meandering, and erosion/sedimentation processes can be understood in relation to theories which explain terrestrial processes. The major difference is that in terrestrial systems periodic large scale floods determine the hydraulic regime and channel geometry, while in a marsh, the regular, twice-daily ebb and flow of the tides within relatively fixed boundaries is the principal determinant of the hydraulic regime.

Zonation and Vegetation in Tidal Marshes

Vascular plants dominate the vegetation of tidal marshes and distinguish marshlands from mud flats. At least 125 species of vascular plants have been identified from the tidal marshes of the overall San Francisco Bay-Delta estuary (Atwater et al., 1979). Species diversity increases from San Francisco Bay to the Delta, thus decreasing with increasing salinity. Tidal marshes around the Bay proper support 13 or 14 species, while approximately 30 species are found in San Pablo Bay marshes, 40 around Suisun Bay, and 80 in Delta marshes (Atwater et al., 1979).

Common pickleweed and California cordgrass dominate salt marsh vegetation around most of the immediate San Francisco Bay. Pickleweed occurs at elevations near and above mean higher high water, while cordgrass occurs within the range of mean tide level to MHW. Several halophytic species grow in the peripheral elevations above the pickleweed zone: salt grass, gum plant, saltbush, alkali heath, and jaumea. The vegetation zones of a generalized San Francisco Bay salt marsh are shown in Figure 1.

Natural tidal freshwater marshes, characteristic of tidal islands in the Delta region, are dominated by common tule, Olney's bulrush, cattails, common reed, and arroyo willows. Below the mean tide level, tules predominate.

Brackish marshes in San Pablo and Suisun Bays and in freshwater tributaries to other parts of the Bay occur along a salinity gradient transitional between the salt water of San Francisco Bay and a freshwater source, such as the Delta.

Most of the dominant salt marsh plants inhabit San Francisco Bay, San Pablo Bay, and, with the exception of California cordgrass, Suisun Bay. The dominant freshwater species also occur in brackish marshes of San Pablo and Suisun Bays. Species composition of a brackish marsh thus depends upon the salinity regime present at a particular location. The vegetation zones of generalized brackish marsh are shown in Figure 2.

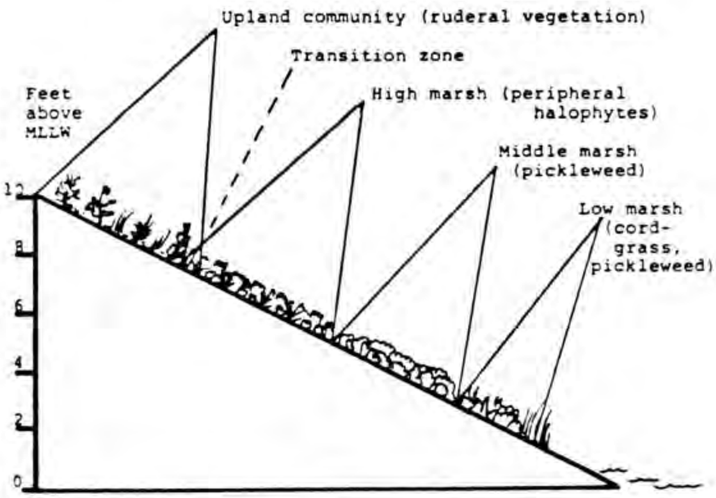
Natural tidal marshes produce large amounts of organic material which is used within the marsh itself and transferred to other parts of the Bay ecosystem.

There are a number of examples around the Bay of tidal salt marshes whose form or natural tidal regime have been altered by adjacent filling and/or development.

1. <u>Salt Marsh with Offshore Shoal</u>

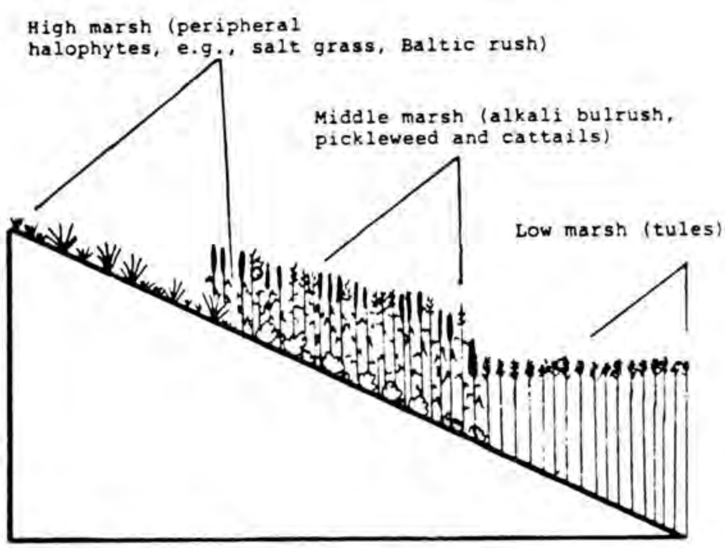
Offshore shoals are created by the transportation of sediment from the shore to an offshore area through the process of littoral drift. The source of this sediment may be sand displaced from beaches by storm waves or material from old fill projects which has flowed out of broken dikes. The shoal builds up offshore and wholly or partially interferes with tidal action in the salt marsh. This type of wetland is more common in coastal waters, occurring infrequently in the relatively protected waters of the Bay. An example occurs at Roberts Landing in Alameda county. The small salt marsh formed behind the shoal has subsequently been disturbed by the East Bay Discharger Authority pipeline installation whose elevations are near Mean Higher High Water (MHHW). Plant species include pickleweed and gum plant (<u>Grindelia</u> sp.).

FIGURE 1



Vegetation zones of a generalized tidal salt marsh in the San Francisco Bay. (Tidal elevations for southern San Francisco Bay.)

FIGURE 2



Vegetation zones of a generalized brackish marsh in the San Francisco Bay.

Source: Harvey and Stanley Associates in California Department of Fish and Game, 1979. Protection of San Francisco Bay Fish and Wildlife Habitat.

Wildlife use of salt marshes with restricted tidal access is similar to but less than that of fully tidal marshes due to the lessened productivity of modified areas. Avocets, black-necked stilt, cinnamon teal, and song sparrow may breed there, while wading birds, shorebirds, puddle ducks, rails, and perching birds feed and roost. Although the salt marsh harvest mouse prefers areas which receive some regular tidal action, this species has also been found in areas which are cut off from the tide (Zetterquist, 1977). Other small mammals as well as reptiles and amphibians occupy these habitat areas. Fish use is primarily restricted to channels in the marsh and is probably limited by the restricted tidal access. Filter-feeding invertebrates are reduced in abundance relative to unmodified baylands, again due to the reduction in tidal exchange.

2. Deltaic Salt Marsh

A deltaic salt marsh is a river estuary salt marsh which has been elevated to above MHHW by river-borne alluvium deposited during periods of peak runoff. This high marsh condition is now extremely rare in the Bay Area, having largely succumbed to urbanization. One remaining example of deltaic salt marsh is the Fagan Marsh on the Napa River. Freshwater examples are present in a few parts of the northern and eastern Delta, where mineral alluvium has been deposited.)

The deltaic salt marsh typically is characterized by great floral species richness, as evidenced by the 39 species of primarily native plants recorded in Fagan Marsh. Typical species are pickleweed, salt grass (Distichlis spicata var. stolonifera), jaumea (Jaumea carnosa), marsh rosemary (Limonium californicum), arrow grass (Triglochin maritima), cattails (Typha, spp.), tule and bulrush (Scirpus spp.), and cordgrass (Spartina foliosa). Two rare plant species, soft bird's beak (Cordylanthus mollis mollis) and Sitka sedge (Carnex sitchensis) also occur in this type of bayland. Fish and wildlife use is similar to that described above for a salt marsh with an offshore shoal restricting tidal access.

3. Eroding Marsh

Comparison of the bay shoreline today with maps from 19th century bathymetric data (Nichols & Wright, 1971) reveals many sections of receding shoreline. Such retreat is often evidenced by an abrupt, elevated edge on the bayward side of a marsh and an absence of typical zonation. A variety of agents contribute to this erosion. Wind, waves and boat and ship wakes wear at the shore. Several forms of mud boring isopods (e.g., Sphaeroma sp.) attack portions of shorelines, banks, and dikes, riddling them with small tunnels which aggravate bank erosion.

The vegetation in these areas is the same as that of other salt marshes except that the low cordgrass zone has been largely eliminated by erosion. Thus, the endangered California clapper rail is unlikely to inhabit such marshes. Use by other fish and wildlife species is similar to that of intact salt marshes, although the absence of an outboard mud flat would limit the feeding area for shorebirds.

Eroding marshes are found at Corte Madera, Larkspur (Triangle and Corte Madera marshes), along the Hayward shoreline, at Tubbs Island, and along most of the northern shoreline of San Pablo Bay.

4. "Cul-de-sac" Salt Marsh

As marshes have been diked and filled around the Bay, numerous small marshes have been left in semi-isolated locations, partially enclosed by filled land, cut off from natural freshwater inflows and connected to the Bay or sloughs by constructed inlets or conduits for tides to enter and drain. De Silva Lagoon in Strawberry, Marin County, provides an example of a salt marsh with constricted tidal action.

This type of tidal salt marsh is generally protected from wind driven waves and pronounced tidal currents. The slackened water movement increases settling of particles in the water column and decreases resuspension of bottom sediments. The enclosed configuration and increased sedimentation rate alters elevations as well as the height and duration of tidal highs and lows. Elevations of these marshes are variable, depending on the history of their isolation. Other related physical conditions -- e.g., submergence time, light penetration, salinity -- also may differ from open marsh systems.

Vegetation in such areas depends on elevation, length of tidal retention time, drainage and channel configuration, and the type of transition between the marsh and surrounding land use. Typical species are cordgrass, pickleweed, alkali heath, jaumea, gum plant and marsh rosemary. Fish and wildlife use is similar to that of salt marshes with restricted tidal access (see above).

FILLED AND/OR DEVELOPED HISTORIC BAYLANDS

Many former wetlands have been partly or entirely filled, generally with dredge spoils, upland fill and rubbish. These areas are usually filled to create land suitable for development and are transformed subsequently into urban areas.

1. Dredge Spoil Disposal Sites

Numerous diked salt marshes in the Bay Area have been used in the past as disposal sites for dredge spoils. Such spoils originate from levee construction, from channel improvement projects, or from marinas dredged for depth maintenance. Spoils have also been used to raise elevations of diked baylands that have undergone subsidence. In some recent restoration projects, dredge spoils have been used to raise elevations with the specific intention of inducing marsh vegetation to reestablish. Usually, however, dredge spoils have been disposed with the intent to fill sites for further development or without any specified future land use plan. The use of dredge spoils in marsh restoration is an active area of research by the U. S. Army Corps of Engineers.

Elevations of former marshes serving as disposal sites vary. As an example, at Corte Madera, Marin County, (where MHHW = 3.1 ft. above NGVD), the marsh was 2.5 ft below to 0.6 ft. above NGVD, with channels as low as 0 ft. NGVD (or 3.1 ft. below MHHW), prior to partial filling with dredge material.

Old dredge disposal areas higher than MHHW around the Bay have become sparsely vegetated with weedy colonizing species which are tolerant of high soil salinities. These include the common native species of coyote brush (Baccharis pilularis) and toyon (Heteromeles arbutifolia), and non-natives such as black acacia (Acacia melanoxlyon) silver wattle (Acacia decurrens var. dealbata), pampas grass (Cortaderia selloana), wild radish (Raphanus sativa) and annual grass such as wild oats (Avena fatua). Wildlife use of dredge disposal sites is highly variable, depending on the habitat of surrounding areas and access to the site. Those sites which retain salt marsh characteristics may be heavily used by birds for resting and preening. Filled areas in East San Rafael (situated near open Bay, channel, salt marsh and impounded lagoon habitats) demonstrated heavy bird use prior to development.

Bay Farm Island, Alameda County; Foster City and Redwood Shores, San Mateo County; and Marin County's Bel Marin Keys, Bahia Vista and East San Rafael are all situated on sites developed originally from engineered dredge spoils. Other disposal sites that have been restored to tidal action and are recovering as marshland are found in upper Richardson Bay, along portions of the Corte Madera waterfront, and on parts of Bair Island adjacent to Redwood Creek.

2. Upland Cut Material Disposal Sites

As Bay area urban communities expanded, dikes were constructed around marshes or into tidal flats and the wetland drained and used as a disposal site for upland excavation material. This practice was an economical way to create dry land surfaces for urban development.

Vegetation on these sites is largely ruderal, including native colonizers, such as coyote brush (Baccharis pilularis var. consanguinea), and non-native annual grass such as wild oats, wild anise (Foeniculum vulgare), wild radish, and wild mustard (Brassica campestris). In areas not yet developed, wildlife use of such lands can be substantial, depending on the use and condition of adjacent parcels and proximity to relatively undisturbed habitats. Examples of this extreme alteration of habitat are parts of the City of San Francisco, Emeryville, and North Richmond. In Marin County, much of the Northgate Activity Center, East San Rafael, and low areas of both Corte Madera and Larkspur have wetland origins, gradually filled by mixed fill materials. Elevations vary considerably from site to site.

3. Solid Waste Disposal Sites

Significant former marsh areas around the Bay have been diked and used for dumping solid waste. While some of these sites are still active landfills, others are near or have reached capacity and have been at least partially "capped." A properly capped site is covered with layers of clay, usually dredge material, that is impervious to moisture once dried. The layers become compacted together, improving the seal.

Vegetation ranges from barren to a few annual grasses and weedy species. Prior to being capped, solid waste disposal sites support rodents (mostly introduced species), gulls, Brewer blackbird, and other scavengers. They may provide nesting sites for terns and killdeer, which sometimes utilize gravelly surfaces. Rehabilitation plans for habitat and recreational use are in various stages of completion for sites around the Bay area. While they have displaced valuable tidal habitats, landfills will be put to eventual use, supporting some terrestrial vegetation and wildlife.

Examples include the Albany, Berkeley, Oakland, Mountain View, Palo Alto, San Mateo, San Quentin, Redwood, and American Canyon landfills. Other smaller sites occur around the bayfront. Solid waste disposal sites may be as much as 25 feet above MHHW when capped.

4. Urban Development

Many areas of wetlands were diked and filled to create land for urban development. In some cases, the area was filled in a haphazard fashion. Newer developments have been placed on engineered fill, designed to accommodate a specific loading level.

(a) Urban Development on Old Fill. This category of development has resulted from placement of fill which was not coordinated for planned development. As a result, underlying surfaces have not always settled evenly, large areas have been subject to subsidence, and adjacent marshes have frequently experienced "mud waves," i.e., displacement from the filled land to create topographic "bubbles" of higher elevation. Urban areas support a limited number of wildlife species. These sites have been disrupted to such an extent that restoration to a natural condition for native vegetation and wildlife is not possible.

Urban development on land fill is common in most of the municipalities surrounding San Francisco Bay. Examples of cities and towns with large sections on former estuarine muds are San Francisco, San Mateo, Alameda, Oakland, Richmond, San Rafael, Larkspur, Corte Madera, Mill Valley, Tiburon-Belvedere, Suisun City, and small portions of Martinez, Rodeo, Pinole, and Vallejo. Elevations vary and cannot be determined from standard (USGS) sources.

(b) Development on Engineered Fill. Newer developments on estuarine muds are built on fills which have been created by plan, designed specifically for the materials used and for the type of development to take place. Fill material for such projects is either dredged from the vicinity of the construction site, creating lagoons and ditches, or imported from upland sites. Care is taken to compact soils uniformly on the fill site and, ideally, elevations are planned for adequate drainage and stability. Settling is expected to occur but proper engineering should result in controlled, predictable elevation changes.

Vegetation in these urbanized areas is mostly non-native. Only that wildlife that has adapted to human activities and disturbances is found in extensively developed areas.

Examples of engineered fill developments are: Foster City, Redwood Shores, San Mateo County; Bay Farm Island, Alameda County; and Bahia Vista, Bel Marin Keys and Greenbrae Marina in Marin County. Elevations of streets and housing pads have been planned to approximately ten feet NGVD or six feet above MHHW. Lagoon surface elevations are designed to be approximately four feet below housing pad elevations.

TIDAL LAGOONS

Most lagoons in the Bay area were created as elongated bodies of water with a narrow opening to the Bay. Some artificial lagoons have been constructed to retain tidal access and circulation, while others are isolated by tide gates. Another type of lagoon environment is provided by sewage treatment plant oxidation ponds.

Artifical lagoons have often been created in conjunction with planned fill projects. Often dredging takes place from the shoreline, leaving a lagoon subject to tidal action. Lagoons excavated for such development are usually about 30 feet deep with relatively steep sides. Rip-rap designed to stablize the shore also discourages plant growth. Lagoons are also created as an indirect result of dredging a new marina. This type of modification creates the problem of water becoming still within the lagoon, with resultant settling of silt and clay. Consequently, sediment collects along the bottom and in channels, requiring periodic dredging to maintain navigable depths. Elevations of these lagoons are equal to tidal elevations.

A variety of algae inhabit protected lagoon waters. Cordgrass and pickleweed grow along the banks of tidal lagoons where they have been left without rip-rap, and where the water line is maintained by a natural tidal regime.

Typical artificial lagoons are used by some diving birds such as canvasback, golden eye, scaups, grebes, and cormorants for resting, but are usually too deep for these species to feed on the bottom. Lagoons open to tidal action have richer diversity and greater abundance of wildife than those equipped with locks or entirely closed off from the Bay. Those lagoons with shallow water are used by shore birds, wading birds and puddle ducks. Tidal lagoons support fish and invertebrates similar to those in tidal salt marsh channels.

Examples of lagoons excavated in conjunction with planned fill projects are in Marin County at Bahia Vista and Bel Marin Keys (where siltation proved to be a problem in an open tidal lagoon and a lock was installed). Lagoons created by marina dredging include Shellmaker Marina, Sonoma County, and harbors such as Richmond Harbor, Contra Costa County. Bay Farm Island was elongated to increase the lagoon-like quality of San Leandro Bay. Lake Merritt is a tidal lagoon which has been completely urbanized. Tidal access is gained through an underground culvert and tide gate (Lauflu, 1981).

REFERENCES

Association of Bay Area Governments, 1979. Treatment of stormwater runoff by a marsh/flood basin. ABAG, Berkeley, CA.

Environ and Madrone Associates, 1981. Environmental assessment, storm drainage project, Naval Air Station, Moffett Field, Ca. Western Division Naval Facilities Engineering Command, Moffett Field, Ca.

Environmental Science Associates, 1981. Environmental impact report, Warm Springs Industrial Park, City of Fremont, CA. ESA, Inc., Foster City, Ca.

______________, 1981. Environmental impact report, San Mateo Shoreline redevelopment plan. ESA, Inc. Foster City, Ca.

Demgen, Francesca. Demgen Aquatic Biology, March 1981. Personal communication.

Harvey H. T., M. J. Kutilek, and K. M. DiVittorio, 1978. Determination of transition zones in California wetlands. Environmental Protection Agency.

Madrone Associates, 1974. Unpublished habitat assessments.

______________, 1974. Biological assessment: Henshaw Property, Redwood City, Ca. Harding-Lawson Associates.

______________, 1974. Draft environmental impact report, Sequoia Pacific Realco Lands development, Tiburon, Ca. City of Tiburon, Ca.

______________, 1979-80. Environmental impact report, East Bay Municipal Dischargers wastewater reclamation and reuse program. Madrone Assoc., Novato, Ca.

______________, 1980-81. Habitat assessment and avian census, unpublished.

Niesen, T. M., M. N. Josselyn, M. J. Leddy, and F. S. Viollis, 1979. A survey of the wetland vegetation and fauna along the Alameda Transportation Corridor, Alameda County, California. U. S. Fish and Wildlife Service. Div. of Ecological Services, Sacramento, California.

Poland, J. E., 1979. In Conomos, ed., San Francisco Bay: The Urbanized Estuary. Pacific Division, American Association for the Advancement of Science, San Francisco, California.

United States Fish and Wildlife Service and California Department of Fish and Game, 1979. Protection and Restoration of San Francisco Bay Fish and Wildlife Habitat. U.S. Fish and Wildlife Service Region 1, Ca.