# CHAPTER 4.0 AFFECTED ENVIRONMENT

The affected environment for the LTMS is the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (the Estuary), which is the largest and most significant estuary along the entire west coast of North and South America. Over 40 percent of the land area of the state of California — with 60 percent of the state's runoff — drains into the Estuary. Estuarine conditions support the most productive kinds of ecosystems in the world although, like many estuaries, this one has been degraded by human activities. The past century of development in the Bay Area has severely stressed the Estuary, and resulted in fundamental changes to the ecosystem. Therefore, any additional impacts can be of concern, including those from dredging and disposal.

This chapter presents a general description of the three environments where dredged material from shipping channels in the Estuary can be disposed or used for beneficial purposes. The individual sections on the aquatic environment in the Estuary (section 4.3), the upland margin around open water embayments where upland disposal and beneficial reuse projects will most likely be located (section 4.4), and the ocean environment (section 4.5) are structured to first describe the general characteristics of each system, then to identify those specific resources that may be affected by dredged material disposal within each environment. The environmental analysis in Chapter 6 is structured to consider the potential impacts of different levels of disposal in each of these environments, then to assess the impacts, risks, and benefits of disposal at a regional level. That analysis builds on the information presented in this chapter.

This chapter differs somewhat from descriptions of affected environments presented in typical EIS/EIRs because it is designed to support a programmatic level of analysis and not to determine the impacts of dredged material disposal or use *at a specific site*. This EIS/EIR compares the effects of disposal at three *types* of sites. As a practical matter, ocean disposal was assumed to be limited to the existing designated deep ocean site near the Farallon Islands. In contrast, the characteristics of each embayment within the Estuary are very different and the potential for water quality, sediment, and other resource impacts due to material disposal differ accordingly. In addition, the potential effects also differ greatly between the disposal site environment and the surrounding waters. The description of the affected in-Bay environment is thus structured to highlight the resources likely to be affected by disposal in each embayment. This information is then used to summarize the general resources of concern within the San Francisco Bay. The description of the upland environment is structured around the types of projects that dredged material may be used for within the LTMS planning area. Like the in-Bay section, it presents a general description of the types of environments in which each use is likely to occur, then highlights those resources that may be affected by the use of dredged material. A key element of the upland section is the identification of those resources that may be affected *differently* by dredged material than other types of material that are currently used for the same purpose. Site specific EIS/EIRs for individual upland projects or new in-Bay disposal sites will be necessary to address environmental effects at that level of detail.

## 4.1 LTMS PLANNING AREA

The LTMS Planning Area encompasses the Pacific Ocean's continental shelf and slope west of the Golden Gate Bridge, San Francisco Bay, and the portion of the Sacramento-San Joaquin Delta west of Sherman Island (Figure 4.1-1). It also includes the wetlands and low upland areas that form a margin around San Francisco Bay and its tributaries. This area spans the jurisdiction of 11 counties (Marin, Sonoma, Napa, Solano, Sacramento, San Joaquin, Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco) but does not include mountainous areas or inland areas far removed from navigable waters. This geographic area defines the region where dredged material disposal and beneficial reuse sites are located, and where additional disposal or reuse may be feasible.

In some cases, material may be transported outside this region for use in landfills, levee restoration, or similar projects. In this document, the potential for environmental effects in these cases is limited to the difference between using dredged material and material currently used for such projects. A complete analysis is more appropriately conducted at the project-specific level when alternate sources of material and transport distances are known. However, a general description of potential environmental affects associated with levee use in the Delta area is presented to support the regional analysis.

Figure 4.1-1 LTMS EIS/EIR Planning Area

The main air basin over this Planning Area is the San Francisco Bay Area Air Basin, but portions of the Sacramento Valley Air Basin and San Joaquin Valley Air Basin overlay segments of the eastern edge of the Planning Area as well.

## 4.2 REGIONAL SETTING

### 4.2.1 Climate of the LTMS Planning Area

The climate of the San Francisco Bay and Delta region plays an important role in determining the environmental conditions found in and around the Estuary. The amount and timing of precipitation, air temperature, and wind patterns influence the Estuary's freshwater inflow, salinity, and currents.

The climate of the LTMS planning area can be classified as Mediterranean, characterized by cool, dry summers and mild, wet winters. The major influence on the regional climate is the Eastern Pacific High, a strong persistent anticyclone. Seasonal variations in the position and strength of this system are a key factor in producing weather changes in the area.

The Eastern Pacific High attains its greatest strength and most northerly position during the summer, when it is centered west of northern California. In this location, the High effectively shelters California from the effects of polar storm systems from the North Pacific. Due to the large-scale atmospheric subsidence associated with the High, an elevated temperature inversion often occurs along the West Coast. The base of this inversion is usually located from 1,000 to 3,000 feet above mean sea level, depending on the intensity of subsidence and the prevailing weather condition. Vertical mixing is often limited to the base of the inversion, trapping air pollutants in the lower atmosphere. Marine air trapped below the base of the inversion is often condensed into fog and stratus clouds by the cool Pacific Ocean. This condition is typical of the warmer months of the year, from roughly May through October. Stratus usually forms offshore and moves into coastal areas during the evening hours. As the land heats up the following morning, the clouds will burn off to the immediate coastline, then move back onshore the following evening.

During the fall and winter months, the Eastern Pacific High can combine with high pressure over the Great Basin to produce extended periods of light winds and low-level temperature inversions. This condition frequently produces poor atmospheric dispersion that results in degraded regional air quality. Ozone standards traditionally are exceeded when this condition occurs during the warmer months of the year.

As winter approaches, the High begins to weaken and shift to the south, allowing polar storms to pass through the region. These storms produce periods of cloudiness, strong shifting winds, and precipitation. The number of days with precipitation can vary greatly from year to year, resulting in a wide range of annual precipitation totals. Storm conditions are usually followed by periods of clear skies, cool temperatures, and gusty northwest winds as the storm systems move eastward. Annual precipitation totals for the Oakland International Airport ranged from 9 to 30 inches during a 40-year period of record (1941 through 1980), with an annual average of 17.77 inches (National Oceanic and Atmospheric Administration [NOAA] 1980). Meteorological data from this station are considered generally representative of regional conditions throughout the LTMS area. Precipitation would be somewhat lower along the coast and within the San Francisco Bay waters and would increase northward and inland toward higher, more mountainous terrain. The wettest areas of the Estuary receive as much as 60 inches of rain annually, with drier areas of the Estuary receiving as little as six inches of rain (SFEP 1992b). About 90 percent of rainfall in the region occurs from November through April.

The air temperatures of the Bay Area reflect the effects of the cool Bay water temperature, with mean monthly temperatures ranging from 50ºF to 60ºF. Areas farther inland and within the Delta region have much higher average temperatures during the summer (80ºF) and lower average temperatures during the winter (43ºF) (Conomos 1979). The average high and low temperatures at the Oakland International Airport in July are 71.1ºF and 55.5ºF, respectively. January average high and low temperatures are 55.6ºF and 40.7ºF. Extreme high and low temperatures recorded from 1941 through 1980 were 107.0ºF and 23.0ºF, respectively (NOAA 1980).

The proximity of the Eastern Pacific High and a thermal low pressure system in the Central Valley region to the east produces air flow generally from the west to northwest along the central and northern California coast for most of the year. The persistence of these breezes is a major factor in minimizing air quality impacts from approximately 6 million people that live in the region. As this flow is channeled through the Golden Gate Bridge, it branches off to the northeast and southeast, once inside the Bay. As a result, winds often blow from the northwest in the South Bay, from the southwest in the Central Bay, then from the west as winds flow through the Suisun Bay and Delta regions toward the San Joaquin Valley. Nocturnal and wintertime land breezes tend to blow in the opposite direction of this pattern. These land breezes may extend many miles offshore during the colder months of the year until daytime heating reverses the flow back onshore.

Wind patterns of the region have a particularly important influence on Bay water circulation and resuspension of Bay sediments (SFEP 1992b). These patterns vary throughout the year, with strong summer westerly winds developing during the afternoon, as warm air in the Central Valley to the east rises and cool air from the Pacific Ocean moves inland. Prevailing winds are also important factors offshore. The high biological productivity of the ocean waters on the continental shelf west of San Francisco are largely associated with wind-driven upwelling of cold, nutrient-rich ocean water during the spring and summer. The richness and diversity of the continental shelf off central California is reflected in the fact that three national marine sanctuaries have been designated there.

Climate directly influences the type and distribution of upland and wetland habitats in the Estuary. For example, watersheds receiving moderate to high amounts of rainfall, such as the Guadalupe River in the South Bay and the Napa River in the North Bay, support tidal brackish marshes at their mouths (Harvey and Associates 1988). In contrast, watersheds receiving low-to-moderate rainfall (which includes the majority of local streams draining into the Estuary) are characterized by salt marshes.

### 4.2.2 Geologic History of the LTMS Planning Area

The geology of the San Francisco Bay Area is characterized by three structural blocks roughly separated by the active San Andreas and Hayward faults, both right-lateral slip faults of the San Andreas fault system. The Hayward fault zone branches off the San Andreas south of the Bay and extends along the base of the Berkeley Hills block, composed of Cretaceous marine sedimentary formations overlain by Tertiary sedimentary and volcanic rocks. The San Andreas rift zone lies west of the Bay and generally traverses both San Mateo and Marin counties to the south and north, respectively. The San Andreas fault separates the San Francisco-Marin block on the east from the Point Reyes-Montara block on the west. As the northernmost land extension of the larger Salinian structural block, the Point Reyes-Montara block is lacking the occurrence of the Franciscan Formation as basement or surface outcrops, which characterizes the San Francisco-Marin and the Berkeley Hills blocks to the east (Oakeshott 1978). Other active faults associated with the San Andreas system that lie east of the Hayward fault zone include the Calaveras, Greenville, Ortigalita, and Concord-Green Valley faults.

The Estuary is located within the Coast Ranges Geomorphic Province of California, which is characterized by a system of northwest-trending longitudinal mountain ranges and valleys formed by faulting and folding. The geologic processes contributing to the Estuary's formation include movements of the earth's crust during the past 150 million years that transformed the region from deep ocean to continental hills and valleys, and more recent local subsidence that created the bedrock trough in which San Francisco Bay lies. Sea level fluctuations also have played an important role in forming the Estuary.

At the end of the last glacial period, some 15,000 to 18,000 years ago, sea level was much lower and the shoreline of the Pacific Ocean was west of the Farallon Islands, on the present day continental shelf (SFEP 1991b and 1992b). About 10,000 years ago, the rising ocean entered the Golden Gate area and began to fill the Estuary basin. Initially, sea water advanced across the basin floor at a rate of nearly 100 feet each year. About 5,000 years ago, as glaciers reached approximately their present size and the rise in sea level markedly slowed, the Estuary's waters were only about 25 feet lower than their present level. In the intervening five millennia, the sea continued its slow rise and the Estuary eventually reached its current elevation.

The Delta formed in an unusual way. Unlike most deltas, which grow seaward as sediments are deposited at river mouths, the Delta formed far inland from the ocean and grew in an upstream direction. This was caused by a barrier of bedrock in the hills at the Carquinez Strait, which trapped sediments carried by the Sacramento and San Joaquin rivers. As the sediments accumulated at the confluence of the two rivers, there evolved a 540-square-mile tidal freshwater marsh interlaced with hundreds of miles of braided channels. In the western Delta, peat as thick as 66 feet indicates that vertical accretion in marshes has kept pace with submergence during the past 4,000 to 6,000 years. Without the bedrock barrier, the sediments would have washed downstream to be deposited as spits or mudflats in the Bay. A notch in the barrier enabled the freshwater flows to reach San Pablo Bay.

The establishment of extensive tidal marshes around south San Francisco Bay appears to have occurred later than in the Delta, probably close to 2,000 years ago. During that period, sea water began flowing over extensive flatland deposits in the South Bay.

The continental shelf offshore of the Golden Gate is a broad, relatively flat plain, with water depths up to 180 m (500 feet). The San Francisco Deep Ocean Disposal Site (SF-DODS) is located on the continental slope beyond the continental shelf, in approximately 10,000 feet of water, in the physiographic province called the Farallones Escarpment. This relatively narrow (about 35 km wide) segment of the continental slope has rugged topographic relief and an average slope of six degrees or more. It is transected by numerous gullies and canyons that are oriented roughly perpendicular to the regional trend (generally northwest-to-southeast) of the Farallones Escarpment.

### 4.2.3 Pre-Settlement Conditions

The recorded history of the San Francisco Estuary spans less than 250 years. Although initially discovered by Spanish explorers and missionaries in 1769, the Estuary was little explored until 1816, when naturalists and cartographers began investigating the shorelines and inland water routes. The early European colonists probably saw extensive marshlands undisturbed by the native inhabitants, except for isolated middens and villages (SFEP 1991b).

Before European settlement, the Estuary's freshwater flows were determined entirely by precipitation patterns and other natural processes. Rain and snow falling in the Sierra Nevada mountains and within the rest of the Central Valley watershed flowed into streams and rivers and percolated into the ground. As the water reached the Valley floor, peak flows over-topped the natural riverbank levees and spread out across the landscape into vast stands of tules and other wetland vegetation.

Under natural conditions in an average year, flows increased in late fall and throughout the winter, and peaked in the spring when warm temperatures melted the Sierra snow-pack. After the spring snow melt, flows declined to low levels until the fall. Many of the estuary's native species of fish and other aquatic and wildlife resources are adapted to an ecosystem characterized by this high seasonal variation in freshwater flows. The high winter and spring flows repelled sea salts from the Delta, ensuring appropriate water quality for freshwater wetlands. They washed nutrients into estuarine waters, encouraging growth of the microscopic plants and animals at the bottom of the food web, and enabled fish to migrate, spawn, and rear successfully.

The total volume of fresh water that entered the Estuary in an average year under natural conditions is unknown. However, based on precipitation records, maps of native vegetation, and hydrologic models, the average annual volume possibly ranged between 19 and 29 million acre-feet (maf). As noted below in section 4.2.4, the seasonal distribution of flows plays a much greater role in determining estuarine biological productivity than does the total annual volume.

Nearly two-thirds of the surface of the pristine Estuary was covered with tidal marshes. The Delta was largely a tidal marshland of about 400,000 acres, surrounded by an additional 200,000 to 300,000 acres of slightly higher lands and shallow back-swamps behind natural alluvial levees (SFEP 1991b). Most of the land was close to mean sea level, with the highest points of land only 10 to 15 feet above that level. Flooding of the back-swamps was frequent; in the spring virtually all of the Delta became a giant inland lake, covered by high tides and runoff from the Sacramento and San Joaquin rivers.

In the South Bay, tidal marshes formed a wide, nearly-continuous corridor from San Mateo on the west to Mt. Eden on the east, ranging from 0.25 mile to over 7.0 miles in width. The Napa Marsh along the northern shoreline of San Pablo Bay totaled approximately 125 square miles, while tidal wetlands extended about 10 miles upstream along the Petaluma River. Suisun Marsh encompassed approximately 111 square miles from Benicia east to Collinsville.

Areas inland from the tidal marshes were characterized by a network of perennial, intermittent, and ephemeral streams bordered by narrow bands of scrub-shrub and forested riparian wetlands. Shallow ponds and salt pans probably were formed intermittently through the landscape on low-lying plains bordering tidal wetlands. High marsh transition zones graded into upland habitats on the inboard margins of South Bay tidal marshes.

Tidal water influence on the low-lying Delta marshes was moderated by natural alluvial levees formed along river and distributor channels. These levees formed a barrier to all but the highest tides and river flows. During periods of low river flow, high tides probably could not surmount many of the levees in the northern Delta. Only riverine floods inundated low-lying marshes that were enclosed by naturally leveed channels. Other areas flooded by the Sacramento River, such as the Yolo Basin, became an immense lake or river that bypassed the

Sacramento River and discharged near Rio Vista. Within the Bay Area, marshes at higher elevations or behind natural levees transitioned naturally from tidal salt marsh into brackish-water marsh and seasonal marsh.

At the onset of European occupation, the Estuary supported a stable population of 50,000 to 55,000 Native Americans, of which 20,000 to 25,000 resided in the Bay Area and another 30,000 inhabited the Delta.

### 4.2.4 Historical Changes

The Estuary supports a diverse set of rich environmental resources and economic activities and is of great social importance to people living in the region. The biological resources of this region reflect the diversity of geographical features, variations in climate, and history of settlement within the area, which have resulted in a complex mosaic of habitats, including native and disturbed environments that range in value and importance to local, regional, and migrating wildlife. Over 6 million people live in the 11 counties surrounding the Estuary. The economy of the region is robust and broad-based, with many sectors that rely on the environmental resources of the Estuary, such as maritime commerce, commercial fishing, recreational boating and watersports, agriculture, and tourism.

Estuaries are among the most productive habitats; mixing of fresh and salt water creates a high level of nutrients. This, in turn, provides excellent habitat for rearing of both salt water and fresh water aquatic and upland wildlife. Like many other estuaries around the country, the San Francisco Bay Estuary exhibits many signs of stress from historical and current human use. These signs, such as diminished natural habitats, declining populations of fish and wildlife, polluted water, and increased sediment deposition reflect the historical development and management of these areas. Development of the waterfront and landfilling along the margins have reduced the original Bay from some 700 square miles to its current size of 470 square miles (Conomos 1979).

Actions have been taken within the region over the past three decades to halt and reverse the trend of declining environmental quality. Government and local entities are now actively engaged in work to restore degraded or lost natural habitat, pollutant loading to Estuary waters has been significantly reduced, and increasing attention has been focused on restoring fish and wildlife populations. The overall goal of these activities is to simultaneously maximize the environmental benefit, minimize the environmental impact, and maximize the economic value of actions within the region.

#### 4.2.4.1 Increased Sediment Deposition

The discovery of gold in the Sierra Nevada in 1848 resulted in rapid population growth in the Estuary basin and throughout much of the Estuary's Central Valley watershed. Between 1848 and 1850, the population of San Francisco grew from 400 to 25,000 persons, while the state's total population grew from 15,000 to 93,000.

It is estimated that the natural annual load of sediment carried by rivers into the Delta, prior to 1849, was approximately 2 million cubic yards (mcy). Hydraulic gold mining and other human activities — such as agriculture, grazing, logging, and urban development — increased the sediment load to an estimated annual average of 18.4 mcy during the period from 1849 to 1914. This huge increase in sediment input smothered fish spawning areas, interfered with navigation, and caused extensive flooding by raising Delta channel bottoms with sediment deposits as much as 15 feet thick.

The historical increase in sediment loads had a substantial effect on mudflat and subtidal areas of the Estuary. The deposition of fine sediments originally raised mud elevations several meters in Suisun Bay, but the elevation of mud apparently migrated as a "mud wave" to San Pablo Bay and the Central Bay over the past century. It is not known whether the effect of these deposits has been dissipated (SFEP 1990).

The capacity of the Estuary to remove sediments has been reduced as a result of these modifications. Reclamation of flood plain and tidal wetlands in the Delta and elsewhere in the Estuary (see section 4.2.4.2 below) eliminated natural sediment traps. Tidal current velocities were reduced in portions of the Bay, diminishing the natural capacity to disperse and flush sediments through the Estuary. Construction of dams and water diversions altered flows and reduced the volume of fresh water inflow (see section 4.2.4.3 below) which may have led to increased shoaling rates in portions of the Bay. The increased sediment inputs and the virtual elimination of many tidal marshes as sediment traps may have also resulted in increased suspended sediment concentrations in the Estuary. High suspended sediment concentrations reduce light availability for phytoplankton and may interfere with the feeding mechanisms of many estuarine animal species.

Court injunctions brought by farmers stopped the practice of hydraulic mining in the late 19th century, and large dams constructed since 1940 have blocked sediments and thus reduced new sediment delivery to the Estuary (although this reduction primarily affects the coarser bedload portion of the total river-borne sediment load). Nevertheless, net sediment accumulation probably continued in the Bay through the early 20th century.

#### 4.2.4.2 Land Reclamation and Agriculture

By 1860 more than half of the state's 380,000 citizens lived around the Estuary or in its watershed. They created an enormous demand for food and other commodities; in response, many of the Estuary's wetlands were "reclaimed" and converted to farmland and other uses.

The presence of large, natural ponds on the eastern shore of the South Bay and the need for salt by a growing population prompted the development of large-scale commercial salt production in the Bay. By the late 1800s, extensive wetland areas were being diked off to produce salt in solar evaporation ponds. In the South Bay, over 61 square miles, or about 50 percent of the South Bay wetlands (83 percent of historic tidal marshes), had been reclaimed for salt production by the 1930s. Additional areas were diked off for evaporation ponds in the North Bay, as well.

During the same period, extensive levee construction in the Delta enabled massive reclamation of Delta lands for agriculture. In the late 1870s, steam-powered dredges excavated material directly from the Delta channels to construct large levees. By 1880, approximately 100,000 acres of land had been reclaimed. Higher and more substantial levees were built in the 1890s by clamshell dredges. By 1900, over half of the Delta had been reclaimed and, by 1930, Delta reclamation was essentially complete, with the formation of almost 60 major islands (SFEP 1991b).

Most Delta agricultural lands are below sea level. Constant subsurface seepage into the islands required continual drainage and pumping through an elaborate system of ditches and siphons to maintain a water table elevation suitable for agriculture. These drainage practices, in combination with peat decomposition and wind erosion processes and other activities such as burning of the soil (no longer practiced), water erosion, compaction by heavy farm machinery, and natural gas extraction led to diked lands subsiding as much as 20 feet below mean sea level.

As a result of the land subsidence in the Delta, breaching of dikes during floods generally created open water habitat rather than tidal wetlands. Flooded Delta islands raise water quality concerns such as increased salinity intrusion and increased wave erosion on the levees of upwind islands. Thus levee maintenance is viewed as an important, ongoing concern. Levee maintenance is a continual and costly requirement in the Delta. The long-term costs of maintaining levees at some Delta islands is greater than the economic return from agriculture and it may be more cost-effective to operate such islands as recreation areas and wildlife preserves. Portions of these islands could be filled and graded to support wetland restoration.

In San Pablo and Suisun bays, land subsidence in agricultural areas has not been as significant as in the Delta. Wetland vegetation typically occurs along drainage and irrigation channels and low-lying, seasonally wet areas. In some instances, removal of the perimeter levees and subsequent tidal inundation may allow a return to more permanently flooded or tidal wetland conditions.

#### 4.2.4.3 Dams and Water Diversions

At the same time as wetlands were being reclaimed and hydraulic mining debris was being deposited within the Estuary, freshwater sources for the Estuary were being dammed and diverted. The demand for irrigation water for expanding agriculture, and for domestic water for growing cities, encouraged the development of extensive water management and diversion systems during the early part of the 20th century. The construction of large dams and water conveyance structures permitted large-scale arid land cultivation, but reduced stream-flows in the Sacramento and San Joaquin rivers to the detriment of wetland areas in the Central Valley and in the Delta (SFEP 1991b).

With the exception of the Cosumnes River, large multi-purpose reservoirs have been constructed on all of the Central Valley's major rivers. Together, Central Valley reservoirs can store about 27 maf of water, which is equivalent to about 60 percent of the State's average annual runoff. Central Valley reservoirs are operated primarily for flood control in the winter and for capturing the spring snow-melt runoff to be released in the summer for agriculture. Although the timing of flow releases varies from reservoir to reservoir, the overall effect of storage operations is to reduce the volume of water flowing downstream throughout the late fall, winter, and spring, and to increase it during the summer and early fall. The result has been a profound change in the seasonal distribution of freshwater flow to the Estuary.

Initial exports of fresh water from the Delta began in 1940, but major diversions began in 1951, when the Central Valley Project (CVP) began supplying water from the south Delta to the Delta-Mendota Canal. The volume of water pumped into the Delta-Mendota Canal has increased from an annual average of about 700,000 acre-feet in the 1950s to more than 2.8 maf in 1989. The State Water Project (SWP) began pumping additional water from the south Delta to the California Aqueduct in 1968. Annual SWP Delta diversions have increased steadily, reaching a peak in 1989 of more than 3 maf (SFEP 1992b).

In addition to Delta exports, the volume of the Estuary's freshwater supply has been depleted by upstream diversions and in-Delta use. During this century, total diversion has grown more than 10-fold, from about 1.5 maf to nearly 16 maf. As a result, diversions have reduced annual Delta outflow by more than one-half on several occasions during the past two decades.

At times, especially during periods of low river flow, the amount of water pumped from the south Delta is high enough to reverse the natural direction of net flow in the distributor channels of the San Joaquin River. These reverse flows may confuse migrating anadromous fish and adversely affect the distributions of many Delta species. Reverse flows probably increase predation on young fish and the risk to plankton and young fish of being entrained by diversion pumps.

The volume of water diverted from the Estuary supply has increased overall during the past several decades. However, it varies relatively little from year to year. At the same time, annual precipitation (and thus the volume of water available in the system during any year) varies greatly. Therefore the effect of diversions on outflow to the Estuary (the percentage of available water diverted) varies from year to year. In wet years, diversions reduce outflow by 10 to 30 percent. In dry years, diversions reduce outflow by more than 50 percent. During recent drought years, diversions reduced annual Delta outflow by more than 70 percent. Outflow reductions have primarily occurred during winter and spring, when freshwater flows are particularly important for many estuarine species.

Intrusion of saltwater from San Francisco Bay up into the Sacramento and San Joaquin rivers and surrounding freshwater marsh and overflow lands historically occurred, particularly in the western Delta. Early records show that salinity intrusion occurred in some years long before extensive development of the Delta. With the onset of reclamation activities and increasing water diversions, the invasion of saline water from the west was more frequent and far reaching in the Delta. Levee construction, channel dredging, and wetland drainage for agricultural purposes, combined with extensive irrigation diversions from the Sacramento River, had the effect of allowing saline water to encroach farther up into the Delta. Since the 1940s, however, releases of fresh water from upstream storage facilities have increased summer and fall Delta outflows and these flows have correspondingly limited the extent of salinity intrusion into the Delta. Reservoir releases have helped to ensure that the salinity of water diverted from the Delta is acceptable during the summer and late fall for farming, municipal, and industrial uses (SFEP 1991a).

Even with upstream releases to reduce the extent and frequency of saltwater intrusion into the Delta, the overall effect of changes in seasonal flows has been to increase salinity slightly in the western Delta and in Suisun Bay during spring and summer, and to decrease it substantially during fall and winter. Generally increased salinity conditions have threatened to alter water and soil conditions within Suisun Marsh and to lower the production of important marsh plants, some of which are rare or endangered. Salinity increases in Suisun Bay have also caused some fishes such as the Delta smelt to shift their habitat use upstream (SFEP 1992a).

#### 4.2.4.4 Flood Control

Flood control projects have been a feature of the Estuary basin and its tributaries since the 1860s. On the Estuary's tributaries, flood control features consist of a number of "improvements" such as straightening and deepening to increase channel capacity, removal of riparian vegetation to facilitate high flows, lining channels with concrete or covering banks with rock to reduce erosion, and constructing levees adjacent to channels to confine high flows to a prescribed course. Dams also play an important role in regulating peak flows. In the Delta and along the edges of the Bay, levees are the most visible flood control features. Most Bay levees prevent flooding of lands a few feet below sea level; those in the Delta protect lands as much as 20 feet below sea level (SFEP 1992b).

The construction of flood control projects on streams has resulted in severe impacts to stream channels and adjacent riparian corridors. Channel straightening, removal of instream and riparian vegetation, placement of rock revetment along banks, and construction of concrete channels greatly lower habitat values and reduce the ability of streams to support diverse populations of fish and wildlife. Project maintenance generally keeps habitat values low by preventing the growth of mature riparian vegetation on all but the uppermost portions of stream banks.

Along the Bay shoreline and in the Delta, levees result in drastically altered hydrologic conditions. In the Bay, levees prevent or inhibit tidal excursion into thousands of acres of seasonal wetlands; they also protect developments in the floodplain. In the Delta, levees keep more than 350,000 acres of seasonal farmed wetlands from flooding. Without these levees, much of the Delta would be open water.

#### 4.2.4.5 Pollution

Pollution was a problem beginning at least as early as 1879, when the California Division of Fish and Game described damage to the Estuary "inflicted by the constant fouling of the waters and consequent destruction of life by the fetid inpourings of our sewers." In the early 1900s, contamination from raw sewage was blamed for the decline of the Bay's oyster and soft-shell clam fisheries, and oil became a concern after the first of the Estuary's major refineries was built in 1896. Over the first half of this century, waste discharges and contamination of the Estuary steadily increased, particularly near municipal and industrial sewage outfalls that were located either in shallow waters or in partially enclosed basins with poor circulation (SFEP 1991a).

Municipal sewage plants began installing sewage treatment in the 1950s and 1960s. Many sewage outfalls were also moved to deeper water, where currents are stronger and a larger volume of water is available to dilute the discharge. Between 1955 and 1985, while the population served by the municipal sewage plants doubled and the volume of sewage treated and discharged more than doubled, improved treatment reduced the total amount of organic matter in the discharge by over 70 percent.

Industrial waste loads also declined dramatically during this period. From 1961 to 1984, refineries cut their organic waste loads by 93 percent, oil and grease by 95 percent, and chromium and zinc by more than 99 percent.

Despite these major improvements, nearly 50 municipal and 140 industrial dischargers still dump significant quantities of wastes into the Estuary each year, including 300 tons of trace metals. Areas with large discharges and poor water circulation, such as the far South Bay, which in the summer receives more wastewater than river water, are thought to be particularly vulnerable. In addition, some waste materials and contaminants from old mine sites continue to enter the Estuary.

Even larger amounts of wastes enter the Estuary from urban runoff (which carries oil, grease, lead, and zinc washed from streets) and agricultural runoff (which can contain pesticides, herbicides, nitrates, and metals leached from the soil). Other sources of contamination include accidental spills, discharges from ships and boats, and particles that settle out of the air.

The deep ocean outside the Golden Gate also has not escaped its share of pollutants over the years. Historically, the SF-DODS and adjacent areas have been used for disposal of dredged materials, chemical and conventional munitions, and low-level radioactive waste.

#### 4.2.4.6 Introduced Species

The Estuary is an ecosystem now dominated by introduced species, from top predators such as striped bass to plankton feeders such as the Asian clam (*Potamocorbula amurensis*). The introduction of oysters, bullfrogs, crayfish, striped bass, and American shad was only the beginning of a long series of introductions that continues to this day. In the 19th century and the first half of this century, most introductions either were made deliberately in efforts to "improve" the local fauna from the perspective of western culture or they were made accidentally, as species hitched rides in containers with the authorized species or came attached to ships. As a result, more than half the fishes in the Delta and most of the benthos of the Bay are made up of non-native species. New species are continuing to arrive in the Estuary, especially in ballast water of ships, as demonstrated by the recent destructive invasion of the Asian clam. The presence of so many recently established species in the Estuary, combined with continual arrival of new species, contributes greatly to the instability of the Estuary's biotic communities and increases the difficult of managing it to favor desired species (SFEP 1992a).

#### 4.2.4.7 Commercial and Recreational Fisheries

Many of the mollusks, crustaceans, and fishes of the Estuary have been heavily harvested by humans for commercial and recreational purposes. There is little doubt that over-exploitation of species such as Chinook salmon, white sturgeon, soft-shell clam, and crangonid shrimp contributed to their declines in the early part of this century. The sturgeon and shrimp populations showed dramatic recoveries once commercial fisheries were eliminated or reduced. However, over-harvest has played a minor role in the long-term declines of the Estuary's aquatic resources (SFEP 1992a).

Several commercial fisheries exist or have existed offshore San Francisco, including fisheries for adult Pacific herring, adult salmon, adult tuna, adult mackerel, and juvenile Pacific hake. The commercially and/or recreationally important invertebrates collected within the Gulf of the Farallones include Dungeness crab, market squid, and several species of shrimp.

### 4.2.5 Navigation in the Estuary Today

Today, San Francisco Bay is one of the world's great natural harbors and is a hub of international commerce in the region. In addition, the Stockton and Sacramento Deep Water Ship Channels provide access through San Francisco Bay to the inland ports of Sacramento and Stockton. There are 14 major, federally maintained deep-draft shipping channels in the LTMS Planning Area, not including the Stockton and Sacramento Ship Channels in the Delta. Their locations and the locations of additional major dredging areas are shown in Figure 4.2-1. These channels serve six public ports in the Bay Area, as well as several important military facilities and numerous privately operated industrial facilities. In addition, dozens of smaller, privately-maintained channels, basins, and berthing areas support shallow-draft commerce, commercial fishing, and recreational boating. These facilities support over 220 public and private marinas throughout the Estuary that provide over 33,000 boat slips. Together, the major and minor shipping channels, ports, marinas, and other maritime facilities of the San Francisco Bay Area support over $7 billion in regional economic activity. The "dredging-related" economy of the Bay Area is described in section 4.6.

The majority of dredged material generated in the Bay Area comes from the construction, deepening, and/or maintenance of the major shipping channels and the deep-draft ship berths and turning basins associated with them. Overall, several million cubic yards of dredged material are removed each year from these navigation facilities. Even though earlier estimates of the region's long-term dredging needs have been lowered as a result of recent military base closure decisions, LTMS projections are that approximately 300 mcy of dredging will still need to be accommodated over the next 50 years. This equates to an average of 6 mcy per year. Adequate capacity for disposal and reuse of this material, on a timely basis when dredging is needed, is critical to the smooth, uninterrupted operation of the region's navigation facilities and to the health of a substantial portion of the region's economy.

#### 4.2.5.1 Shipping Lanes and Vessel Traffic

Due to the importance of maintaining efficient access to port facilities, the Ports and Waterways Safety Act of 1972 established guidelines for entering and leaving ports, established traffic lanes for inbound and outbound vessel traffic, and specified separation zones between

Figure 4.2-1 U.S. Army Corps of Engineers
Major Navigation Projects in the Bay/Delta Estuary

them. The established vessel traffic lanes in the Bay Area are described below. In addition, the Coast Guard has established a Vessel Traffic System (VTS) for large commercial and military vessels, to reduce the potential for vessel collisions and groundings and environmental or other resource damage that could result from such incidents. VTS serves in an advisory capacity, coordinating and monitoring vessel movements using commercial and surveillance radar as well as closed circuit television, and utilizes a radio network to communicate information to inbound and outbound vessels, and to vessels operating within the Bay (USACE and Port of Oakland 1994; Chambers Group 1994). Traffic data are maintained by vessel type for movements within the Bay, but are not maintained for movement through the Golden Gate, in the precautionary zone, or in the vessel traffic lanes. Approximately 38 percent of arriving and departing vessels use the Northern Traffic Lane, 20 percent the Western, and 42 percent the Southern. The majority of tanker traffic uses the Western Traffic Lane. VTS coverage does not extend to the EPA-designated SF-DODS some 50 miles outside of the Golden Gate.

Extending several miles west of the Golden Gate Bridge, but still within the coverage of the VTS, there are established traffic lanes for vessels approaching from the north, west, and south, as shown in Figure 4.2-2. Each approach lane from seaward is composed of a mile-wide inbound traffic lane and a mile-wide outbound traffic lane with a mile-wide separation zone. Outside these shipping zones, the U.S. Navy has established areas designated for submarine diving exercises and does not allow barge operations or the towing of submersibles in these areas. All approach lanes lead to a large offshore light station with a rotating beacon that marks the beginning of the main channel to the Golden Gate Bridge. The beacon, which is located approximately 10 miles west of Point Bonita is in the center of a large precautionary area where all ships leaving and entering port converge. In addition, many ships take on or discharge bar pilots there (USACE and Port of Oakland 1994).

From the rotating beacon, ships proceed in an easterly direction toward the Golden Gate through a narrow channel, which is again composed of inbound and outbound traffic lanes with a separation zone between them. These traffic lanes are 600 yards wide with a 150-yard-wide separation zone. The channel is marked on either side with a series of buoys through the San Francisco Bar Channel, a shoal area approximately half-way between the rotating beacon and a line drawn from Point Bonita to Point Lobo. The channel is usually more than 90 feet deep throughout the area, with the exception of the shoal areas that are maintained at a depth of 50 feet by annual dredging. There are shoal waters less than 30 feet deep on either side of this narrow channel. Additional aids to navigation such as horns, bells, and lights are provided at appropriate locations near submerged rocks and points of land (USACE and Port of Oakland 1994).

East of the Golden Gate Bridge, the traffic lanes continue with the separation zone between east and westbound traffic being located on a line from center of the Golden Gate Bridge to Alcatraz Island (see Figure 4.2-3). All eastbound traffic passes to the south of Alcatraz Island. Westbound traffic passes to the north of the Island. There is a precautionary area immediately east of Alcatraz Island where the channel from the South Bay meets that of the North Bay. This area is small and is highly congested because it is the confluence of several channels of traffic moving in opposing directions. The southerly traffic lanes continue along the San Francisco city front from the Blossom Rock light to the San Francisco-Oakland Bay Bridge, with the separation zone extending along a line form the center anchorage of the Bay Bridge to Blossom Rock. Inbound traffic must pass southwest of the center anchorage of the Bay Bridge with outbound traffic passing northeast of the center anchorage (USACE and Port of Oakland 1994).

South of the Bay Bridge, traffic lanes diverge in several directions. Ships destined for Oakland and Alameda turn left and cross the north-bound traffic lane, while vessels bound for Hunter's Point and the San Francisco southern waterfront continue in the southerly direction. The east side of southern San Francisco Bay from central Alameda to the San Mateo Bridge is a general anchorage area. Within this area, there are two explosive anchorage areas with forbidden anchorage zones surrounding them (USACE and Port of Oakland 1994).

Ships inbound for ports along the way to Sacramento or Stockton turn left after reaching the precautionary area east of Alcatraz. They proceed in the northbound traffic lane toward the San Rafael Bridge. These traffic lanes vary in width from 500 to 1,100 yards and have a 150-yard separation area between them. The channel narrows under the San Rafael Bridge and then opens to nearly 1,500 yards beyond the San Pablo Straits. -

Figure 4.2-2 Traffic Lanes Outside the Golden Gate Bridge

Figure 4.2-3 Typical Vessel Traffic Routes in the San Francisco Bay

Adjacent to Pinole Point, the channel reduces to a 600-foot width and continues at that width with no separation of opposing traffic lanes through the Carquinez Strait (USACE and Port of Oakland 1994).

The Sacramento and San Joaquin rivers from the Carquinez Strait to Twitchell Island have reaches of deep navigable water. Naturally shallower reaches of the rivers have dredged channels that are marked with buoys on both sides (USACE and Port of Oakland 1994).

To transport dredged material to aquatic disposal or reuse sites, barges would often have to traverse or use the established inbound and outbound vessel traffic lanes. Often, weather conditions in the LTMS planning area are rough and inclement, and could result in an increased risk of collision. Historically, the number of collisions involving dredge barges and tugs has been small. For example, between 1980 and 1989, 25 collisions involving tugs, barges, or self-propelled dredges occurred. In addition, four barge breakaways occurred and 13 were grounded (USEPA 1993a).

Vessel traffic data compiled for 1987 and forecast for 1995 are presented in Tables 4.2-1 and 4.2-2, respectively. The location of the vessel traffic subzones indicated in these tables is shown in Figure 4.2-4.

**Table 4.2-1. Vessel Transits for the San Francisco Bay Area (1987)**

| *Vessel Type* | *Large* | *Medium* | *Small* | *Total* |
|---|---|---|---|---|
| Subzone 1401A | | | | |
| Passenger | 0 | 60 | 0 | 60 |
| Dry Cargo | 3,439 | 7,266 | 1,149 | 11,854 |
| Tanker | 2,040 | 2,388 | 1,008 | 5,436 |
| Dry Cargo Barge Tow | 85 | 0 | 358 | 443 |
| Tanker Barge Tow | 156 | 0 | 184 | 340 |
| Tug/Tow Boat | 0 | 0 | 151 | 151 |
| SUBZONE TOTAL | 5,720 | 9,714 | 2,850 | 18,284 |
| Subzone 1402B | | | | |
| Passenger | 0 | 60 | 3,850 | 3,910 |
| Dry Cargo | 1,841 | 3,629 | 882 | 6,352 |
| Tanker | 1,141 | 1,402 | 804 | 3,347 |
| Dry Cargo Barge Tow | 57 | 0 | 0 | 57 |
| Tanker Barge Tow | 120 | 0 | 0 | 120 |
| SUBZONE TOTAL | 3,159 | 5,091 | 5,536 | 13,786 |
| Subzone 1403C | | | | |
| Passenger | 0 | 60 | 42,107 | 42,167 |
| Dry Cargo | 1,841 | 3,629 | 4,412 | 9,882 |
| Tanker | 1,141 | 1,402 | 804 | 3,347 |
| Dry Cargo Barge Tow | 57 | 0 | 6,746 | 6,803 |
| Tanker Barge Tow | 120 | 0 | 3,773 | 3,893 |
| Tug/Tow Boat | 0 | 0 | 12,750 | 12,750 |
| SUBZONE TOTAL | 3,159 | 5,091 | 70,592 | 78,842 |
| Subzone 1404D | | | | |
| Passenger | 0 | 0 | 100 | 100 |
| Dry Cargo | 1,267 | 1,504 | 310 | 3,081 |
| Tanker | 1 | 0 | 1 | 2 |
| Dry Cargo Barge Tow | 0 | 0 | 697 | 697 |
| Tanker Barge Tow | 0 | 0 | 625 | 625 |
| Tug/Tow Boat | 1 | 0 | 6,170 | 6,171 |
| SUBZONE TOTAL | 1,269 | 1,504 | 7,903 | 10,676 |
| Subzone 1405F | | | | |
| Dry Cargo | 264 | 1,012 | 201 | 1,477 |
| Tanker | 571 | 732 | 380 | 1,683 |
| Dry Cargo Barge Tow | 56 | 0 | 2,889 | 2,945 |
| Tanker Barge Tow | 90 | 0 | 1,662 | 1,752 |
| Tug/Tow Boat | 0 | 0 | 1,287 | 1,287 |
| SUBZONE TOTAL | 981 | 1,744 | 6,419 | 9,144 |
| ZONE TOTALS | | | | |
| Passenger | 0 | 60 | 42,107 | 42,167 |
| Dry Cargo | 3,439 | 7,266 | 4,679 | 15,384 |
| Tanker | 2,040 | 2,388 | 1,008 | 5,436 |
| Dry Cargo Barge Tow | 85 | 0 | 7,104 | 7,189 |
| Tanker Barge Tow | 156 | 0 | 3,957 | 4,113 |
| Tug/Tow Boat | 0 | 0 | 12,901 | 12,901 |
| 1987 ZONE TOTAL | 5,720 | 9,714 | 71,756 | 87,190 |

| *Vessel Type* | *Large* | *Medium* | *Small* | *Total* |
|---|---|---|---|---|
| Subzone 1401A | | | | |
| Passenger | 0 | 63 | 0 | 63 |
| Dry Cargo | 4,439 | 9,428 | 5,868 | 19,735 |
| Tanker | 2,170 | 2,564 | 1,064 | 5,798 |
| Dry Cargo Barge Tow | 0 | 0 | 8,240 | 8,240 |
| Tanker Barge Tow | 0 | 0 | 4,266 | 4,266 |
| Tug/Tow Boat | 0 | 0 | 16,242 | 16,242 |
| SUBZONE TOTAL | 6,609 | 12,055 | 35,680 | 54,344 |
| Subzone 1402B | | | | |
| Passenger | 0 | 63 | 4,054 | 4,118 |
| Dry Cargo | 2,405 | 4,712 | 5,522 | 12,639 |
| Tanker | 1,208 | 1,503 | 848 | 3,559 |
| Dry Cargo Barge Tow | 0 | 0 | 7,832 | 7,832 |
| Tanker Barge Tow | 0 | 0 | 4,057 | 4,057 |
| Tug/Tow Boat | 0 | 0 | 16,404 | 16,404 |
| SUBZONE TOTAL | 3,613 | 6,278 | 38,717 | 48,609 |
| Subzone 1403C | | | | |
| Passenger | 0 | 63 | 49,680 | 49,743 |
| Dry Cargo | 2,405 | 4,712 | 5,522 | 12,639 |
| Tanker | 1,208 | 1,503 | 848 | 3,559 |
| Dry Cargo Barge Tow | 0 | 0 | 7,832 | 7,832 |
| Tanker Barge Tow | 0 | 0 | 4,057 | 4,057 |
| Tug/Tow Boat | 0 | 0 | 16,404 | 16,404 |
| SUBZONE TOTAL | 3,613 | 6,278 | 84,343 | 94,234 |
| Subzone 1404D | | | | |
| Passenger | 0 | 0 | 4,547 | 4,547 |
| Dry Cargo | 1,681 | 2,015 | 412 | 4,108 |
| Tanker | 1 | 0 | 0 | 1 |
| Dry Cargo Barge Tow | 0 | 0 | 798 | 798 |
| Tanker Barge Tow | 0 | 0 | 700 | 700 |
| Tug/Tow Boat | 0 | 0 | 8,244 | 8,244 |
| SUBZONE TOTAL | 1,682 | 2,015 | 14,701 | 18,398 |
| Subzone 1405F | | | | |
| Dry Cargo | 322 | 1,238 | 238 | 1,798 |
| Tanker | 603 | 786 | 398 | 1,787 |
| Dry Cargo Barge Tow | 0 | 0 | 3,350 | 3,350 |
| Tanker Barge Tow | 0 | 0 | 1,785 | 1,785 |
| Tug/Tow Boat | 0 | 0 | 1,444 | 1,444 |
| SUBZONE TOTAL | 925 | 2,024 | 7,215 | 10,164 |
| ZONE TOTALS | | | | |
| Passenger | 0 | 63 | 44,343 | 44,406 |
| Dry Cargo | 4,049 | 8,622 | 5,485 | 18,156 |
| Tanker | 2,170 | 2,564 | 1,064 | 5,798 |
| Dry Cargo Barge Tow | 0 | 0 | 8,240 | 8,240 |
| Tanker Barge Tow | 0 | 0 | 4,260 | 4,266 |
| Tug/Tow Boat | 0 | 0 | 16,242 | 16,242 |
| PROJECTED 1995 ZONE TOTAL | 6,219 | 11,249 | 79,640 | [illegible] |

Figure 4.2-4 Vessel Traffic Zone Map