4.3 AQUATIC ENVIRONMENTS OF THE SAN FRANCISCO BAY/DELTA ESTUARY

The Estuary, with a surface area of 1,631 square miles, is the largest estuary on the Pacific coast of North and South America (SFEI 1994). The San Francisco Bay is located at the mouth of two major rivers, the Sacramento and the San Joaquin rivers, which carry 60 percent of the state runoff from tributary rivers and streams draining about 40 percent of California's surface area (Conomos et al. 1985; Nichols and Pamatmat 1988). This section describes the environmental characteristics of the Estuary, beginning with a general description of the Estuary-wide setting (section 4.3.1) and then followed in subsequent sections by more specific descriptions of each major embayment (section 4.3.2) and, where appropriate, existing dredged material disposal sites.

4.3.1 Estuary-Wide Conditions

The Estuary can be divided into several segments: the Sacramento-San Joaquin Delta, Suisun Bay, Carquinez Strait, San Pablo Bay, Central Bay, and South Bay. The most upstream portion of the Estuary, the Sacramento-San Joaquin Delta (Delta), is a 1,150-square-mile, triangular-shaped region of land and water at the confluence of the Sacramento and San Joaquin rivers. The Delta is bounded by the city of Sacramento to the north, Vernalis to the south, and Chipps Island to the west. The Delta's western segment is subject to the greatest tidal effects. The central Delta, surrounded by the other segments, includes many channels where waters from all four rivers — the Sacramento, San Joaquin, Cosumnes, and Mokelumne rivers — mix. The Delta's rivers, sloughs, and excavated channels comprise a surface area of about 75 square miles (SFEP 1992b).

Suisun Bay is a shallow embayment between Chipps Island at the western boundary of the Delta and the Benicia-Martinez Bridge at the eastern end of Carquinez Strait. Adjacent to Suisun Bay is Suisun Marsh, the largest brackish marsh in the United States. The narrow, 12-mile-long Carquinez Strait joins Suisun Bay with San Pablo Bay. San Pablo Bay is a large, open bay that extends from Carquinez Strait to the San Pablo Strait near the Richmond-San Rafael Bridge. Adjacent to San Pablo Bay lies the northern part of San Francisco Bay, known informally as the Central Bay; it is bounded by the San Pablo Strait to the north, the Golden Gate Bridge to the west, and the Oakland-San Francisco Bay Bridge to the south. The southern part of San Francisco Bay, known informally as the South Bay, includes all Bay waters south of the Oakland-San Francisco Bay Bridge. The embayments are shown on Figure 4.3-1.

4.3.1.1 Hydrology

The northern reach of the San Francisco Bay (comprised of Suisun Bay, Carquinez Strait, and San Pablo Bay) is geographically and hydrologically distinct from the Central and South bays. The South Bay is a tidally oscillating, lagoon-type estuary, where variations are determined by water exchange between the northern reach and the ocean. Water residence times are much longer in the South Bay than in the North Bay. The northern reach is a partially to well-mixed estuary (depending on the season) that is dominated by seasonally varying river inflow. The timing and magnitude of the highly seasonal river inflow modulates permanent estuarine circulation, which is largely maintained by salinity-controlled density differences between river and ocean waters.

Freshwater inflows, tidal flows, and their interactions largely determine variations in the hydrology of the Bay/Delta. Hydrology has profound effects on all species that live in the Bay/Delta because it determines the salinity in different portions of the Estuary and controls the circulation of water through the channels and bays.

The disposal of dredged material has the potential to affect Bay hydrology under scenarios where large areas of land are converted from upland to tidal wetlands. These effects are discussed in more detail in the section on the upland environment (section 4.4).

Freshwater Flows in the Sacramento-San Joaquin Delta

Approximately 60 percent of all the fresh water runoff in California enters San Francisco Bay via the Sacramento-San Joaquin Delta. Sacramento River flow dominates the northern Delta, while waters of the San Joaquin River dominate the southern Delta, and waters of the Cosumnes and Mokelumne rivers dominate the eastern Delta. The Delta's western segment is subject to the greatest tidal effects. The central Delta, surrounded by the other segments, includes many channels where waters from all four rivers mix. The Delta's rivers, sloughs, and excavated channels comprise a surface area of about 75 square miles (SFEP 1992a). The Estuary receives 90 percent of its fresh water inflows from streams and

Figure 4.3-1 San Francisco Embayments

rivers of the Central Valley and about 10 percent from tributaries and other sources surrounding San Francisco Bay. Of the fresh water flows entering the Estuary from the Central Valley, the Sacramento River typically accounts for 80 percent, the San Joaquin River 15 percent, and smaller rivers and streams the remainder. However, the total volume of water flowing into the Delta and subsequently into the San Francisco Bay system (discussed below) is extremely variable on both a seasonal and annual basis.

San Francisco Bay Circulation

Water flows in the Estuary follow complex daily and seasonal patterns. Circulation is affected by tides, local winds, basin bathymetry, and the local salinity field (Cloern and Nichols 1985).

The Estuary has two low tides and two high tides every 24.8 hours. During each tidal cycle, an average of about 1.3 million acre-feet of water, or 24 percent of the Bay/Delta's volume, moves in and out of the Estuary. On the flood tide, ocean water moves through the Golden Gate and into the Estuary's southern and northern reaches, raising the water level at the end of South Bay by more than 8 feet, and raising the height of the Sacramento River at the upstream edge of the Estuary by about 3 feet. It takes about 2 hours for tidal influence to reach the end of South Bay and 8 hours to reach Sacramento.

Under today's flow regime, freshwater flowing from the Delta usually meets saltwater from the ocean in the vicinity of Suisun Bay. Because freshwater is less dense than saltwater, when they meet, freshwater tends to flow over the surface of the saltwater before the two are partially mixed by tidal currents and winds. This separation of fresh and salt water results in a vertical salinity gradient that may occur over an area extending several miles in length and which is most prominent when Delta outflow is high. When outflow is low, the waters are well-mixed, with only a small salinity gradient from the surface to the bottom.

The downstream flow of the freshwater surface layer induces an upstream counter-current flow of saltier water along the bottom in a pattern known as gravitational circulation. The most landward zone of gravitational circulation, where bottom ebb and flood currents are nearly equal, is called the null zone. The location of the null zone is influenced mainly by Delta outflow. A moderate Delta outflow of about 10,000 cubic feet per second (cfs) positions the null zone at the upstream end of Suisun Bay. A flow greater than about 20,000 cfs positions it in San Pablo Bay, and a flow of less than 5,000 cfs positions it in the upstream waters of the Sacramento River. Tidal currents also influence the location of the null zone, moving it upstream and downstream 2 to 6 miles twice each day.

Associated with the null zone is a region just downstream where gravitational circulation concentrates suspended materials such as nutrients, plankton, and very fine suspended sediments in what is called the entrapment zone. In this zone, suspended materials are circulated as they settle out of the upper water layer and are carried upstream by the bottom current and toward the surface by vertical currents near the null zone. In this way, the entrapment zone concentrates phytoplankton, zooplankton, and nutrients, providing a rich habitat thought to be important for the rearing of young striped bass and other fish species. Concentrations of suspended sediments and plankton are often many times higher in the entrapment zone than upstream or downstream of the entrapment zone.

Suisun and San Pablo bays receive the majority of freshwater input. There, density/salinity-driven currents show ebb dominance of the surface water and flood dominance of the bottom water. Thus, waters in these embayments are characterized as being oxygenated, of low- to moderate-salinity, and high in suspended solids. The residence time of water in the Estuary's northern reach, particularly in Suisun and San Pablo bays, is strongly influenced by Delta outflow. During the low flow period of the year (late summer), the residence time of freshwater moving from the Delta to the ocean can be relatively long (on the order of months) compared to when outflow is very high (winter), when freshwater can move from the Delta to the ocean in a matter of days. Water residence time affects the abundance and distribution of many estuarine organisms, the amount of production by phytoplankton, and some of the chemical and physical processes that influence the distribution and fate of pollutants.

Central Bay is most strongly influenced by tidal currents due to its proximity to the Pacific Ocean. The Central Bay is characterized by Pacific waters that are cold, saline, and low in total suspended sediment. Water quality parameters fluctuate less than in other sectors of the Bay due to the predominance of ocean water. Net exchanges of ocean and Bay waters depend on net freshwater flow in the Bay, tidal amplitude, and longshore coastal currents.

The South Bay receives less than 10 percent of the freshwater budget of the Bay. It also receives the majority of wastewater discharged to the Bay (>75 percent). During the summer, treated sewage discharge exceeds freshwater in-flow in this area. South Bay waters are influenced by Delta outflow during the winter months, when low-salinity water moves southward into the southern reach displacing the saline, denser water northward. In the summer months, however, South Bay currents are largely influenced by wind stress on the surface; northwest winds transport water in the direction of the wind, and the displaced water causes subsurface currents to flow in the opposite direction. Because the South Bay receives only minor amounts of freshwater in-flow from the surrounding watershed, it is essentially a tidal lagoon with a relatively constant salinity.

BATHYMETRY. The average depth of the Bay is about 19 feet at mean lower low water while median depth is about 6 feet (Conomos et al. 1985) (see Figure 4.3-2). The Bay's deepest sections, at the Golden Gate (360 feet) and the Carquinez Strait (88 feet), are topographic constrictions where scouring by strong tidal currents contributes to maintaining these depths. Table 4.3-1 shows average depths in different areas of the Bay.

The bathymetry of the Bay is an important factor affecting sediment dynamics. San Pablo Bay, Suisun Bay, and the South Bay are characterized by broad shallows that are incised by narrow channels, which are typically 33 to 66 feet deep. These shallower areas are more prone to wind-generated currents and sediment resuspension than deeper areas such as the Central Bay.

Table 4.3-1. Bathymetric Data for San Francisco Bay

Region	***Surface Area * (sq. mi.)***	***Mean Depth (feet)***	***Mean Volume (acre feet)***
Suisun Bay	36	14	323,000
Carquinez Strait	12	29	223,000
San Pablo Bay	105	9	605,000
Central Bay	103	35	2,307,000
South Bay	214	11	1,507,000

Note: * At mean lower low water including saturated mudflats.
Source: SFEP (1992a).

Bay bathymetry has the potential to be locally affected by the disposal of dredged material. The clearest example of this is the formation of a mound at the Alcatraz disposal site in 1982 and several other occasions during the 1980s. The extent to which mounding occurs depends on the rate at which material is disposed and the rate at which currents scour, resuspend, and remove disposed sediment from the site.

CURRENTS AND CIRCULATION. Currents created by tides, freshwater inflows and winds cause the erosion and transport of sediments away from dredged material disposal sites. Tidal currents are usually the dominant form of observed currents in the Bay. There is more intense vertical mixing and reduced vertical stratification during spring tides than during neap tides (Cloern 1984). Tidal currents are stronger in the channels and weaker in the shallows, and tend to parallel the bathymetry of the Bay (Cheng and Gartner 1984). These processes enhance exchange between shallows and channels during the tidal cycle, and contribute significantly to landward mixing of ocean water and seaward mixing of river water. Also, the South Bay begins flooding while San Pablo Bay is still ebbing, making it possible for South Bay to receive some water from the northern reach (Smith 1987).

Generally, tides appear to have a significant influence on sediment resuspension during the more energetic spring tide when sediment concentrations naturally increase, and particularly during the ebbs preceding lower low water when the current speeds are highest (Cheng and McDonald 1994). The substantial increase in suspended sediment concentrations following a lower low water ebb on a spring tide may be due to the longer duration of higher currents as well as a greater absolute current velocity. Powell et al. (1989), however, observed no correlation between tidal cycle and suspended sediment loads or distribution in the South Bay, although tidal cycling may have had an impact on sediment resuspension at times of the year other than winter/spring high-water flow. Their conclusion was that winds were the most important factor in resuspending sediments in the South Bay, and that local sources of sediments were more important than the import of sediment resuspended from elsewhere (Reilly et al. 1992).

As described earlier, freshwater inflows induce gravitational circulation, where salinity/density differences result in ebb currents near the surface and flood currents near the bottom. Although

Figure 4.3-2 Bathymetry of San Francisco Bay gravitational currents are generally weaker than tidal currents, they contribute significantly to the sediment cycle within the Bay. Freshwater inflow carries sediment loads downstream via surface currents. Suspended sediments settle out as mixing occurs and salinity concentrations increase. The fine sediments that settle out near the bottom are carried back upstream by the counter-flowing gravitational circulation near the bottom. The sediment cycle begins again as the fine suspended sediments are entrained in the freshwater flow and carried back downstream (Cheng and McDonald 1994). The landward extent of gravitational currents are determined by the magnitude of inflows.

Strong seasonal winds create circulation and mixing patterns and add to tide- and river-induced current forces. Wind-induced currents have a significant effect on sediment transport by resuspending sediments in shallow waters (Krone 1979; Cloern et al. 1989). It has been estimated that 100 to 286 mcy of sediments are resuspended annually from shallow areas of the Bay by wind-generated waves (Krone 1974; SFEP 1992b).

In summary, net circulation patterns within the Bay are influenced by Delta inflows, gravitational currents, and by tide- and wind-induced horizontal circulation. The cumulative effects of the latter three factors on net circulation within embayments tend to dominate over that of freshwater inflows except during short periods after large storm events (Smith 1987). Exchanges between embayments are influenced both by mixing patterns within embayments and by the magnitude of freshwater inflows (Smith 1987).

Currents and thus circulation within the Bay are potentially affected by the disposal of dredged material in two ways: first, mounding at a disposal site may affect the strength or pattern of currents moving through a nearby channel; second, restoring significant areas of land to tidal action through wetland restoration may affect the overall tidal exchange volume (prism) in the Estuary. Mounding is only expected to occur when there is a high level of disposal at one disposal site or one placement environment, as has occurred at the Alcatraz disposal site. Dredged material disposal is otherwise not expected to affect wind-generated waves and currents. Potential effects on overall tidal prism are discussed in section 4.4.

SEDIMENT BUDGETS. River inflow is the major source of new sediment input into the Estuary. Most new sediment (approximately 80 percent) originates in the Sacramento-San Joaquin River drainage and enters primarily as suspended load during the high winter inflows.

Long-term average estimates of the sediment budget have been performed by several researchers, including Gilbert (1917), Krone (1979), and LTMS (1992e). While Krone (1979) estimated a long-term average annual new sediment input of 10.4 mcy, the sediment budget study reported in LTMS (1992e) demonstrated that between 1955 and 1990, an average of 7.88 mcy of sediment flowed into the Bay system annually from the Central Valley and local streams.

Sediment loading into the Bay system, particularly that associated with winter and spring flows, has been reduced as a result of managed impoundments and diversions. Freshwater diversions and releases may be the largest factor controlling Bay sedimentation processes. Flow regulation using releases and diversions is primarily intended to control salinity within the western Delta (LTMS 1992e). Other factors affecting the overall sediment delivery to the Bay include upstream dam trapping, delta channelization, and increasing urbanization. Reductions in sediment loading and required dredging that may result from dam construction could nevertheless be offset by downstream degradation, channelization, and continued use of agricultural methods that produce significant total suspended sediment loadings (LTMS 1993d).

Estimates of the fraction of the new sediment input that is discharged to the ocean vary widely: from 4 percent by Gilbert (1917) and 6 percent by Conomos and Peterson (1977); to 30 percent of an annual 11.1 mcy by Schultz (1965), 42 percent of an annual 10 mcy by the COE (USACE 1967), 43 percent of the 7.9 mcy by LTMS (1992e), and 50 percent of the 10.4 mcy by Krone (1979). Much of the winter sediment load from the Sacramento-San Joaquin rivers initially settles out in San Pablo Bay. During the lower flow summer months, wind-generated waves and tidal currents erode the previously deposited sediment and redistribute it over a wide area.

Sediment loading aside, there are numerous other factors that significantly influence the natural sedimentation cycle of the Estuary. Changes in the rates or patterns of sediment loading as well as changes in hydrodynamics affecting sediment transport have caused a shift in the important (and little understood) equilibrium between sedimentation and erosion. For example, reclamation of floodplain and tidal wetlands in the Delta and the Bay margins have eliminated these areas as natural sediment traps. Water diversions have altered flows, reducing the volume of freshwater available to scour and flush sediments from various portions of the Estuary. The alterations in flow patterns that result from these and other human activities disturbs the dynamic equilibrium that controls sediment deposition, resuspension, and the overall stability of the deposit (SFEP 1990).

Disposal of significant quantities of dredged material in upland and ocean environments, compared to continuing to dispose of most material within the Estuary, could alter the overall sediment budget of the San Francisco Bay, and has the potential to significantly alter the sediment budgets within each embayment.

4.3.1.2 Water Quality

The most comprehensive data sets describing water quality in the Estuary come from the Regional Monitoring Program managed by the San Francisco Estuary Institute (SFEI 1994) and ongoing studies by the Interagency Ecological Program (IEP) focusing on parameters affected by water flow. In addition, numerous short-term studies that focus on specific sites, resources, or pollutants are conducted on a regular basis by researchers and entities discharging permitted wastes. The primary water quality parameters discussed below include the following: salinity, dissolved oxygen, pH, total suspended solids (TSS), turbidity, unionized ammonia, and pollutants. Federal and state water quality standards are presented in Appendix H. The potential impacts associated with dredged material disposal on these water quality parameters are also described below.

Salinity

The salinity of water entering the Estuary varies greatly. The Sacramento River and eastside streams flowing into the Delta are low in salts, with salinity averaging less than 0.1 parts per thousand (ppt). San Joaquin River water is more saline than these tributaries and, since the 1930s, its average salinity has increased from less than 0.2 ppt to about 0.4 ppt, primarily as a result of increased agricultural drainage.

The salinity of the Estuary's northern reach varies considerably and increases along a gradient from the Delta to Central Bay. At the mouth of the Sacramento River, for example, the mean annual salinity averages slightly less than 2 ppt; in Suisun Bay it averages about 7 ppt; and at the Presidio in Central Bay it averages about 30 ppt. The entrapment zone (see discussion of San Francisco Bay Circulation under section 4.3.1.1) is generally located where the surface salinity is between 1 ppt and 6 ppt and the near-bottom salinity is 2 ppt. In the southern reach, salinities remain at near-ocean concentrations (32 ppt) during much of the year. However, during the summer, high evaporation rates may cause salinity in South Bay to actually exceed that of ocean water.

Seasonal changes in the salinity distribution within the Estuary are controlled mainly by the exchange of ocean and Bay water, and by river inflow. River inflow has the greater influence on salinity distribution throughout most of the Estuary because inflow varies widely, while ocean input varies relatively little. In winter, high flows of freshwater from the Delta lower the salinity throughout the Estuary's northern reach. High Delta flows also intrude into South Bay, lowering salinity there for extended periods. In contrast, during the summer, when freshwater inflow is low, saline water from the Bay intrudes into the Delta. The inland limit of salinity intrusion varies greatly from year to year. Salinity of 1 ppt has extended upstream of Rio Vista several times in this century. Channel dredging increases gravitational circulation and enhances salinity intrusion (Nichols and Pamatmat 1988).

Disposal of dredged material may have local, short-term effects on salinity within disposal site areas. There is often a salinity gradient with depth at most locations throughout the Estuary. Disposal of material can cause an increase in vertical mixing, but any associated changes in salinity are expected to be very short-term and limited to the disposal site. Salinity may also be affected in situations where material is dredged from saline waters and disposed in upland or inland freshwater areas. These potential impacts are discussed under the upland and Delta environment (section 4.4).

Dissolved Oxygen

Oxygen concentrations in estuarine waters are increased in several ways: by the mixing action of wind, waves, and tides; by photosynthesis of phytoplankton and other aquatic plants; and by high dissolved oxygen (DO) in freshwater inflow. Dissolved oxygen concentrations are lowered by plant and animal respiration, chemical oxidation, and bacterial decomposition of organic matter.

The Estuary's waters are generally well oxygenated, except during the summer in the extreme southern end of the South Bay where concentrations are reduced by poor tidal mixing and high water temperature. Typical concentrations of DO range from 9 to 10 mg/l throughout the entire Estuary during periods of high riverine flow, 7 to 9 mg/l during moderate riverine flow, and 6 to 9 mg/l during the late summer months when flows are the lowest. Unlike the 1950s and 1960s, when inadequately treated sewage and processing plant wastes depleted oxygen in parts of the Bay and Delta, today there are few reports of places in the Estuary where low oxygen concentrations adversely affect beneficial uses. Today, the lowest concentrations in the Estuary are typically observed in the extreme South Bay but, in some instances, DO levels in semi-enclosed embayments such as Richardson Bay can be much lower than in the main water body (SFEI 1994).

The disposal of dredged sediment has the potential to affect levels of DO at any disposal site, particularly in waters near the Bay floor. Short-term depressions in DO levels were measured in waters immediately adjacent to the Carquinez site during disposal of material from the Mare Island Strait in 1973. Levels of DO near the Bay floor declined from 80 to 85 percent to 20 to 30 percent saturation within several minutes after material was released from the barge, but recovered to ambient levels within 10 minutes (USACE 1976c). The extent of this kind of effect depends on the amount of oxygen-demanding substances present in the material. Anoxic sediments containing reduced substances such as hydrogen sulfide would cause the greatest temporary depression in DO levels at the disposal site. However, the effects of dredged material disposal on DO levels in Bay waters are usually short term, generally limited to the plume associated with each dump, and confined to the disposal area and immediately adjacent waters. However, disposal in areas where DO levels are already depressed (such as in the South Bay or in Richardson Bay) and/or disposal at high dumping frequencies could cause more extensive water quality impacts.

pH

The pH of waters in San Francisco Bay is relatively constant and typically ranges from 7.8 to 8.2. The disposal of dredged material may change the pH of waters at disposal sites as the material is typically more acidic than Bay waters. Such an effect, however, is expected to be of extremely short duration and limited to the disposal site area. Dredged material disposal thus is not expected to significantly affect this water quality parameter.

Total Suspended Solids (TSS) and Turbidity

Turbidity and total suspended solids (TSS) are used interchangeably in some of the literature. The distinction lies mainly in the method of measurement; i.e. turbidity measurements are optical, while TSS measurements are gravimetric. In general, higher TSS results in more turbid water. The level of turbidity and TSS in Estuary waters is a function of the dynamic sediment processes described above (see San Francisco Bay Circulation under section 4.3.1.2). The turbidity distribution in the Bay under typical summer and winter conditions is shown in Figure 4.3-3.

Regions of maximum suspended solids occur in the North Bay in the null zone (generally 50 to 200 mg/l, but as high as 600 mg/l TSS). The null zone also accumulates high concentrations of phytoplankton (Smith 1987). The specific location of the null zone changes depending upon freshwater discharge from the Delta. TSS levels in the Estuary vary greatly depending on the season, ranging from 200 mg/l in the winter to 50 mg/l in the summer (Nichols and Pamatmat 1988; _Buchanan and Schoellhamer 1995). Shallow areas and channels adjacent to shallow areas have the highest suspended sediment concentrations. TSS levels vary throughout the Estuary depending upon season, tidal stage, and depth (Buchanan and Schoellhamer 1995). The Central Bay generally has the lowest TSS concentrations; however, wind-driven wave action, tidal currents, as well as dredged material disposal and sand mining operations cause elevations in suspended solids concentrations throughout the water column.

The disposal of dredged material causes a temporary increase in the level of suspended material (turbidity) in site waters. Most of the material in the descending

Figure 4.3-3 Horizontal and Vertical Distribution of Turbidity Under Typical Summer and Winter Conditions cloud reaches the substrate, but a small percentage (approximately 10 percent of sediments dredged from a clamshell dredge) of finer material remains in the water column (SAIC 1987b). In addition to this material, a more dense cloud of material forms near the bottom after dynamic collapse of released material. This near-bottom plume of highly concentrated suspended solids spreads horizontally until its momentum has dissipated.

The turbidity plume resulting from disposal typically disperses, and water column TSS levels return to near-background within 15 to 20 minutes of release (Reilly et al. 1992). Observed plumes migrate in the direction of the current at time of discharge (SAIC 1987b). For example, vertical profiles of turbidity plumes at the Alcatraz site monitored in 1976 showed that the maximum increases in suspended solids on site occur at near-bottom depths. At a depth of 1 meter, suspended solid concentrations rose from roughly 25 mg/l TSS (background) to approximately 275 mg/l TSS 50 meters from the release point, then declined again to near-background levels 400 meters from the release point. Suspended sediment concentrations at 5 and 9 meters above the Bay floor were much lower, ranging from 25 to 75 mg/l TSS (USACE 1976c).

At any unconfined aquatic disposal site, disposal of dredged material is thus expected to cause short-term changes in water column turbidity with each material dump. These changes are primarily limited to near-bottom waters within and immediately adjacent to the disposal site. At disposal frequencies that exceed or approach the time it takes for the near-bottom plumes to disperse or settle, the effect on this water quality parameter would be greatly increased. In addition, the nature and significance of the impact depends on the characteristics of the embayment; areas and seasons of low turbidity would be affected more than areas or seasons with naturally higher levels of turbidity.

The disposal of large quantities of dredged material also has the potential to alter the sediment budget, which in turn can affect levels of suspended sediment within each embayment. Analysis of turbidity data collected by Johnson Offshore Services demonstrated that substantial changes in turbidity (as measured over a 17-day period with nephelometers at a depth of 4.6 m) in the vicinity of the Alcatraz disposal site were related to tidal action. The source of turbidity, however, was speculated to be either tidally transported from other locations, or a result of resuspension of material in and around the region of Alcatraz. The latter explanation was determined to be the more likely (O'Connor 1991).

Un-ionized Ammonia

Ammonia is produced as a result of the microbial break-down of nitrogenous organic matter that is derived from natural sources (e.g., plant and animal matter) or from anthropogenic sources (e.g., sewage). The toxicity of aqueous ammonia to aquatic organisms is primarily attributable to the un-ionized form. Because the speciation of ammonia varies as a function of pH, temperature, and salinity, these parameters must be considered when attempting to determine the bioavailable fraction of ammonia in a sample.

Generally, concentrations of unionized ammonia are low in Estuary waters, with the highest levels typically found near the mouths of rivers and creeks during periods of high flow. Concentrations in the extreme South Bay and the mouth of the Napa River ranged from 0.18 to 0.30 mg/l during a period of high riverine flow in 1993, compared to levels ranging from 0.10 to 0.16 mg/l at most of the other monitoring stations (SFEI 1994). During periods of moderate and low riverine flow, ammonia levels were much lower, ranging from 0.001 to 0.01 mg/l throughout the Bay.

The magnitude and extent of changes in ammonia levels as a result of dredged material disposal has not been extensively monitored in San Francisco Bay. Short-term changes in this water quality parameter are expected to occur, particularly in conjunction with the near-bottom turbidity plume described above under Total Suspended Solids and Turbidity. However, oxidative removal of ammonia from the water column generally occurs quite rapidly in well-oxygenated waters such as those of the Estuary (and particularly in the Central, San Pablo, and Suisun bays).

Pollutants

Pollutant loading to San Francisco Bay has long been recognized as one of the many factors that have historically stressed the environmental resources of the aquatic system. Pollutants enter the aquatic system through atmospheric deposition, runoff from agricultural and urbanized land, and the direct discharge of waste to sewers and from industrial activity (see section 3.2.3.2 for a detailed discussion of pollution sources).

The Bay's sediment can be both a source of and a sink for pollutants in the overlying water column. The overall influx of pollutants from the surrounding land and waste discharges can cause increases in sediment pollutant levels. Natural resuspension processes, biological processes, other mechanical disturbances, dredging, and sediment disposal can remobilize particulate-bound pollutants. The potential impacts of dredged material disposal on water column levels of pollutants is described in more detail below.

CONCENTRATIONS OF METALS IN THE WATER COLUMN. Ten trace metals are monitored in the aquatic system and in waste discharged to the Bay on a regular basis. Total and dissolved fractions are sampled three times a year at Regional Monitoring Program (RMP) stations throughout the Estuary. Tables 4.3-2 and 4.3-3 present typical trace metal concentration ranges taken from 1993 RMP data (SFEI 1994).

Dredging and disposal of dredged material has the potential to remobilize metals associated with sediment particles into the water column. The primary factors controlling the degree of mobilization are the oxidation-reduction potential of the sediment, the pH of the sediment pore water and overlying water, and the salinity of water on site. Higher oxygen levels in site water than in the sediment would promote some initial oxidation of substances in dredged material, which would, in turn, influence the adsorption and desorption of chemical contaminants to/from complexes (e.g., with sulfides). The typically higher pH of Central Bay waters compared to dredged material would also promote desorption of contaminants. Conversely, higher on-site salinity, which is a less important factor than pH or redox potential, would serve to increase adsorption of contaminants onto sediments (U.S. Navy 1990).

Studies conducted in the early 1970s found dissolved concentrations of lead, cadmium, and copper in disposal plumes were 9, 6, and 4 times greater, respectively, than concentrations observed in surrounding Central Bay waters. However, these elevated concentrations lasted less than 1.5 hours (USACE 1976d). Other studies during the same period indicate that cadmium, copper, lead, and zinc can be released into oxygen-rich conditions, increasing water column concentrations by as much as two times (USACE 1977).

The overall impacts of short-term increases of pollutant levels in the water column depend on background concentrations present in the water column, whether water quality objectives are exceeded, and the extent of the mixing zone within which concentrations are elevated above ambient levels. The highest risk of environmental impact from this phenomenon occurs when dredging or disposal could cause increases in water column concentrations above EPA criteria or state water quality objectives (see Appendix H). This is particularly true in cases where water quality within an embayment is already impaired. Within the Estuary, ambient concentrations of some metals are already at or above criteria or objectives (see Appendix H for a list of these standards). Of particular concern is chromium in Suisun Bay, Carquinez Strait, and San Pablo Bay; copper, mercury and nickel in South, San Pablo, and Suisun bays, and Carquinez Strait; and lead in San Pablo Bay and Carquinez Strait. At certain times of the year, depending on riverine flows, ambient concentrations of these metals in these embayments have exceeded EPA criteria (SFEI 1994). As mentioned above, sediments are often the sink for water

Table 4.3-2. Ranges of Near Total Concentrations of Trace Metals in Water Samples (SFEI 1994)

Location	***Ag ng/L***	***As µg/L***	***Cd ng/L***	***Cr µg/L***	***Cu µg/L***	***Hg ng/L***	***Ni µg/L***	***Pb ng/L***	***Se ng/L***	***Zn µg/L***
South Bay	4-141	1.5-4	42-145	1-4	2-4	3-14	2-10	160-848	165-406	1-7
Central Bay	0.6-71	1.5-2	16-73	0.2-3	1-2	1-10	1-4	77-888	128-318	1-3
North Bay	3-126	1-4	26-111	2-38	3-11	6-63	3-16	220-6459	113-353	2-30

Table 4.3-3. Ranges of Dissolved (< 0.45 *µ*) Concentrations of Trace Metals in Water Samples (SFEI 1994)

Location	***Ag ng/L***	***As µg/L***	***Cd ng/L***	***Cr µg/L***	***Cu µg/L***	***Hg ng/L***	***Ni µg/L***	***Pb ng/L***	***Se ng/L***	***Zn µg/L***
South Bay	1-9	2-4	40-131	0.1-0.4	2-3	2-9	2-4	9-87	0.2-0.5	1-3
Central Bay	1-4	1-2	26-88	0.1-0.2	0.2-2	0.3-2	0.3-2	3-16	0.1-0.2	0.1-1
North Bay	1-5	1-2	8-97	0.2-0.7	2-3	1-5	1-6	5-259	0.2-0.3	0.4-2

column pollutants (especially in estuarine conditions), and dredged material disposal can be a further source of water column pollutants. Potential environmental impacts associated with metal concentrations from dredged material disposal is discussed in more detail below for each of the embayments (see section 4.3.2).

CONCENTRATIONS OF ORGANIC POLLUTANTS IN THE WATER COLUMN. Three general types of trace organic contaminants are measured in San Francisco Bay water on a regular basis: polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides.

Water column concentrations of PAHs were below EPA criteria (31 ppt) at all monitoring stations throughout the Estuary in 1993 (SFEI 1994). Total levels of PAHs measured in Bay water ranged from 4 to 28 parts per trillion (pptr) with the highest concentrations seen at the Dumbarton Bridge and the lowest in the San Joaquin River. The pattern of dissolved PAHs was different, ranging from 1 to 7 pptr, with the highest concentrations measured at Yerba Buena (SFEI 1994).

PCB concentrations measured throughout the Estuary in 1993 were above water quality criteria (45 parts per quadrillion [ppq]) with total concentrations of PCBs monitored in water ranging from 239 to 847 ppq (SFEI 1994). Within the Estuary, the highest total concentrations were found at the Dumbarton Bridge, Yerba Buena Island, and the Napa River. Dissolved concentrations ranged from 26 to 492 ppq with the highest concentrations observed at the same locations.

Measured water concentrations of pesticides were highest in the rivers and the extreme South Bay; lowest levels were observed in the Central and San Pablo bays. Total levels ranged from 1,629 to 9,011 ppq and dissolved levels ranged from 1,477 to 7,512 ppq during a period of high riverine flow in March 1993 (SFEI 1994). Concentrations of chlordane and dieldrin were above water quality criteria (590 ppq and 140 ppq, respectively) in most samples taken throughout the Estuary; DDT levels exceeded the water quality criteria (590 to 840 ppq) in Suisun Bay and the Sacramento River.

Disposal plume studies performed by the COE have shown that levels of chlorinated hydrocarbons increase immediately after disposal, then return to background levels within 30 minutes (USACE 1976d). As with metals, the potential impact of short-term increases in organic pollutant concentrations in the water column depends on background concentrations.

4.3.1.3 Sediment Quality

Sediment quality in the Estuary varies greatly according to the physical characteristics of the sediment, proximity to historical waste discharges, the physical/chemical condition of the sediment, and sediment dynamics that vary with location and season. The distribution of surface sediment types in the Bay is shown in Figure 4.3-4. Sediments in the Bay generally contain elevated levels of pollutants compared to coastal reference sites. Generally, the level of sediment contamination at a given location will vary depending on the rate of sediment deposition, which varies with seasons and tides (Luoma et al. 1990). Chemical contaminant dynamics in an estuary are closely associated with the dynamics of suspended and deposited sediments. Overall, a sediment's physical characteristics, chemical characteristics, and the bioavailability and toxicity of sediment-associated chemicals to aquatic organisms are particularly important in determining their potential impact on environmental quality. A detailed discussion of these characteristics relative to dredged material is provided in section 3.2.3.

While pollutant loading to the Estuary from point and non-point sources has declined dramatically over the past two decades, and surface sediment contamination may be declining from historical highs, Bay sediments are still an important source and sink of pollutants. Much of the data documenting concentrations of trace metals and organics in Bay sediments are found in the historical summary of Long and Markel (1992) and in the more recent monitoring efforts by the state's Bay Protection and Toxic Cleanup Program (BPTCP) (SFBRWQCB 1994) and Regional Monitoring Program (SFEI 1994 and 1995). Sediment data from these studies are summarized below for 10 of the most commonly measured metals and three classes of organic compounds. These data represent both sediments from polluted/industrialized areas as well as those removed from contaminant sources. Section 3.2.3.3 provides information on the specific subset of

Figure 4.3-4 General Distribution of Surface Sediment Types in the San Francisco Bay/Delta Estuary these data that represents ambient concentrations in areas removed from known sources of contamination (i.e., background levels) for these chemicals.

Concentrations of Metals in San Francisco Bay Sediments

The mean concentrations of metals in sediments vary according to grain size, organic carbon content, and seasonal changes associated with riverine flow, flushing, sediment dynamics, and anthropogenic inputs. Anthropogenic inputs appear to have the greatest effect on sediment levels of copper, silver, cadmium, and zinc, but may also have elevated concentrations of chromium, nickel, and cobalt above background (SFBRWQCB 1994).

CADMIUM. Sediment cadmium levels measured in state monitoring programs ranged from 0.04 to 0.4 ppm with the highest concentration observed at Pinole Point in 1994. In contrast, Long and Markel (1992) report average concentrations of 0.7 ppm in San Pablo and Central bays and 1.44 ppm in the South Bay. Cadmium in samples from the northern reaches of the Estuary was generally higher than that in sediments elsewhere in the Bay. Concentrations of cadmium in sediments taken from harbors and other enclosed areas around the Bay margins exhibit higher concentrations than those found in the main embayments. Reported concentrations at peripheral sites range from 0.65 to 2.47 ppm (Long and Markel 1992). These concentrations are higher than the median ambient concentration of cadmium reported for each of the embayments (0.2 ppm) (see section 3.2.3.3, Table 3.2-4).

CHROMIUM. Chromium levels in South, Central and San Pablo bays generally range from 50 to 102 ppm (SFBRWQCB 1994) but have been observed as high as 280 ppm at locations in San Pablo Bay (Long et al. 1988). Concentrations of chromium in known impacted areas along the periphery of the Bay can be much higher; levels in Islais Creek were found to average 140 ppm (Long and Markel 1992) and sediments from the Oakland Inner Harbor ranged from 289 to 368 ppm (USACE and Port of Oakland 1994). In contrast, median ambient concentrations range from 76 to 93 ppm (see section 3.2.3.3, Table 3.2-4).

COBALT. Cobalt concentrations in Bay sediments ranged from 11.1 to 19.7 ppm with the highest levels observed at the mouths of the Petaluma and Napa rivers and Suisun Bay (16.5 to 19.7 ppm). The lowest concentrations were found in Central and South bays and the San Joaquin River mouth (11.1 to 16.4 ppm) (SFBRWQCB 1994). Median ambient concentrations for cobalt are not available for comparison.

COPPER. Copper concentrations in Bay sediments are generally much lower in the central area of each embayment compared to levels found in samples taken from harbors and enclosed areas along the periphery. Long and Markel (1992) report average concentrations in South and Central bays of 33 ppm, slightly lower than values reported in the state's monitoring studies that show these sites ranging from 28 to 54 ppm. Levels in San Pablo Bay sediment appear to be roughly the same as those from the South and Central areas (20 to 50 ppm), while concentrations in Suisun Bay are the highest for any main embayment (40 to 70 ppm). Concentrations in periphery samples taken at Oakland Harbor, Islais Creek harbor, and Redwood Creek range from 87 to 102 ppm (Long and Markel 1992). Sediment copper concentrations in the central areas of the South, Central, and San Pablo embayments are similar to the median range of ambient copper concentrations (33 to 46 ppm) (see section 3.2.3.3, Table 3.2-4).

LEAD. Sediment concentrations of lead range widely from 6 to 110 ppm in San Francisco Bay and from 8 to 27 ppm at the mouths of the Sacramento and San Joaquin rivers. Long and Markel (1992) report average concentrations in the main embayments of 30 to 34 ppm, with much higher levels in sediments that are in the vicinity of historical industrial activity (39 to 102 ppm). State monitoring program data suggest that concentrations at the mouths of small rivers are also generally higher than in the main embayments; in 1991 and 1992, Napa and Petaluma River station samples ranged from 37 to 65 ppm (SFBRWQCB 1994). Concentrations from harbors and other stations along the periphery of the Bay indicate a much higher degree of contamination, ranging from 87 to 102 ppm (Long and Markel 1992). These lead concentrations are higher than the median for ambient conditions (approximately 22 ppm) (see section 3.2.3.3, Table 3.2-4).

MERCURY. Mercury concentrations in sediment measured in the state's monitoring programs ranged from 0.15 to 0.540 ppm. The lowest levels were observed in Central Bay near the Golden Gate. The highest levels were found at Pinole Point during high flow, and in the extreme South Bay. The lower end of this concentration range is similar to the median range observed at ambient stations (0.2 to 0.3 ppm) (see section 3.2.3.3, Table 3.2-4).

NICKEL. Nickel levels in Bay sediment ranged from 46 to 110 ppm. The highest concentrations were measured in the Suisun Bay in 1994, when concentrations ranged from 90 to 124 ppm (SFEI 1994). However, even these nickel concentrations are not dramatically elevated over median ambient concentrations, which range from 73 to 76 ppm (see section 3.2.3.3, Table 3.2-4).

SELENIUM. Selenium levels in surficial sediments throughout the Bay vary according to season. During a period of high riverine flows, concentrations ranged from 0.07 to 0.43 ppm, and 0.17 to 3.30 ppm during low flow in 1993 (SFEI 1994). Levels in the South Bay range from 0.23 to 1.3 ppm; in Central Bay, 0.14 to 0.86 ppm; in San Pablo Bay, 0.14 to 1.51 ppm; and in Suisun Bay, 0.16 to 3.30 ppm. Median ambient concentrations are generally lower, approximately 0.3 ppm (see section 3.2.3.3, Table 3.2-4).

SILVER. In state monitoring, silver concentrations in estuarine sediments are generally lowest at the confluence of the Sacramento and San Joaquin rivers (0.05 to 0.3 ppm). Long and Markel (1992) report average concentrations in San Pablo Bay sediment as 0.45 ppm, Central Bay as 0.72 ppm, and South Bay as 0.57 ppm. Peripheral areas such as Islais Creek harbor and Cordornices Creek had levels that were significantly higher (4.7 ppm and 1.8 ppm, respectively). These peripheral concentrations are significantly elevated in comparison to median ambient levels which range from 0.2 to 0.4 ppm (see section 3.2.3.3, Table 3.2-4).

ZINC. Sediment concentrations of zinc measured in state monitoring programs ranged from 50 to 151 ppm and were generally lowest in Central Bay (50 to 120 ppm — excluding a boat yard in Richardson Bay). Zinc levels in river sediments ranged from 72 to 110 ppm during low riverine flows. These levels are similar to median ambient concentrations, which range from 88 to 120 ppm (see section 3.2.3.3, Table 3.2-4). The highest zinc levels were observed in 1991-92 at peripheral areas of the Bay such as Cordornices Creek (320 ppm) and Emeryville Marsh (278 ppm).

Concentrations of Organic Pollutants in San Francisco Bay Sediments

Numerous organic contaminants have been measured in Bay sediments. These include three major classes of compounds: PAHs, PCBs, and pesticides.

PAHS. Great differences are observed in sediment concentrations between basins and peripheral areas, with the latter often having PAH concentrations 3 to 10 times greater than the former. For example, Long and Markel (1992) reported mean basin concentrations in the Bay to range from 2,600 to 3,900 ppb, whereas mean concentrations at peripheral stations such as Oakland Inner Harbor and Islais Creek Harbor were 7,200 and 62,700 ppb, respectively. Likewise, state monitoring programs have identified several areas with elevated PAH concentrations in sediments, such as Castro Cove and Cordornices Creek, where mean PAH concentrations were as high as 28,000 ppb and 9,900 ppb, respectively (SFBRWQCB 1994). PAH levels measured in basin samples of the state monitoring programs ranged widely from 160 to 7,600 ppb in the South Bay, 170 to 6,200 ppb in the Central Bay, and 380 to 7,500 ppb in San Pablo Bay. PAH levels were generally lowest in the North Bay with a range of 180 to 4,300 ppb. In contrast, median concentrations of PAHs in ambient sediments (550 to 2,400 ppb) are lower than those observed near industrial activity, although maximum ambient concentrations as high as 6,800 ppb are occasionally observed (see section 3.2.3.3, Table 3.2-4).

PCBS. Like PAHs, sediment levels of PCBs vary widely throughout the Bay. Long and Markel (1992) reported concentration ranges of 27 to 71 ppb in basin locations. Likewise, PCB concentrations from basin testing performed in 1991 and 1992 for the BPTCP (SFBRWQCB 1994) ranged from 3 to 38 ppb (with the exception of a single sample from Davis Point in which levels 117 ppb were observed). PCB levels measured in sediment samples from harbor and peripheral locations can be up to an order of magnitude higher than those in basins. For example, sediment samples taken from the creek mouths and marshes along the Emeryville to Richmond shoreline in 1991 and 1992 had elevated PCBs ranging from 100 to 300 ppb (SFBRWQCB 1994). Levels of PCBs in ambient samples are generally much lower (median concentrations range from 9 to 11 ppb) than those observed in either peripheral or basin samples, although maximum values as high as 117 ppb have been observed in North Bay locations (see section 3.2.3.3, Table 3.2-4).

PESTICIDES. State monitoring programs typically test for a variety of chlorinated pesticides and pesticide derivatives. However, only a handful of these compounds are detected on a regular basis. Those that were most frequently detected from 1991 to 1994 include six isomers of DDT and its breakdown products DDD and DDE, dieldrin, and chlordanes. Generally, pesticide concentrations in sediment were directly related to sediment type and are significantly correlated to the percent fines and total organic carbon content of a sample. Typically, total DDT concentrations at basin monitoring stations in the Bay range from 0.05 to 33 ppb. In contrast, DDT levels as high as 633,000 ppb have been observed in the Lauritzen Canal, an EPA Superfund Site located in Richmond Harbor (Lincoff et al. 1994). Total DDT measured in Richmond Harbor channel sediments outside the Lauritzen channel is generally less than 500 ppb and much of the Harbor is less than 300 ppb. Elevated levels of total DDT have also been measured in sediments from other peripheral areas of the Bay, such as Codornices Creek Mouth (70 ppb) and Oakland Inner Harbor (120 ppb) (SFBRWQCB 1994; Long and Markel 1992). In contrast, concentrations of total DDT in ambient sediments are generally less than 5 ppb (see section 3.2.3.3, Table 3.2-4). Sediment concentrations of dieldrin and chlordane measured in monitoring programs are generally low for both basin and peripheral sediments, with dieldrin ranging from 0.2 to 0.9 ppb and chlordanes ranging from 0.2 to 6 ppb.

4.3.1.4 Aquatic Habitats of the San Francisco Estuary

This section describes the aquatic habitats within the Estuary, including intertidal mudflats, rocky shores, salt marsh, brackish marsh, and freshwater marsh wetlands. Open water habitats and resources are described in section 4.3.2 under each embayment. Other aquatic habitats such as vernal pools, riparian corridors, seasonal wetlands, and levee-related habitats are discussed in section 4.4.2.

Intertidal Mudflats

Centuries of siltation have created approximately 64,000 acres of mudflat habitat between the open water and the vegetated or rocky shoreline of San Francisco Bay. Mudflats vary in composition from clay/silt to sand and include organic debris and shell fragments. Generally, these areas are exposed twice daily during two low tides. Where tidal marshes adjoin mudflats, receding tides bring organic materials from the marshes to the mudflats, providing a food source for millions of detritus-feeding invertebrates.

The mudflats are a living system of diatoms, micro-algae, protozoans and a multitude of arthropod, annelid and molluscan invertebrates. Emergent plants are uncommon in these habitat types, however, micro- and macro-algae form the basis for the food web in this habitat. Micro-algae growing both in the shallow water column and on the sediment surface are transported across the intertidal or shallow subtidal mudflats by wind- and tide-induced currents making them available to suspension or surface deposit feeding invertebrates. The benthic invertebrates are, in turn, eaten by such large consumers as shorebirds, demersal fishes, elasmobranchs, juvenile Dungeness crabs in the northern reaches of the Bay, and by human clam diggers.

The most notable consumers of this high secondary productivity are migratory shorebirds. The extensive intertidal mudflats of San Francisco Bay provide major feeding habitat for over-wintering shorebirds of the Pacific Flyway and are considered a key migratory staging and refueling area (SFEP 1991b).

The organic material transported to mudflats by receding tides constitutes the base of the food web for both benthic and pelagic invertebrates. The distribution of benthic invertebrate species associated with mudflats and, to some extent, rocky shores is related to temporal variations in salinity and sediment stability (Nichols 1979). Depending upon the salinity, common invertebrate species of intertidal mudflats include clams (*Gemma gemma*, *Macoma balthica*, *Mya arenaria*, *Corbicula fluminea*, and *Potamocorbula amurensis*), amphipods (*Ampelisca abdita*, *Corophium spinicorne*, and *C. stimpsoni*), shrimp (*Crangon franciscorum* and *Palaemon macrodactylus*), and polychaetes (*Streblospio benedicti* and *Asychis elongata*) (Nichols and Pamatmat 1988; SFEP 1991b). Except for the clam *Macoma balthica* and the shrimp *Crangon franciscorum*, all of these species have been introduced to the Estuary. Since its discovery in the Estuary in 1986, the Asian clam *Potamocorbula amurensis* has become the numerically dominant species in many mudflat habitats. Rocky shores are typically inhabited by hard-surface oriented marine taxa and the native cosmopolitan bay mussel *Mytilus galloprovincialis* (formerly known as *Mytilus edulis*) (Nichols and Pamatmat 1988). Mudflat areas at the base of riprap dikes and breakwaters, where sediments contain cobbles and sand, are important habitat for the clams *Tapes japonica* and *Mya arenaria* (Nichols and Pamatmat 1988).

The distribution of fishes associated with these habitats varies in accordance with freshwater outflow and salinity. Both intertidal mudflat and rocky shore habitats serve as important forage habitats for a number of sportfish and special status species. These areas provide important nursery habitats for native forage fish such as Pacific herring and northern anchovy (SFEP 1991b). Important sportfish that forage and/or rear young in these areas include native species such as chinook salmon, white sturgeon, diamond turbot, and a variety of sharks in addition to the introduced striped bass. Special status species that utilize intertidal mudflat and rocky shore habitats include winter-run chinook salmon, Delta smelt, longfin smelt, and Sacramento splittail.

Since pre-settlement conditions, mudflat habitat has declined throughout the Estuary, with losses since 1958 in the South Bay alone estimated at approximately 500 acres (SFEP 1991b). Within the Planning Area, general factors affecting mudflat habitats include the following: invading plants (smooth cordgrass and Chilean cordgrass), sea level rise, disturbance by boaters and fishermen, and point and non-point sources of pollution (SFEP 1992c).

Dredged material disposal at existing in-Bay sites would not directly affect mudflat habitat in the Bay. However, disposal operations may indirectly affect mudflat habitat to the extent that material transported away from in-Bay disposal sites settles there. Additionally, dredging of new channels through mudflats will permanently convert this to subtidal or deep water habitat.

Rocky Shore Habitat

The rocky shore habitat in the Estuary occurs around the margins of Central and San Pablo bays and is primarily found around Yerba Buena, Angel, and Alcatraz islands, and the shoreline of the Tiburon peninsula. Vegetation along rocky shores is predominantly algae. Wildlife species that utilize these habitats include shorebirds, brown pelicans, cormorants, gulls, and harbor seals.

Dredged material disposal at existing in-Bay sites would not directly affect rocky shore habitat in the Bay. However, disposal operations may indirectly affect rocky shores through the increased deposition of suspended sediment from nearby disposal sites (e.g., Alcatraz).

Tidal Marshes

Tidal marshes are extremely productive and diverse ecological communities that provide important habitat and resources both to organisms that live solely within the marsh and to species more commonly found in upland and aquatic areas. Tidal marshes occur at scattered locations along the margins of the South Bay, along the waterways of the Delta, at the margins of San Pablo Bay, and within Suisun Marsh. These marshes can be segregated into salt, brackish, and freshwater types based on water and soil salinity. These marsh types can be further subdivided into 12 eco-geomorphic classes (LTMS 1994g).

The loss of tidal marsh habitat is well documented within the Planning Area (LTMS 1994g). Due to human activities, such as Gold Rush era (late 1800s) hydraulic mining activities in the Sierra, reclamation for agricultural uses, and fill for development, over 479,000 acres of tidal wetland habitat have been lost or converted to other uses (SFEP 1992b). This decline is one of the many factors associated with increasing stress on the Estuary ecosystem; the remaining marsh habitat is extremely important to estuarine biological resources. Existing marshes around the Bay are still productive habitats but are subject to several factors that degrade habitat quality, including habitat losses that fragment existing habitat, disturbance from recreational activities (hunting, fishing, biking, etc.), point and non-point sources of pollution, and introduced animals, such as the red fox that has increased predation pressures.

The composition of the invertebrate community in tidal marsh habitats is primarily influenced by salinity, the frequency and duration of tidal inundation, and the type and density of emergent vegetation. Common invertebrate species in tidal marsh habitats include the mussel *Ischadium demissum*; the clams *Macoma balthica*, *Tapes japonica*, *Potamocorbula amurensis*, and *Mya arenaria*; the isopod *Sphaeroma quoyana*; the amphipods *Corophium spinicorne* and *Grandidierella japonica*; the snails *Cerithidea californica*, *Assiminea californica*, and *Ovatella myosotis*; the polychaete *Capitella capitata*; and the yellow shore crab, *Hemigrapsus oregonensis* (SFEP 1991b). Of these species, only *Macoma balthica*, the yellow shore crab, and the three snail species are native. As in mudflats, the Asian clam, *Potamocorbula amurensis*, has become the numerically dominant species in many tidal marsh habitats.

Tidal marshes provide critical cover, forage, and nursery areas for adults and juveniles of a number of sportfish and special status fishes (SFEP 1991b). The distribution of fish communities in tidal marsh habitats is influenced by the same factors that influence the composition of invertebrate communities. Common fishes include native species such as arrow goby, topsmelt, Pacific staghorn sculpin, and tule perch and introduced species such as yellowfin goby, catfish, and mosquitofish. Commercially important species that rear and forage in these habitats include native chinook salmon and the introduced striped bass. Special status species that utilize tidal marshes include winter-run chinook salmon, Delta smelt, longfin smelt, Sacramento splittail, green sturgeon, and tidewater goby.

Tidal marshes also provide a variety of wildlife resources, including resting, nesting, and escape cover and, most importantly, foraging habitat. These tidal marshes support a diversity of wildlife, including amphibian, reptile, bird, and mammal species (SFEP 1992c). In addition to other habitat types, tidal marshes within the Planning Area are very important for migratory birds, providing foraging habitat and roosting sites (SFEP 1992c). Dredged material disposal has the potential to significantly benefit tidal marsh habitat around San Francisco Bay, primarily by providing material with which this habitat can be restored.

TIDAL SALT MARSHES. Tidal salt marshes are found along much of the Bay shoreline except in urbanized areas and on rocky shorelines such as the Tiburon Peninsula. A typical tidal salt marsh is characterized by a band of cordgrass extending from approximately mean sea level to mean high water with several other vegetation subdivisions by elevation. At mean high water, pickleweed forms an ecotone with the low cordgrass band ("low marsh"). In the middle marsh, the ecotone yields to almost pure stands of pickleweed, which persists to elevations equivalent to the highest tides. At higher elevations, pickleweed is found in combination with peripheral halophytes and forms the high marsh. Above the high marsh, the adjacent upland habitat forms a transition zone that supports plants from the high marsh and the upland plant community. Tidal salt marshes range from a few feet to over a thousand feet in width and, depending on the slope, and may exhibit the typical zonal pattern or contain only one or two of the components described above (SFEP 1991b). Salt marshes commonly contain tidal channels or pond connections that distribute water within the marsh plain, circulating bay water during high tides and draining these areas during low tides. Within marsh habitats, these channels are important microhabitats that also serve as nursery areas for fish, foraging areas for shorebirds, and resting areas for waterfowl. The presence of channels greatly increases the species and habitat diversity of salt marshes.

Salt marshes provide habitat for a diverse array of special status bird and mammal species, including the salt marsh harvest mouse, the California clapper rail, black rail, salt marsh common yellowthroat, Suisun song sparrow, Alameda song sparrow, San Pablo song sparrow, yellow rail, short-eared owl, salt marsh-vagrant shrew, Suisun ornate shrew, and San Pablo vole (CNDDB 1995; SFEP 1991b; Williams 1986).

TIDAL BRACKISH MARSHES. Tidal brackish marshes occur where the tidal salt water of the Bay has been diluted by freshwater runoff. Like salt marshes, brackish marshes commonly contain tidal channels or pond connections that distribute water within the marsh plain, circulating bay water during high tides and draining these areas during low tides. Within marsh habitats, these channels are important microhabitats that also serve as nursery areas for fish, foraging areas for shorebirds, and resting areas for waterfowl. The presence of channels greatly increases the species and habitat diversity of brackish marshes.

The plants of these marshes are species of *Scirpus* and *Typha*, which vary with elevation. Brackish tidal marshes can be characterized by three major zones: low marsh dominated by California bulrush; middle marsh with a mixture of cattails and bulrushes; and high marsh with a varied group of halophytes, including saltgrass, brass buttons, and Baltic rush. Within the Planning Area, extensive stands of brackish marsh occur along the Napa and Petaluma rivers, and smaller marshes occur at scattered locations within Suisun Marsh (SFEP 1991b). Tidal brackish marshes provide habitat for an array of special status species that is similar to those listed above for salt marshes.

TIDAL FRESHWATER MARSHES. Within the Bay Area, tidal freshwater marsh habitat is limited to streams, creeks, and rivers entering the Bay. These habitats are generally dominated by bulrush, with scattered stands of willow, button-willow, and dogwood.

Within the Delta portion of the Planning Area, freshwater tidal wetlands provide important nesting and foraging habitat for several special status species, namely the tricolored blackbird, double-crested cormorant, western least bittern, and white-faced ibis. These species may also occur in freshwater habitats at other locations within the Planning Area, in conjunction with the yellow rail, short-eared owls, saltmarsh common yellowthroat, and western pond turtle (SFEP 1991b, 1992c; CDFG and DWR 1993).

Over 90 percent of the freshwater marshes in the Delta region have been converted to cropland. Remaining habitats are affected by a variety of factors, including recreational boating disturbance, agricultural discharges, water exports, and introduced species, such as the brown-headed cowbird and water hyacinth (SFEP 1992a). These factors have reduced the carrying capacity of regional marsh resources for wildlife, including migratory waterfowl and shorebirds, as well as local wildlife populations.

Salt Ponds

Salt pond habitat did not exist under pre-settlement conditions within the Planning Area and was created by diking and draining tidal marshes and mudflat habitats (LTMS 1994g). Salt pond development began in the mid-1800s, when large-scale conversion of tidal marshes and mudflats was conducted using ditches, pumps, and tide gates. The subsequent landscape was large expanses of shallow flat water, and salt crusted barren soil. In some cases, subsidence has occurred due to groundwater overdraft (WRA 1994). Salt ponds currently cover a large portion of formerly tidal marsh in the San Pablo and South bays, or approximately 6 percent of all wetlands within the Estuary. Within the Planning Area there are 9,000 acres of ponds in the Napa-Solano area of the North Bay and nearly 27,500 acres in the South Bay (with 11,770 acres within the boundaries of the San Francisco Bay National Wildlife Refuge).

Salt ponds of the Planning Area support green and blue-green algae, and scattered vascular vegetation (wigeon grass). Salinity can range from hypersaline to brackish in areas where inflow from the Bay occurs. Salt ponds with low to moderate salinity provide valuable foraging, nesting, and roosting habitat for migratory and local populations of shorebirds and waterfowl, including terns, gulls, grebes, pelicans, cormorants, and herons. In addition, most salt ponds retain the potential for restoration to tidal marshes (SFEP 1991b). The composition of invertebrate communities in salt ponds is influenced primarily by salinity, with the number of species decreasing as salt content increases (SFEI 1991b). Common salt pond invertebrates include water boatman (Corixidae) and brine shrimp (*Artemia salina*).

As with invertebrates, the number of fish species in salt ponds decreases as salt content increases (SFEI 1991b). Because of their high salt content, these habitats are of negligible value to sportfish and special status species. Common fishes in salt ponds with moderate to low salinities include native species such as threespine stickleback, Pacific staghorn sculpin, and topsmelt, in addition to introduced species including rainwater killifish and yellowfin goby. No special status fishes are known to utilize these habitats.

These habitats have become important foraging and roosting sites for a wide variety of shorebirds and waterfowl. The creation of salt pond habitat has allowed for several species of ground-nesting shorebirds (California gull and herring gull) to become more abundant within the Planning Area.

Salt ponds within the Planning Area support a variety of special status wildlife, including resident and migratory species. Species observed at salt ponds of the Planning Area include the California brackish water snail, Barrow's goldeneye, western least bittern, long-billed curlew, saltmarsh common yellowthroat, tricolored blackbird, and Alameda song sparrow (WRA 1994). South Bay salt ponds provide important post-breeding foraging habitat for the endangered California least tern. Other species known to occur at these sites include the California gull, American white pelican, elegant tern, and the double-crested cormorant (SFEP 1992c).

Dredged material disposal has the potential to benefit salt pond habitat, mainly through the restoration of levees (see section 4.4.4.2). This habitat, however, is considered less valuable than marsh habitat. The potential environmental impacts associated with this use of dredged material are minimized by the material suitability policies described in Chapter 5.

4.3.1.5 Biological Resources of the San Francisco Bay Estuary

The Estuary supports a strikingly complex array of biological resources. The aquatic resources of the Estuary that are associated with the main bodies of water can be grouped into four categories: phytoplankton, zooplankton, benthos, and fish. A similar but slightly different set of resources is associated with five distinct habitat types within the transition zones between the purely aquatic environment and upland areas: intertidal mudflats, rocky shore, salt marsh (including salt ponds), brackish marsh, and freshwater marsh. The following section describes these aquatic resources and habitat types. Resources associated with water-dependent upland habitats such as vernal pools, seasonal wetlands, managed wetlands, and riparian corridors are described in the upland section (4.4.2).

Phytoplankton and Zooplankton

Phytoplankton production is the major source of organic matter in the Bay/Delta, accounting for about 50 percent of the total (SFEP 1992b). In wet years, river transport of detrital material is another important source of organic matter, at least for the Delta and Suisun Bay. Phytoplankton dynamics are influenced by currents, light availability, and aquatic organisms living in the system. Light and nutrients (from the rivers, waste treatment plants, and decomposition) are sufficient to support much larger blooms of phytoplankton than are typically observed. Results from several studies suggest that much of the phytoplankton produced in the water column settles to the bottom, where it is consumed by a variety of organisms from bacteria to large clams and worms. Benthic diatoms growing on the sediment surface throughout the Bay, together with temporarily or permanently settled phytoplankton, may represent the most readily available food resource for bottom organisms. Recent declines in observed phytoplankton and suspended material concentrations in Suisun Bay and other parts of the northern reach have been attributed, at least in part, to high benthic grazing by a recently introduced species of clam, *Potamocorbula amurensis*.

The organic matter produced in or transported to the Bay is ingested directly by planktonic invertebrates (zooplankton) who digest and metabolize it to carbon dioxide, water, and dissolved nutrients. There are estimated to be over 200 species of zooplankton in the Estuary, most of which have not been well-studied. Important species include the opossum shrimp (*Neomysis mercedis*) that ranges from Suisun Bay down into San Pablo Bay during periods of high riverine flow, and the copepod *Eurytemora* that also resides in the northern reaches. Recently introduced species of copepod, *Sinocalanus doerri* and *Pseudodiaptomous forbesi*, have also been found in increasing numbers. Zooplankton are consumed by larval and juvenile stages of most fish species; by adult stages of fish species such as anchovy, smelt, and shad; and by macro-invertebrates such as bay shrimp.

Disposal of dredged material at existing in-Bay sites is not expected to pose a risk to phytoplankton populations within San Francisco Bay. Although dredging and dredge disposal constitute minor sources of organic matter, disposal of material in the South Bay has the potential to affect the annual bloom (and thereby zooplankton populations) in shallow areas and should be thoroughly evaluated if disposal in this area is considered in the future.

Macroalgae and Eelgrass

Macroalgae are most commonly found growing in hard bottom areas (rock outcrops, coarse sediments, and human-made structures) in the central and northern regions of the Estuary. Eelgrass is also found in the Bay, but is largely limited to the Central Bay region where salinity is highest. The marshes of the Bay/Delta, because of their greatly reduced size following more than 130 years of reclamation, are probably only a minor source of organic matter to the Bay system. The amount of organic matter washed into the Bay from the marshes may be only about 5 percent of the amount produced by phytoplankton in the Bay. Nevertheless, within marshes and other shallow areas, dense zones of macroalgae such as eelgrass beds provide an important source of organic matter, substrate, and a nutrient-rich habitat for smaller organisms.

Disposal of dredged material has the potential to physically alter/cover the substrate upon which macroalgae grow (coarse sediments and rocky shorelines) and to affect eelgrass beds. These are discussed in more detail under each embayment (section 4.3.2).

Benthos

Benthic organisms dwell on the Estuary's mudflats, on the bottom of tidal marshes and openwater areas, and on hard surfaces below the intertidal zone. Benthic organisms have adopted a variety of life strategies. Some, such as worms, burrow into the bottom sediment; some, such as crabs and oysters, live on the sediment surface (epibenthic); other such mussels live on rock pilings or other hard objects. Most benthic species are either filter-feeders or grazers, although some are active predators. Benthic invertebrates are an important component of the food chain as they are an important food source for demersal fishes, crabs, and shorebirds.

Most benthic organisms in the Estuary are introduced species, arriving attached to imported commercial species, attached to ship bottoms, or in ballast water. New species entering the system have led to complete changes in community structure, particularly in San Pablo and Suisun bays. The most striking (and recent) example of such an introduction has been the Asian clam, *Potamocorbula amurensis*, which was first discovered in the Estuary in 1986. Since that time it has spread rapidly and now dominates most of the benthic communities in San Pablo and Suisun bays (SFEP 1992a). The ecological (and economic) impacts of these introduced species have been extensive, from reducing the availability of food to higher trophic levels to damaging various water-related structures.

Factors affecting the abundance, composition, and health of the benthic community include outflow from the Delta, substrate, salinity, and pollution. In general, diversity is lowest in the Delta where, of the more than 82 benthic species recorded, only five species account for 90 percent of the individuals at most sites (SFEP 1992a). In the more saline waters of San Pablo Bay, the number of benthic species increases to more than one dozen. In the South Bay, where there are several substrate types, diversity is even greater. Mollusks comprise the greatest biomass of larger benthic species in the Bay (Thompson and Nichols 1981), with the most abundant species including *Mytilus galloprovinciallis*, *Macoma balthica*, *Mya arenaria*, *Tapes japonica*, and the recently introduced Asiatic clam, *Potamocorbula amusrensis*. Other important components of the benthos include numerous polychaete and amphipod species as well as crabs and shrimp. Examples are discussed below; see Fish and Shellfish section below and discussion of each embayment, section 4.3.2.

The disposal of dredged material significantly affects the benthos at each disposal site and has the potential to affect the benthos within each embayment. These effects result from burial of habitat and changing the composition of the substrate, and will largely be limited to designated disposal sites. However, in cases where high levels of disposal occur within the in-Bay environment, there is also a risk of affecting the benthos in other areas of the embayment as a result of sediment transport processes discussed earlier (see San Francisco Bay Circulation under section 4.3.1.1).

Fish and Shellfish

The fish and shellfish of the Estuary can be placed into four categories: true estuarine species, freshwater species, marine species, and anadromous species. Many of these fish and shellfish are commercially and/or recreationally important. In addition, some of them are threatened or endangered, or otherwise special status species. This section briefly describes the life history, status, and distribution of these four categories of fishes and invertebrates, with particular attention paid to those that are special status and/or are commercially/ recreationally important. Fisheries of the Estuary include anadromous and resident species, crab and shrimp. All areas of the Bay/Delta support commercially and/or recreationally important fisheries.

Climatic changes in oceanic and continental conditions, and physical features such as salinity, temperature, and bathymetry affect the distribution, abundance, and composition of fishes in the Estuary. In addition, human activities such as introduction of non-native species, pollution, changes to the freshwater inflow and outflow regime, and modification of waterways and wetlands from dredging and disposal have also controlled the distribution and abundance of fish species in the Estuary (SFEP 1992a; USFWS 1994). Most of the fish described in this section are species introduced to California. Introductions of non-natives into the Estuary are primarily a result of attempts by resource agencies to enhance the fishery by providing game fishes or new forage for game fishes, and ballast water release from overseas cargo ships (USFWS 1994; SFEP 1992a; Leidy 1984). The introduction of non-native species to the Estuary has created a shift in the food web. This could ultimately drive some native species to extinction or inhibit their recovery (SFEP 1992a).

The potential impacts from dredging and disposal on fish in the Estuary vary according to the location of the activity, time of year when the activity occurs, and the location of each fish species during their respective life cycle. Impacts on fish may include, but are not limited to, interference with migration, degradation of water quality, habitat loss or degradation, and interference with foraging habitat and food resources. The greatest potential for impacts occurs in affected habitats within each embayment that support sensitive lifestages of important species. Negligible impacts are expected where habitats are not significantly altered. In general, disruption of the benthic and near-bottom waters at and immediately adjacent to disposal sites, and disruption of sensitive habitats (e.g., eelgrass) and key migratory corridors are of greatest concern.

TRUE ESTUARY SPECIES. The Delta smelt (*Hypomseus transpacificus*) is the only true estuarine species of fish. Longfin smelt (*Spirinchus thaleichthys*) has been identified, albeit rarely, outside the Golden Gate; all other species maintain part of their populations outside the Estuary. Sacramento splittail (*Pogonichthys macrolepidotus*) had a historical distribution that included the Central Valley. However, due to habitat alterations in the Central Valley drainages, this species is now primarily found in the Delta and is now considered an estuarine species.

FRESHWATER SPECIES. Freshwater fishes consist of native and introduced species. Native freshwater species found in the Estuary include the Sacramento splittail, Sacramento squawfish (*Ptychocheilus grandis*), hitch (*Lavinia exilcauda*), Sacramento blackfish (*Orthodon microlepidotus*), hardhead (*Mylopharodon conocephalus*), Sacramento sucker (*Catostomus occidentalis*), prickly sculpin (*Cottus asper*), and the live-bearing tule perch (*Hysterocarpus traski*). The Sacramento perch (*Archoplites interruptus*) is now believed extirpated from the Delta (USFWS 1994; SFEP 1992a).

Introduced species include centrarchids such as sunfish (*Lepomis* sp.), crappie (*Pomoxis* sp.), and bass (*Micropterus* sp.), as well as catfish (*Ameirus*). These species are most abundant in channels dominated by San Joaquin River waters (SFEP 1992a).

MARINE SPECIES. Marine species can be separated into two categories: those species that maintain part of their population in the Estuary and can be referred to as seasonal species, and those species that reside in the Estuary year-round. Northern anchovy (*Engraulis mordax*) and the Pacific herring (*Clupea harengeus*) are the most abundant of the seasonal species. Northern anchovy enter the Estuary as adults and, while there is evidence of all life stages using the Bay Area, none reside all year. The Pacific herring enters as adults to spawn, but is only present in large numbers for a few months. Other seasonal species include the starry flounder (*Platichthys stellatus*), English sole (*Parophrys vetulis*), and white croaker (*Genyonemus lineatus*), which enter the Bay through bottom currents and tidal forces (SFEP 1992a).

Most of the resident species are benthic fishes. These species include shiner perch (*Cymatogaster aggregata*), bay goby (*Lepidogobius lepidus*), and the staghorn sculpin (*Leptocottus armatus*). They are known to show strong parental care and have a high tolerance of environmental change. Other resident marine species include introduced species such as the yellowfin goby (*Acanthogobius flavimanus*) and the chameleon goby (*Tridentiger trigonocephalus*) (SFEP 1992a).

ANADROMOUS SPECIES. The native anadromous species found in the Estuary include chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Oncorhynchus mykiss mykiss*), green sturgeon (*Acipenser medirostris*), and white sturgeon (*Acipenser transmontanus*). Introduced species include American shad (*Alosa sapidissima*) and striped bass (*Morone saxatilis*). These species have commercial and recreational value in the Estuary. Anadromous species are highly sensitive to environmental change that may affect their migration, spawning habitat, and habitat for nurseries (USFWS 1994; SFEP 1992a). The coho salmon (*Oncorhynchus mykiss*) was historically found in the Estuary, but is now believed to be extirpated (Brown et al. 1994).

SPECIAL STATUS SPECIES. The species discussed below are identified by resource agencies and LTMS lead agencies as being species of concern based on potential impacts upon the species' ecological function and viability within the Estuary, as well as their recreational and/or commercial value. Included are species listed as threatened or endangered under either the state or federal Endangered Species Act. The green sturgeon (*Acipenser medirostris*) (USFWS 1994; SFEP 1992a; Leidy 1984), tidewater goby (*Eucyclogobius newberryi*) (USFWS 1995; Leidy 1984), and Sacramento perch (*Archoplites interruptus*) (USFWS 1994; Leidy 1984) are either rare in occurrence or believed extirpated from the Estuary, and therefore are not considered a species of concern for the purposes of this EIS/EIR.

<u>Chinook salmon (*Oncorhynchus tshawytscha*)</u>. The federal and state status for the chinook salmon is endangered. These are the largest species of salmon (Moyle 1976). There are four runs of the chinook salmon in the Estuary representing different life histories: fall-run, late fall-run, winter-run, and spring-run. The four runs are distinguished based on the timing of adult upstream migration and spawning. These runs are differentiated based on the maturity of the fish entering freshwater, time of spawning migrations, spawning areas, incubation times, incubation temperature requirements, and the migration timing of juveniles (USFWS 1994).

Fall-run salmon migrate through the Estuary to their spawning grounds in the Sacramento and San Joaquin River Basin from July through November. Late-fall salmon migrate during October to February, winter-run migrate December to April, and spring-run migrate April to July. Juvenile fish mature in the ocean off the California coast, with fall and winter-run fish remaining in continental shelf waters and spring-run chinook moving into the high seas (Allen and Hassler 1986). Adult chinook typically return to freshwater to spawn during their third or fourth year (Allen and Hassler 1986). Juveniles feed primarily on macro-invertebrates in freshwater, and on zooplankton during their migration through the Delta (SFEP 1992a). An estimated 10 to 50 million juvenile smolts migrate through the Delta annually (SFEP 1992a). Out-migration peaks between April and June (Allen and Hassler 1986; Kjelson et al. 1982). Nursery areas for chinook salmon are in the Sacramento and San Joaquin rivers and their tributaries, as well as the Delta.

While salmon support a large ocean sport fishery off the coast of San Francisco, environmental changes caused by dam construction, water diversion, pollution, habitat degradation, and overfishing have significantly reduced salmon populations in the Estuary. Historically, chinook salmon were abundant in the Sacramento and San Joaquin rivers and their tributaries. In the mid-1800s, the commercial salmon fishery was initiated due to the large abundance of salmon. By 1919, following mean annual catches of more than 3,000 tons, commercial salmon canning was banned

(Skinner 1962). Today, salmon populations have greatly declined due to dam construction, water diversion, pollution, overfishing, and habitat degradation. As a result, some runs have been almost totally extirpated.

The winter-run chinook salmon population, in particular, has declined over the past two decades. Population levels have dropped from an estimated 117,000 fish in the late 1960s to slightly less than 350 fish by 1993 (USFWS 1995). The Sacramento River supports the only remaining winter-run chinook salmon population in California and is currently listed as endangered by the federal and state government (USFWS 1995). In November and December, winter-run chinook migrate through the San Francisco Bay as adults to spawn upstream and may be present in the Estuary until April. Spawning occurs by May, followed by juveniles that pass through on their way to the ocean as early as June. Peak out-migration occurs during February and March (CDFG 1991). Shallow water habitats within the Sacramento River and the Estuary provide important cover and feeding habitats for out-migrating and/or rearing fry and smolts en route to the Pacific Ocean. Winter-run chinook salmon typically spend between 2 and 3 years in the ocean.

The primary causes of winter-run decline are thought to be habitat loss and degradation, along with fish entrainment from dams and diversions on the Sacramento River and the Delta. Specifically, the Shasta and Keswick dams blocked access to the upper Sacramento tributary streams, and the Red Bluff Diversion Dam inadequately screened water diversions. Additionally these structures created inadequate passage for adults and juveniles (USFWS 1995). Following the construction of the Red Bluff Diversion Dam in conjunction with the drought in 1976 and 1977 and again in 1987, increase in water temperature, reduced flow and lack of access, further reduced the winter-run population. Other factors that may contribute to the decline are dredging and disposal activities that result in interference with migration due to delay or temporary blockage. Degradation of water quality may directly affect the winter-run chinook salmon as well as suspended sediments affecting their foraging habitat and food resources (CDFG 1991).

The fall-run is now the largest and is primarily supported by hatcheries; the majority of chinook salmon migrating through the Estuary are fall-run fish (SFEP 1992a). Today only sportfishing is allowed in the Estuary. The 1991 sport and commercial harvest south of Point Arena totaled 316,100 fish. On February 25, 1998, the NMFS proposed listing the spring-run chinook salmon as endangered, and the fall and late-fall runs as threatened.

<u>Delta Smelt (*Hypomesus transpacificus*)</u>. The federal and state status for the delta smelt is threatened. The delta smelt is a nongame species endemic to the upper Sacramento-San Joaquin Estuary. They are found primarily in the Delta below Isleton on the Sacramento River and below Mossdate on the San Joaquin River, as well as in Suisun Bay (USFWS 1994). From January to July they move into freshwater for spawning and, during high flows, they can be washed downstream into San Pablo Bay (Ganssle 1966 as cited in Moyle et al. 1992). They are known to occur in the Napa River and White Slough. Designated critical habitat for the Delta smelt includes the Delta west to the Carquinez Bridge.

Delta smelt inhabit open surface waters where they school. Spawning occurs primarily in sloughs and shallow edge-waters of channels in the upper Delta and in the Sacramento River. The delta smelt eggs are demersal and adhesive, sticking to hard substrates and submerged vegetation (Moyle 1976). Delta smelt feed on zooplankton, primarily copepods.

In 1993, the federal government listed the delta smelt as a threatened species. The delta smelt has declined nearly 90 percent over the last 20 years and is primarily threatened by freshwater exports from the Sacramento and San Joaquin rivers for agriculture and urban use. The decline also coincided with increased human changes to the Delta hydrology and the accompanying changes in the temporal, spatial, and relative ratios of water diversions. These changes, coupled with drought and the introduction of non-indigenous species appear to have reduced this species' capacity to recover (USFWS 1994). The USFWS has determined that the delta smelt is highly vulnerable to extinction because of its short life span, small population size, and restricted distribution. The delta smelt is also vulnerable to disposal activities that result in habitat degradation to its limited spawning grounds.

<u>Sacramento Splittail (*Pogonichthys macrolepidotus*)</u>. The federal status for the Sacramento splittail is proposed threatened; the state status is species of special concern. The Sacramento splittail is a cyprinid endemic to California (Moyle 1976). It was once found throughout the Central Valley and is now largely confined to the Sacramento-San Joaquin Estuary (Meng and Kanim 1994 as cited in Meng and Moyle 1995). Splittails are common in the backwaters of Suisun Bay, Suisun Marsh, the inland Delta near the Sacramento and San Joaquin rivers, and the Petaluma River (Meng and Moyle 1995; Moyle 1976; Caywood 1974). The

Sacramento splittail is usually found in dead-end sloughs and slow-moving portions of the river (Moyle et al. 1989). They spawn from early March through May in the Delta in submerged or flooded vegetation in seasonal wetlands, tidally influenced sloughs, and in shallow, low velocity channel edge waters (Meng and Moyle 1995; Wang 1991; Moyle 1976). Larvae remain in vegetated shallow water areas near spawning sites, but move into deeper offshore habitats as they mature (Wang 1986). Sacramento splittail are benthic foragers, although opossum shrimp (*Neomysis mercedis*) and detritus comprise a high percentage of their diet (Daniels and Moyle 1983).

In 1994, the USFWS proposed the Sacramento splittail as a threatened species. Over the last 15 years, this species has declined by over 62 percent. This is a result, in part, of large freshwater exports from the Sacramento and San Joaquin River diversions, prolonged drought, loss of shallow-water habitat, introduced aquatic species, and agricultural and industrial chemicals (Meng 1993).

<u>Coho Salmon (*Oncorhynchus kisutch*)</u>. The federal status for the coho salmon is proposed threatened; state status is threatened south of San Francisco Bay. The coho salmon is an anadromous fish found in the Pacific northwest. Following approximately 18 months in the ocean, coho salmon begin their spawning migration. Spawning usually occurs from October to March, peaking in November to January (Moyle et al. 1989). Coho salmon use different types of spawning areas but generally prefer small coastal creeks or the tributary headwaters of larger rivers (Brown et al. 1994). Juvenile salmon prefer deep pools in the shaded areas of streams. This type of habitat is synonymous with that found in old growth forests and therefore the decline of the coho salmon in the Pacific northwest is attributed to the elimination of the old growth forest on the California coast (Brown et al. 1994). Juveniles initiate their migration to the ocean during late March and early April. This migration usually peaks in mid-May. These salmon remain in nearshore waters close to their parent stream, then gradually move northward (Brown et al. 1994).

Coho salmon have declined by at least 70 percent since the 1960s. Counts for the current presence of coho salmon in the LTMS planning area did not identify any in the Sacramento River and other tributaries of San Francisco Bay. It is believed that the coho salmon is nearly extirpated in the San Francisco Bay tributaries and very few remain in the Sacramento River drainage (Brown et al. 1994). Brown et al. (1994) estimates the current population of coho salmon in California at 31,000 fish, of which hatcheries contribute approximately 57 percent. Their decline is attributed to loss of stream habitat due to large dams and diversions as well as logging, agriculture, and urbanization.

<u>Longfin Smelt (*Spirinchus thaleichthys*)</u>. The longfin smelt is a federal species of concern; the state status is species of special concern. Longfin smelt are planktivorous fish found within the Estuary. Adults occur seasonally from south San Francisco Bay upstream to Rio Vista on the Sacramento River, although they are primarily concentrated in salt and brackish waters in Suisun, San Pablo, and north San Francisco bays (USFWS 1994). In the fall, adults migrate upstream into freshwater habitats of the upper Estuary and lower Sacramento River. Most spawning occurs between February and April in the upper end of Suisun Bay and the lower and middle Delta, primarily in the Sacramento River and adjacent sloughs (USFWS 1994; Wang 1991). The diet of the longfin smelt consists of opossum shrimp and other large zooplankton (Moyle 1976).

The longfin smelt has declined steadily over the past few decades (USFWS 1994). The cause of decline may be attributed to the reduction in outflows, entrainment losses to water diversions, drought, pollution, predation, and introduced species (USFWS 1994). Disposal activities could result in habitat degradation of spawning grounds.

<u>Steelhead Trout (*Oncorhynchus mykiss mykiss*)</u>. In August 1997, steelhead trout of the San Francisco Bay eastward to the Napa River (inclusive) were listed by the NMFS as threatened under the Endangered Species Act. Steelhead trout that spawn farther upstream in the Sacramento and San Joaquin rivers are still under review by the NMFS. Steelhead trout are the anadromous form of rainbow trout. They migrate to the Sacramento and San Joaquin river basins from October to April, and spawn from December to May. Their life history and environmental requirements are similar to those of chinook salmon with two major differences. First, steelhead do not always die after spawning (Barnhart 1986); many return to the ocean and spawn in subsequent years. The second major difference is that steelhead spend from 1 to 4 years rearing in freshwater before migrating to the ocean (Barnhart 1986).

Currently, steelhead make spawning runs into several rivers and small creeks flowing into the Bay, including the Napa River, Petaluma River, Sonoma Creek, and Guadalupe River. Spawning runs are also made into the Sacramento and San Joaquin river basins. Hatcheries greatly augment the natural production of steelhead. However, the overall population size of steelhead has declined substantially, with many rivers supporting only remnant fish runs. Steelhead populations are currently supported primarily by hatcheries, which support a small recreational sportfishery. The factors contributing to the decline of steelhead are similar to those affecting chinook salmon. Habitat degradation resulting from disposal of dredged material may adversely affect the steelhead.

COMMERCIAL AND RECREATIONAL FISHES. Fisheries of the Estuary include anadromous and resident species, crab, and shrimp. All portions of the Bay/Delta support commercially and/or recreationally important fisheries. This section describes the life history, status and distribution of fishes and invertebrates that are commercially and/or recreationally important.

Striped Bass (*Morone saxatilis)* were first introduced into California in the Carquinez Strait in 1879 (Skinner 1962). They are the principal sport fish in the Estuary and are highly sought after despite recent declines in their populations. Their successful introduction into the Estuary was primarily due to their anadromous nature as well as their semi-buoyant, non-adhesive eggs which are not susceptible to suffocation by silt loads from hydraulic mining (SFEP 1992a). Survival of the striped bass requires a large river for spawning with water velocities capable of suspending their eggs during incubation, abundant forage fish, and an estuary where juveniles can forage on large invertebrate populations (Moyle 1976).

Striped bass spawn in May and June in the lower Sacramento and San Joaquin rivers and their tributaries. Eggs and larvae are transported into Suisun Bay during high flow years and into the western Delta during low flow years. The larvae and young juveniles usually concentrate in the vicinity of the entrapment zone in Suisun Bay or the Delta, where they feed on zooplankton and amphipods (Turner and Chadwick 1972). Juveniles range into San Pablo Bay. Adults live up to 20 years and prey upon threadfin shad, smaller striped bass, northern anchovy, chinook salmon, and shiner perch (Stevens 1966; Moyle 1976).

Commercial fishing of striped bass began in 1888, only 9 years after their initial introduction into the Bay. Following a decline of the population, commercial fishing for striped bass ended in 1935 (SFEP 1992a). Annual catches from 1936 to 1953 were between 1 million and 2.3 million fish annually (Chadwick 1964). The striped bass is now managed as a sportfishery. Despite the ban on commercial fishing of the striped bass, its population continues to decline. Annual recreational catches today are currently less than 100,000 and the estimated population in 1991 was only 625,702 fish (CDFG 1992). While the subsidiary industries supported by the striped bass fishery are estimated to bring $45 million to local economies, declines since the 1970s have reduced this estimate by more than $28 million (SFEP 1992a).

Northern Anchovy (*Engraulis mordax*) reside primarily along coastal waters of California and migrate into the Estuary in late spring for feeding. They out-migrate in the fall. The majority of anchovies spawn outside the Estuary, although eggs and larvae are found in abundance in the Estuary. The young anchovies are transported by currents into the Bay, where they feed on phytoplankton and zooplankton in the midwater zone (SFEP 1992a). Eggs are widely distributed within the Bay, while larvae are found in areas of high zooplankton abundance. The diet of the northern anchovy consists of zooplankton and phytoplankton (SFEP 1992a).

Northern anchovy are the most abundant fish in San Francisco Bay (SFEP 1992a). In most years they are abundant in Central Bay and generally more abundant in San Pablo Bay as compared to the South Bay (SFEP 1992a). Due to overfishing of sardines, the northern anchovy population increased (Baxter 1967). While anchovies have not replaced the Pacific sardine industry, they support a commercial bait fishery. Due to the large population of anchovy offshore, there is little concern over the impact of the bait fishery on the population (Smith and Kato 1979).

Pacific Herring (*Clupea harengeus*) spawn and rear in the Bay. Adult Pacific herring enter San Francisco Bay in late November, initiating spawning primarily from December into March. Spawning locations within the Estuary have shifted in the past 20 years from Richardson Bay to the San Francisco and Oakland waterfronts (CDFG 1993a). This may be in response to habitat loss (SFEP 1992a). Spawning most often occurs in intertidal and shallow habitats on aquatic vegetation or marina pilings. Herring do not spawn over mud substrates found on the east side of the Bay. As juveniles, they are distributed in shallower habitats in South, Central and San Pablo bays. As they grow they move to deeper waters and emigrate from the Bay between April and August (SFEP 1992a).

The Pacific herring support a large fishery in the Estuary as bait and human food, but more importantly as the roe and roe-on-kelp fishery for export to Japan. The roe fishery is closely regulated by the California Department of Fish and Game (CDFG 1993a).

Dredging activities within Central San Francisco and Richardson bays could result in interference with spawning activity, reduced hatching success and larval survival.

American Shad (*Alosa sapidissima*) is an anadromous fish of the herring family introduced to the Estuary in 1871. American shad are oceanic as adults yet move into the Estuary to spawn in freshwater. Spawning occurs in the north Delta and the Sacramento River and its tributaries, beginning in March and ending by June (Stevens 1966). Young shad migrate to open water shortly after hatching. Their diet consists of zooplankton and small fish. While most adults die after spawning, some return to the ocean and spawn again a few years later (SFEP 1992a).

Soon after introduction of the shad, it supported a large commercial fishery. Commercial fishing was later banned in 1957 due to declining populations. Today a sport fishery exists in the Estuary.

White and Green Sturgeon (*Acipenser* spp.) are anadromous and native to the Estuary (Moyle 1976). Sturgeon can by found in saltwater from Mexico to the Gulf of Alaska (Miller and Lea 1972). The white sturgeon is much more abundant than the green sturgeon in the Bay and Delta and is an important fishery resource. The green sturgeon is a former federal candidate threatened species, now a federal species of concern.

White sturgeon generally complete their life cycle within the Estuary and its major tributaries, although a few fish enter the ocean and make extensive coastal migrations (Moyle 1976). During most of the year, adults are concentrated in San Pablo and Suisun bays feeding primarily on bottom-dwelling invertebrates. Adult sturgeon mature slowly and do not begin to spawn until they are about 10 years old. Individuals spawn in the Sacramento River and its tributaries roughly every 5 years (Moyle 1976).

Suisun Bay and the Delta are the principle nursery areas for sturgeon during their first year. The young sturgeon feed primarily on small crustaceans, while older sturgeon feed on clams, crabs, polychaete worms, fish, and fish eggs. Adult white sturgeon utilize muddy bottom habitats of the Delta, Suisun, San Pablo and San Francisco bays throughout the year (Miller and Lea 1972).

White sturgeon are particularly vulnerable to the effects of over-harvesting because they mature slowly. Commercial fishing of sturgeon dates back to the mid-1800s, but declined by the early 1900s. In 1954, the Fish and Game Commission abolished the commercial fishery and established a sport fishery that continues today. Populations have continued to decline in recent years. The major factor affecting sturgeon populations is believed to be decreased outflow into the Bay (CDFG 1992).

Flatfishes. Two species of flatfish present in the Estuary that are commercially and/or recreationally important are the English sole (*Parophrys vetulus*) and the starry flounder (*Platichthys stellatus*). These flatfish are found throughout the Estuary and in coastal waters. The English sole occur in the Bay as young adults. They spawn in the shallow areas along the coast from November to May, primarily in Central Bay as well as South and San Pablo bays (Wang 1986 as cited in SFEP 1992a). Starry flounder occur in high numbers in San Francisco Bay. Adult starry flounder appear to be most abundant near Alcatraz and San Pablo Bay. Young flounder are found in Suisun Bay. Both the English sole and the starry flounder immigrate into the Bay using both density and tidal currents. The young of both species rear in the Bay and in coastal waters. Larvae are bilaterally symmetrical and feed on zooplankton. Juveniles become laterally asymmetrical and feed primarily on crabs, polychaete worms, and molluscs (Wang 1986).

The adult English sole and starry flounder support a small commercial ocean fishery. While English sole shows no signs of decline, the starry flounder has declined specifically in San Pablo and Suisun bays. The starry flounder appears to be more sensitive to hydrologic and environmental changes (SFEP 1992a).

Dungeness crab (*Cancer magister*) has provided a valuable commercial fishery for San Francisco for over a century. Dungeness crab reproduction occurs entirely in nearshore ocean waters. Spawning occurs primarily in October and November. Dungeness crabs enter San Francisco Bay as juveniles during May or June and leave the Bay by August or September of the following year. The Bay serves as a nursery ground with an abundance of juveniles located in navigational channels and shallow berthing areas from Richardson Bay through Suisun Bay. San Pablo Bay has consistently served as a nursery for high numbers of juveniles (CDFG 1983).

The commercial fishery of the Dungeness crab began around 1848. Following a concern over a declining population, the crab fishery began to be regulated in 1903 by the State Board of Fish Commissioners (CDFG 1983). While there is currently an active offshore commercial and sportfishery, sport fishing of Dungeness crab inside the Bay was banned by the CDFG in 1978 due to concern over excess sport take (CDFG 1983).

Shrimp. The four most common shrimp in the Estuary are the blacktail bay shrimp (*Crangon nigricauda*), blackspotted bay shrimp (*Crangon nigromaculata*), California bay shrimp (*Crangon franciscorum*,) and an introduced shrimp from Korea (*Palaemon macrodactylus*) (SFEP 1992a). These shrimp, commonly referred to as grass shrimp, are important prey for Estuary fishes.

Each species has unique salinity preferences and therefore occurs in different areas of the Estuary. Factors limiting their abundance include hydrological modification, competition, and predation (SFEP 1992a).

The shrimp fishery for human consumption diminished by the 1950s following the discovery of offshore populations of shrimp and prawns. Currently, there is an active commercial bait fishery in the Estuary taking over 68 tons of shrimp each year from the Bay for striped bass and sturgeon fishermen (Siegfried 1989).

4.3.1.6 Marine Mammals

There are several species of marine mammals found in the Estuary. Most notably, a group of sea lions reside at Pier 39 along the northern edge of the San Francisco waterfront, and small colonies of harbor seals range throughout South, Central, and San Pablo bays. Harbor seal haulout grounds are found at several sites in the South Bay, Castro Rocks near the Richmond-San Rafael Bridge, Corte Madera Marsh, and on lower Tubbs Island in San Pablo Bay. Occasionally, individual juvenile whales also enter the Bay during their migrations up and down the coast of California.

Dredged material disposal is not considered likely to directly impact marine mammals except in cases where equipment operating near a haulout ground causes flushing.

4.3.2 Embayments

Section 4.3.1 above generally described the environmental resources of the overall San Francisco Bay Estuary. Disposal of dredged material has the potential to affect environmental resources at specific disposal sites in very similar ways, regardless of site location. Overall, however, the environmental effects are not always confined to the disposal sites, and different collections of resources within each embayment can be affected in different ways. To fully assess the potential impacts of in-Bay disposal, a more detailed analysis of the potential for impact with each of the embayments is necessary. This section presents a more detailed discussion of the environmental resources that could be affected by dredged material disposal in each of the seven embayments: Central Bay, San Pablo Bay, Carquinez Strait, Suisun Bay, South Bay, and the Sacramento-San Joaquin Delta. Existing monitoring programs of dredging and dredged material disposal are also discussed in the following section.

4.3.2.1 Central Bay

Central San Francisco Bay is the area bounded to the north by the Richmond-San Rafael Bridge, the west by the Golden Gate Bridge, and the south by the Bay Bridge. The western portion of Central Bay is characterized by relatively deep water, high tidal water exchange through the Golden Gate, and strong currents. This area is dominated by marine habitat conditions, and is bordered by rocky shoreline. The eastern portion of Central Bay is dominated by shallow mudflats. Small embayments off the main water body also contain mudflats. Overall, habitat diversity is relatively high because Central Bay has both marine and estuarine characteristics and has the greatest depth range of any region in the Estuary. The Alcatraz disposal site is located within this embayment.

This section first describes the environmental conditions at the Alcatraz disposal site. This is followed by a discussion of environmental parameters within the broader Central Bay embayment that may be affected by dredged material disposal at the Alcatraz site.

Environmental Characteristics of the Alcatraz Disposal Site

The Alcatraz disposal site (known as “SF-11”) is a 2,000-foot-diameter circle located 0.3 mile south of Alcatraz Island (centered at 37°49'17"N, 122°25'23"W) (see Figure 2.2-1 and Figure 4.3-5). Dredged material has been disposed at this site since 1894 (LTMS 1994j) and it was formally designated as a disposal site in 1972. Dredged material has been disposed at Alcatraz using both clamshell and hopper dredges; the areas where each of these types of dredges have disposed of material at the Alcatraz site are shown in Figure 4.3-6. It continues to be the most heavily used dredged material disposal site in the Bay. COE records for 1975 through 1994 indicate disposal volumes ranged from a low of approximately 1 mcy in 1980 to a high of over 9 mcy in 1985 (Figure 4.3-7). Recently the COE has been compiling monthly records of disposal volumes at Alcatraz. This information is provided in Figure 4.3-8. In the mid-1980s, as a result of frequent disposal at this site, a mound developed at its eastern portion, posing a hazard to navigation (see Chapter 2 for further discussion of the mounding problem at Alcatraz). Active management of disposal methods, frequencies, and volumes by the COE is required to maintain navigable depths at the site. Currently, there is a yearly disposal volume limitation of 4 mcy for this site.

A portion of the Alcatraz disposal site also overlaps with a portion of the Golden Gate National Recreation Area (GGNRA), as shown in Figure 4.3-9.

WATER COLUMN SALINITY. The Alcatraz site is typically dominated by marine waters, so salinity levels are generally high. Salinity measured at a nearby RMP monitoring station ranged from 24 to 33 ppt (SFEI 1994). There is often a slight salinity gradient from shallow to deep waters at the site.

DISSOLVED OXYGEN. Dissolved oxygen (DO) levels near the Alcatraz site are generally very high, ranging from 7.1 to 9.6 at a nearby RMP station at the mouth of Richardson Bay (SFEI 1994). As described in section 4.3.1.2, the disposal of dredged sediment has the potential to affect levels of DO at each disposal site, particularly in waters near the Bay floor. The extent of this depression depends on the amount of oxygen-demanding substances present in the material. Anoxic sediments containing reduced substances such as hydrogen sulfide would cause the greatest

Figure 4.3-5 Alcatraz Open Water Disposal Site
SF-11

Figure 4.3-6 Alcatraz Disposal Site: Areas of Clamshell vs. Hopper Disposal

Figure 4.3-7 Annual Disposal Volumes at Alcatraz
(1975-1994)

Figure 4.3-8 Monthly Disposal Volumes at Alcatraz (September 1993 — September 1994)

Figure 4.3-9 Alcatraz Disposal Site and Golden Gate National Recreation Area Locations depression in DO levels on site. Some reductions in DO levels are expected to occur at theAlcatraz site but these effects are generally very short term and localized.

CONTAMINANT CONCENTRATIONS IN WATER. Levels of contaminants in the water column at the site are affected by the disposal of dredged material, although measurable differences in parameters are only observed for a short period of time (less than 1.5 hours) after the release of dredged material (USACE 1976d). Representative water column data from a monitoring location near the Alcatraz site are presented in Table 4.3-4.

sediment composition on the site from 1 to 3 months after disposal. Absent any dredged material, the disposal site was historically approximately 165 feet deep.

TOTAL SUSPENDED SOLIDS (TSS) AND TURBIDITY. Current SFBRWQCB objectives limit increases in turbidity in Bay waters to 10 percent above background(see Appendix H-2). Time-averaged data from Winzler and Kelly Consultants (1985) gave a TSS concentration of 19.5 mg/l at Alcatraz, and a range of TSS in the Central Bay generally of from 10 to 60 mg/l TSS (see section 4.3.1.2).

While increased turbidity from each individual disposal event is not considered to be significant due to its short duration, the cumulative effect of multiple releases from barges occurring within a short time may result in significant, long-term elevations of near-bottom turbidity levels at the site. Such increases in turbidity over extended periods of time thus have the potential to significantly affect water column and benthic habitat quality outside the disposal site, as noted below in the discussion of environmental characteristics of Central Bay outside the Alcatraz site.

Table 4.3-4. Water Quality Parameters near the Alcatraz Disposal Site

Parameter	***Dissolved Concentrations***	
PH	7.8 - 8.0	
Ammonia	1.84 - 2.10	µM
Ag	0.68 - 1.95	ng/l
As	1.57 - 2.08	µg/l
Cd	33.63 - 66.1	ng/l
Cr	0.09 - 0.13	µg/l
Cu	0.87 - 1.91	µg/l
Hg	0.79 - 1.64	ng/l
Ni	0.84 - 1.99	µg/l
Pb	7.92 - 10.7	ng/l
Se	0.14 - 0.19	µg/l
Zn	0.49 - 1.22	µg/l
PAHs	2,926*	pg/l
PCBs	2,886*	pg/l
Pesticides	1,722*	pg/l

Notes: Sampling Station at the mouth of Richardson Bay
* sample taken at the Golden Gate
Source: SFEI 1994.

SEDIMENT CHARACTERISTICS. The native material at the Alcatraz site is characterized by predominantly fine to coarse sand, with pockets of finer silt and areas of bedrock and boulders just south and southwest of Alcatraz Island. In the area immediately surrounding the Alcatraz site, the sediment is comprised of 81 to 98 percent sand with up to 17 percent gravel and 0 to 6 percent silt and clay (USACE 1993). In contrast, much of the material from dredging projects is predominantly clay and silt from channels. Cores taken at the site show that recently disposed dredged material is a mixture of clays with clayey sands, while older dredged material is primarily clays (LTMS 1994j). The high rate of disposal at the site has also resulted in a heterogeneous substrate. A study by SAIC (1987b) showed that there were no significant changes in

CONTAMINANT CONCENTRATIONS IN SEDIMENT. Sediment quality at the Alcatraz site is highly variable. However, historic use has resulted in elevated levels of pollutants within the boundaries of the site. Sediments at the site generally contain elevated levels of most metals, oil and grease, TRPHs, and PAHs compared to sediments in the surrounding area (e.g., Alcatraz environs). Pesticides and PCBs were often not detected during sampling conducted in 1991 and 1992. Current sediment contaminent levels at the Alcatraz site are presented in Table 4.3-5.

AQUATIC RESOURCES. The primary aquatic resources within the boundaries of the Alcatraz site that could potentially be affected by dredged material disposal are those associated with the benthic community. Other resources such as phytoplankton, zooplankton, pelagic fish, and wildlife are discussed below in the context of the broader Central Bay embayment.

Environmental Characteristics of Central Bay Outside the Alcatraz Disposal Site Potentially Affected by Dredged Material Disposal

Much of the sediment disposed at the Alcatraz site does not remain within site boundaries. A small fraction remains in the water column as the bulk of the material initially falls to the Bay floor during disposal operations. Following disposal, material is resuspended by currents and dispersed over a wide area, with the extent of dispersal depending on a number of complex, interrelated factors (see Chapter 3). Therefore, disposal of dredged material at the Alcatraz site has the potential to affect resources over a broader area. This section describes the environmental characteristics of the Central Bay outside the Alcatraz site that could be affected by dredged material disposal.

Table 4.3-5. Physical and Chemical Parameters Measured in Alcatraz Disposal Site Sediments

Parameter	***Source (1)***	***Source (2)***	***Source (3)***
Grain Size (percent)			
Gravel	0	5	0
Sand	98	61	15
Silt	0	14	40
Clay	2	20	45
Total Organic Carbon (percent)	0.05	0.43	0.94
Total Volatile Solids (percent) (Dry wt.)	1.2	4.89	8.61
Organic Contaminants (μg/kg)			
Tributyltin	<1.0	<0.8	
Dibutyltin	1.1	<0.7	4.2
Monobutyltin	<1.0	1.3	1.0
Oil and Grease (mg/kg)	7	115	92
TRPH (mg/kg)	5	110	78
DDT and metabolites	<5.0	3.33	<4.0
total PCBs	<20	ND	<35
total PAHs	759	36,830	2,983
Metals (mg/kg)			
Arsenic	6.92	11.7	10.7
Mercury	0.08	0.183	0.306
Selenium	<0.11	0.13	0.21
Cadmium	0.07	0.21	0.23
Chromium	171	414	229
Copper	10	32.2	56.1
Lead	14.7	23.1	24.4
Nickel	37.6	80.4	104
Silver	0.026	0.201	0.320
Zinc	34.1	78.2	115.3

Notes: (1) Battelle 1992a (Phase IIIB)
(2) Battelle 1992b (Berths)
(3) Battelle 1992c (Phase IIIA repeat)
Source: USACE and Port of Oakland 1994.

WATER QUALITY. In general, water quality parameters such as pH, DO, ammonia, salinity, and pollutant levels are affected by disposal of dredged material, but these changes are only expected to be short term and localized near the site. Thus, water quality within the Central Bay is expected to be only marginally affected by disposal, assuming that disposal events are much less frequent than the time it takes disposal plumes to fully diffuse.

SEDIMENT CHARACTERISTICS. The floor of much of the Central Bay consists of sand and coarse channel-bottom sediments formed from strong currents focused along narrow channels. The sand deposits form waves as high as 8 m that, over time, move with strong ebb and flood tidal flow through the Golden Gate (Rubin and McCulloch 1979). The only part of Central Bay that is predominantly mud is the shallow eastern shoreline (Nichols and Pamatmat 1988). Characteristics of the surface sediment vary according to seasonal riverine flow, material transport, and wave-induced suspension of material in shallow areas during the summer.

Disposal of fine-grained material from channels and harbors at Alcatraz has the potential to alter benthic habitat characteristics both in the immediate area of the site and in the off-site habitats located at the margins of the embayment that are sensitive to burial and/or changes in the seasonal patterns of sediment deposition and erosion. The habitats and resources of concern are described below under Benthos.

SEDIMENT DYNAMICS. Transport of suspended material in Central Bay is dominated by strong tidal currents in the main channels and wind-driven currents in shallower areas, particularly along the eastern margin. The fate and transport of suspended sediments is of great interest since a substantial portion of dispersed dredged material may be redistributed across the entire Bay instead of being moved out to the ocean, as assumed in the past.

Concerns have been expressed about intertidal impacts at Alcatraz Island from nearby dredged material disposal operations at the Alcatraz disposal site. Inquiries to the National Park Service (NPS), which manages the adjacent Golden Gate National Recreation Area (GGNRA), indicate that there is no quantitative information on this issue. However, anecdotal evidence from ranger observations and visitor complaints indicate that sediment from the disposal site washes onto the shores of the island. Disposal barges may sometimes get too close to the island, may be outside the designated disposal area, and are probably in GGNRA territory. In addition, sediment plumes may sometimes extend to the island, and sediments and tar may be deposited in the high intertidal area. However, it is not certain whether the sediment deposited in the intertidal area is from upstream sources in the Bay watershed or from disposal operations at the Alcatraz disposal site (personal communication, Darren Fong, NPS Biologist, 1997).

TOTAL SUSPENDED SOLIDS AND TURBIDITY. Recent data on suspended solids levels in the Central Bay collected using optical backscatter sensors indicates that turbidity levels in this embayment are typically much lower than in the rest of the Estuary. Measurements taken off the western edge of the Bay Bridge during the 1992 and 1993 water years indicate average concentrations of 29 mg/l at 13 feet above the Bay floor, and 36 mg/l near the bottom in a deep channel (41 feet MLLW depth). In addition, these data indicate less long-range variability in suspended solids levels in the deep channel in this embayment compared to other Bay sites (Buchanan and Schoellhamer 1994). However, there can be a large degree of instantaneous variability in TSS levels in the Central Bay associated with tidal action. Therefore, time averaged TSS data or data from discrete grab samples are not adequate to fully determine the influence of dredged material disposal on the Central Bay environment. Peak levels of TSS are likely to be related, in part, to dispersion of dredged material from the Alcatraz site, since the site is now actively managed to maximize dispersion and minimize mounding.

SEDIMENT QUALITY. Sediment quality data for "Alcatraz Environs" (which has been used as the reference site for dredged material testing since Public Notice 93-2, and includes sampling stations outside of the dredged material mound itself) is presented in Table 4.3-6. Generally, contaminant concentrations in these sediments are lower than those observed at the Alcatraz disposal mound. Nevertheless, recent data show that concentrations of some contaminants such as PAHs and PCBs have been increasing over time. It appears that ongoing disposal and/or site management to maximize dispersion and minimize mounding at Alcatraz is having influences on sediment quality in the Central Bay beyond the boundaries of the disposal site.

EELGRASS BEDS. Eelgrass (*Zostera*) beds are found only in the shallow areas of the Central Bay where the substrate is mud or mixed mud and sand. These beds form complex, important, and highly productive habitats. The eelgrass grows in low-energy areas and serves to stabilize sediment, providing a substrate for

Table 4.3-6. Levels of Pollutants Measured in Alcatraz Environs Sediments

Parameter	***Source (1)***	***Source (2)***	***Source (3)***	***Source (4)***
Grain Size (percent)				
Gravel	3	0	7	4
Sand	94	91	90	91
Silt	1	3	1	1
Clay	2	6	2	1
Total Organic Carbon (percent)	0.78	0.19	0.11	0.07
Organic Contaminants (μg/kg)				
Tributyltin	0.8	1.1	0.8	1.0
Dibutyltin	<1.2	<1.0	<0.6	1.6
Monobutyltin	<1.3	<1.0	1.0	<0.6
Oil and Grease (mg/kg)	41	<0.7	<1.3	13
TRPH (mg/kg)	<12	8	<1.3	<0.6
DDT and metabolites	0.5	<5.0	0.7	<2.0
total PCBs	<2.8	<20	<20	<24
total PAHs	5,129	1,620	669	139
Metals (mg/kg)				
Arsenic	9.1	6.55	8.01	13.2
Mercury	0.036	0.05	0.009	0.048
Selenium	<0.12	<0.11	<0.12	<0.08
Cadmium	<0.1	0.09	0.05	0.04
Chromium	190	156	136	121
Copper	11.5	12.4	11.7	11.4
Lead	15.2	14.4	13.8	11
Nickel	42.3	40.7	51.8	38.8
Silver	0.042	0.033	0.015	0.02
Zinc	36.8	37.7	32.3	35.4

Notes: (1) Battelle 1993 (Intensive Study)
(2) Battelle 1992a (Phase IIIB)
(3) Battelle 1992b (Berths)
(4) Battelle 1992c (Phase IIIA repeat)
Source: USACE and Port of Oakland 1994.

epiphytes, producing organic matter, and exporting detritus. It also provides a diverse habitat for invertebrates and provides forage, spawning, and nursery substrate for numerous species of fish (Chambers Group 1994). Eelgrass beds provide important foraging habitat for the endangered California least tern and other piscivorous birds. A 1987 aerial survey found 17 separate beds totaling 53 hectares (ha) in the Central Bay (Echeverria and Rutten 1989) (see Figure 4.3-10).

Eelgrass bed habitats are sensitive to the disposal of dredged material within the Central Bay embayment for several reasons. First, they exist in low-energy areas where suspended sediment naturally settles out of the water column. Second, excess siltation in these habitats can smother sensitive benthic organisms. One fish species that is particularly vulnerable to changes in eelgrass beds and other areas of aquatic vegetation is the Pacific herring, which spawns in and uses these areas as nurseries.

PHYTOPLANKTON AND ZOOPLANKTON. Phyto-plankton and zooplankton populations in the Central Bay are largely dominated by influxes from ocean and South Bay waters. Ghost shrimp and oceanic species of krill enter the Bay as a result of extreme currents.

While material disposal may affect turbidity levels that, in turn, change the depth of the photic zone, this embayment is not among the most productive segments of the Estuary. Dredged material disposal within Central Bay is thus not expected to pose a risk to phytoplankton or zooplankton.

BENTHOS. Central Bay benthic habitats are diverse and include large areas of tidal and subtidal mudflats,

Figure 4.3-10 Eelgrass Beds in San Francisco Bay subtidal shell deposits, sandy shoals, cobbles and exposed rocky outcrops. Each of these benthic habitats has its characteristic benthic community.

Benthic organisms that live in the deeper parts of the Central Bay are typical of those found in sandy sediments along the outer coast (Nichols and Pamatmat 1988). Density and species composition appear to be correlated with particle size and organic content of the sediments. Polychaetes *Armandia brevis*, *Mediomastus* sp., *Siphones missionensis*, and *Glycinde picta* are commonly encountered. The amphipod *Foxiphalus obtusidens* and the crab *Cancer gracilis* also are common. All of these are native species. The benthic community associated with sand sediment is not well-adapted to silt and clay and is susceptible to numerous impacts related to the disposal of this material in this embayment.

Rocky outcrops are a benthic habitat that is important but less common in the Central Bay. There are several rocky outcrops, including Harding Rock, Shag Rock, and Arch Rock (LTMS 1994j). These rocky outcrops are inhabited by hard-substrate organisms with marine affinities such as the native bay mussel *Mytilus galloprovincialis*. Large numbers of the clams *Tapes japonica* and occasionally *Mya arenaria* are found in discrete intertidal beds, particularly in the narrow band of rock, cobble, and broken concrete riprap along the base of dikes, piers, and breakwaters (Nichols and Pamatmat 1988).

Organisms that inhabit rocky outcrops, like those adapted to sandy substrates, are likely to be affected by dredged material disposal in the area. A primary concern is burial and covering of these surfaces by fine sediments that settle out some distance from the disposal site. Other concerns relate to the adaptability of hard-surface organisms to short- and medium-term increases in turbidity.

FISH AND SHELLFISH. Fish commonly found in Central Bay include the northern anchovy, halibut, American shad, chinook salmon, bay goby, white croaker, Pacific staghorn sculpin, and marine surfperches. Within the Estuary, the English sole is found most abundantly in Central Bay. Pacific herring spawn in the eelgrass beds and other areas of aquatic vegetation in Central Bay within the vicinity of Angel Island and the Tiburon Peninsula between December and March. Except for striped bass, all of the species commonly found in Central Bay are native. In recent years, the species composition of fishes has remained relatively stable. The overall abundance also has remained relatively stable, except for annual fluctuations in northern anchovy and Pacific herring stocks, an increase in white croaker abundance, and a decrease in longfin smelt abundance.

Shiner surfperch, jacksmelt, topsmelt, diamond turbot, and the speckeled sand dab are common in shallow waters around Central Bay. Anadromous fish such as the striped bass, steelhead trout, chinook salmon, and the white and green sturgeons migrate from the ocean to upstream spawning areas. The leopard shark, seven-gill shark, and the brown smoothhound are abundant in the intertidal mudflats of the Central Bay.

Pelagic species such as the northern anchovy, Pacific herring, and jacksmelt dominate catches from surveys conducted by the CDFG in Central Bay (SFEP 1992a). The sand substrate and rock outcrops in the Central Bay support recreational fish such as the halibut, striped bass, rockfish, and lingcod.

There are three basic concerns regarding the potential impact of dredged material disposal on resident and migratory fish species: disruption of habitat, physiological effects on fish species, and avoidance by fish of the area around the disposal site. During periods of intense disposal, fish avoidence can affect a significant portion of the broader embayment. Avoidance may interfere with foraging habitat and food resources, but there is little information available with which to evaluate those effects (SFEP 1992a). Field studies at the Alcatraz site indicate that fish may disperse after individual disposal events due to acoustic effects or turbidity, but return within an hour or two (O'Connor 1991).

SPECIES OF SPECIAL CONCERN. Fish species of special concern identified by the resource agencies within Central Bay are the chinook salmon, coho salmon, Pacific herring, and recreational marine fishes. The chinook salmon are of greatest concern. While little information exists on potential effects of sediment disposal at Alcatraz on this species in Central Bay, disposal activities could degrade water quality and/or habitat, directly affecting adults and juveniles in the vicinity. The Pacific herring is another species of concern in Central Bay. Impacts on the herring are most likely to be associated with dredging (as opposed to dredged material disposal at Alcatraz) and may include interference with spawning activity, and reduced hatching success and larval survival. Concerns have been expressed about the potential impact on herring spawning in the vicinity of the Alcatraz disposal site. According to the California Department of Fish and Game (CDFG), herring do spawn each year along the perimeter of Alcatraz Island starting in

December (personal communication, Diane Watters, CDFG Biologist, 1997). Whether there is any adverse impact on herring spawning from disposal operations at the Alcatraz site is unknown.

Other special concern species that occur in the Central Bay include the peregrine falcon, brown pelican, California clapper rail, California least tern, and salt marsh harvest mouse.

Although impacts associated with individual disposal events are thought to be temporary and therefore of little concern (particularly for migrating species that could avoid the area), cumulative effects associated with frequent disposal events over a limited period of time could be of more concern for these species.

WILDLIFE RESOURCES. Typical birds of the open water of the Central Bay are the western grebe, scaup, canvasback, surf scoter, and the osprey. The common loon, American coot, and Caspian tern also use the open water habitat of the Central Bay. Particular to the rocky shore areas are cormorant, black oystercatcher, and western gull. Mallards, rails, black necked stilts, and the salt marsh yellowthroat use the marshes around the Central Bay. California sea lions and harbor seals use open water, rocky shore, and intertidal mudflat habitats of the Central Bay.

The following is a brief summary of some of the sensitive biological resources on and in the immediate vicinity of Alcatraz Island. Figure 4.3-11 shows the location of a number of sensitive biological resources.

While Alcatraz has historically been home to a variety of waterbirds, increased human disturbance and use of the island present an ongoing challenge to wildlife management. For example, more than 1 million people visit the 20-acre island annually. Prior to 1981, only two colonial nesting species, the black-crowned night-heron and the western gull, were documented on the island. In 1981, San Francisco Bay's only pigeon guillemot colony was discovered on Alcatraz. Since 1981, increased wildlife protection by the National Park Service (NPS) has resulted in increases in the number of colonial nesters. Pelagic and Brandt's cormorants first bred on the island in 1993, followed by great egrets and black oystercatchers in 1995. With increased protection under NPS management, the numbers of colonial nesters increased dramatically during the 1980s and reached an all-time high in 1996, when over 1,000 pairs of colonial waterbirds of six species bred on Alcatraz (Hatch et al. Undated).

Concern has been raised about the possible adverse effects of dredged material disposal at Alcatraz on the birds that nest on the island. One study (Hothem 1996) evaluated the effects of environmental contamination on the reproductive success of the black-crowned night-heron nesting on Alcatraz Island from 1990 to 1996. From 1990 to 1995, between 90 and 200 night-heron nests on the island were monitored each year. In every year, nesting levels either remained constant or increased. In 1996, more nests (341 nests) were monitored, but less often (the nests were visited only four times during that year). In that year, nesting success was lower, but the difference was not statistically significant, and fledgling success was also lower. While no abnormal embryos were found during 1996, the number of dead chicks was higher, although these data have not yet been analyzed.

A 3-year study (Brown 1996) evaluated the breeding success of the western gull colony on Alcatraz Island (Figure 4.3-12) as a function of parental investment in the chicks. From 1992 to 1996, the western gull population on the island fluctuated, peaking in 1996 with 566 nests. The 1996 peak coincided with similar peaks in the number of nesting black-crowned night-herons and Brandt's cormorants on the island.

A study of Brandt's cormorants nesting on Alcatraz in 1996 (Fairman et al. 1997) revealed that the breeding colony is relatively productive and affected little by island-based and external disturbances (e.g., local sea and air traffic). Disturbances to the colony were recorded frequently, but rarely were effects on the breeding cormorants detected. Overall, the productivity of Brandt's cormorants on Alcatraz compared favorably with that observed in both the established offshore Farallon Island population and a small coastal population at the Point Reyes headlands. However, because the Alcatraz population's annual variation is considerable and the colony's establishment is relatively new, the success of these birds is still unknown. Pigeon guillemots, pelagic cormorants, and black oystercatchers were also documented on the island, although monitoring of these birds was less detailed than the monitoring of Brandt's cormorant. The study recommended that public access restrictions remain in areas where

Figure 4.3-11. Location of Sensitive Biological Resources on Alcatraz Island.

Figure 4.3-12 The Western Gull Study Area on Alcatraz Island colonial waterbirds nest. The current restrictions are considered sufficient, but if new areas are opened for visitors, disturbances may increase.

Existing Monitoring Programs

Currently there are two types of monitoring conducted for in-Bay aquatic disposal: mapping of the disposal site (i.e., bathymetric charts), and Estuary-wide contaminant monitoring; these two types of monitoring are described below. In addition, all dredged material undergoes a pollutant evaluation prior to receiving approval for disposal.

For the first type of monitoring, the Corps of Engineers conducts monthly surveys of the Alcatraz disposal site and quarterly surveys of the San Pablo Bay and Carquinez Strait disposal sites using its own survey crew. The purpose of this monitoring is to detect and monitor changes in the shape of the bottom (topographic) and changes in the depth, particularly as changes in depth could cause the site to become a navigational hazard.

The second type of monitoring concerns contaminant and sediment transport from the disposal site to surrounding waters. The disposal sites currently in use are considered "dispersive" sites, i.e., sediment disposed of at the site is intended to be moved to other areas, with some unknown fraction transported out of the Bay through the Golden Gate to the Pacific Ocean. Since the dispersive disposal method moves all sediments into the ecosystem, there is a high potential for pollutants present in the sediments to have harmful effects. For many classes of pollutants, the act of dredging and disposal at the in-Bay sites will actually *increase* the contact that organisms have with the particle-bound contaminants in the Estuary, i.e., make them more "bioavailable." Section 3.2.2.2 discusses concerns about pollutants. While there is currently no *on-site* contaminant monitoring of the disposal sites, all the dredged material approved for disposal must first be evaluated for pollutant load and toxic effects. In most cases, sediments are subjected to chemical analysis and bioassays as part of the permit process. The goal is to ensure that the dredged sediment approved for disposal at these sites is free of significant levels of contaminants.

This second type of monitoring could be considered "off-site" monitoring in that it is the monitoring of conditions beyond the disposal site. This "far-field" monitoring is known as the Regional Monitoring Program for Trace Substances (RMP). The RMP is carried out by the San Francisco Estuary Institute and overseen by the Regional Water Quality Control Board. Under the RMP, contaminants in Bay water, sediment, and shellfish tissue are tested several times a year at about 20 locations throughout the Estuary, from the Delta to San Jose. Station locations reflect the background (or "ambient") condition of the Bay and are not intended to be influenced by any one source of pollution. The goal of the RMP is to provide baseline data on aquatic media to determine pollutant loads, trends, and the overall health of the Estuary (i.e., is the Bay ecosystem getting healthier?). Additionally, the RMP monitors suspended sediment loads at various locations (on a continuous basis), evaluates new test methods, and conducts special and pilot studies related to contaminant fate and transport.

The RMP monitoring stopped in 1995 but began again in 1997. Unfortunately, no baseline data exist to determine if impacts are occurring. Thus there can be no comparison with and without in-Bay disposal.

The Corps conducts quarterly bathymetric surveys of the three existing in-Bay disposal sites, and keeps a record of these surveys for inspection by the Regional Board, other regulatory agencies, and interested members of the public upon written request to the Corps staff.

The Corps also keeps a record of all disposal events that take place at the in-Bay and ocean (aquatic) disposal sites in the San Francisco Bay area. A quarterly summary report (Quarterly Report) of all dredging activities in San Francisco Bay is available to the Regional Board staff and interested members of the public through the Dredged Material Management Office (DMMO), which is hosted by the Corps. The Quarterly Report contains the following information for each project: the name of the project, the dates dredged, the volume of material proposed for removal (in-place, surveyed), the dredged volume disposed (referred to as the "bin"), the disposal site(s) used, and the name of any affiliated dredging permit holders (permittees).

On a quarterly basis, the Corps provides a report summarizing the site capacity and topography for all three of the in-Bay disposal sites — SF-9, SF-10, and SF-11 — based upon recent bathymetric surveys. A written summary of disposal and reuse at upland locations is also included. This requirement is applicable to all dredging activities by public and private sector entities which occur in the quarterly period.

Material is sampled for contaminants prior to being disposed of at Alcatraz (SF-11) or is granted an exclusion from testing. The reference site for Alcatraz is sampled periodically to determine if there is any increase in contaminants at the reference site.

The limit of disposal of material at Alcatraz is required to conform with Public Notice No. 93-3.

Summary of Environmental Characteristics of Central San Francisco Bay Potentially Affected by Dredged Material Disposal

Table 4.3-7 presents the resources at the Alcatraz site and within the Central Bay embayment that may be affected by dredged material disposal. The magnitude of potential impacts depends on the overall amount and frequency of material disposed in the Central Bay over the course of the next 50 years and on the development and implementation of policies that will limit the adverse environmental effects of disposal.

4.3.2.2 San Pablo Bay

San Pablo Bay is bounded to the southwest by the Richmond/San Rafael Bridge and to the northeast by the mouth of Carquinez Strait. This embayment is characterized by extensive shallow water habitat and a variable salinity regime resulting from fluctuating freshwater inflow. Freshwater inflow is primarily from the Sacramento-San Joaquin river system with additional inflow from the Napa River, Petaluma River and Sonoma Creek. Seasonal fluctuations in salinities are considerable in San Pablo Bay, although salinities rarely fall below 5 ppt. Except for shipping channels, San Pablo Bay is comprised of shallow mudflats. The shallow waters of San Pablo Bay are characterized by high levels of suspended fine sediments throughout the year, a result of storms in the winter and strong winds during the summer. The San Pablo Bay disposal site is located in the south central portion of San Pablo Bay.

This section first describes the environmental conditions at the San Pablo Bay disposal site. This is followed by a discussion of environmental parameters within the broader embayment that may be affected by dredged material disposal at the San Pablo Bay site.

Environmental Characteristics of the San Pablo Bay Disposal Site

The San Pablo Bay disposal site ("SF-10") is a 1,500-foot by 3,000-foot rectangle located 0.3 mile northeast of Point San Pedro in San Pablo Bay (see Figure 2.2-1 and 4.3-13). COE records indicate disposal quantities ranged from less than 1,000 cy to a high of nearly one mcy in 1987 (Figure 4.3-14). Use of this site is currently limited to small projects of 100,000 cy or less, no more than 50,000 cy in one month, and a total annual disposal volume limitation of 500,000 cy. Monthly information on disposal volumes at this site is presented in Figure 4.3-15. The estimated capacity is 0.5 mcy per year and disposal is limited to 50,000 cy per month. Like Alcatraz, the San Pablo Bay site is considered dispersive.

WATER QUALITY. Water quality within the site is affected by the disposal of dredged material. However, measurable differences in water quality parameters are only observed for a short time after the release of dredged material.

Table 4.3-7. Summary of Resources of Concern for the Alcatraz Dredged Material Disposal Site and Central Bay

Resource	***On Site***	***Embayment***
Water Quality		
Dissolved oxygen	X	
Ammonia	X	
Pollutant levels	X	
Toxicity	X	
Sediment		
Characteristics	X	X
Bathymetry/dynamics	X	X
Quality	X	X
Total Suspended Solids/Turbidity	X	X
Aquatic Resources		
Habitats		
Benthos	X	X
Eelgrass		X
Rocky shore/reefs		X
Migratory corridor		X
Fish/Shellfish		
Herring		X
Crab		X
Bottom fish	X	X
Special Status Species		
Chinook salmon		X

SALINITY. Salinity is much more variable at the San Pablo Bay site, and in San Pablo Bay in general, than in the Central Bay or at the Alcatraz site. Salinity levels at a nearby monitoring station varied from 6 ppt in March to 26 ppt in September 1993, depending on river flow (SFEI 1994).

Figure 4.3-13 San Pablo Bay Open Water Disposal Site SF-10

Figure 4.3-14 Annual Disposal Volumes at San Pablo Bay (1975-1994)

Figure 4.3-15 Monthly Disposal Volumes at San Pablo Bay (September 1993 — September 1994)

DISSOLVED OXYGEN. DO levels are generally high at this site. DO levels at a nearby monitoring station varied from 10 mg/l in March to 7 mg/l in September 1993. Short-term depressions in DO levels during disposal are expected to be similar to those found in waters immediately adjacent to the Carquinez Strait site (USACE 1976c). In that study, levels of DO near the Bay floor declined from 80 to 85 percent to 20 to 30 percent saturation within several minutes after material was released from the barge, but recovered to ambient levels within 10 minutes. Like the other in-Bay disposal sites, short-term changes in DO levels are expected to occur during disposal events at the San Pablo Bay site, but the overall effects would not be significant unless the frequency of disposal approached the amount of time it takes for DO levels to return to background after individual disposal events.

PH, UN-IONIZED AMMONIA AND POLLUTANTS. Water quality parameters measured in 1993 at a monitoring station near the San Pablo Bay site are summarized below in Table 4.3-8. The magnitude and extent of changes in pH, ammonia levels, and pollutant concentrations in the water column associated with dredged material disposal are not known for the San Pablo Bay site. Changes in these water quality parameters are expected to occur, but to be of short duration and primarily limited to the immediate vicinity of the disposal site except when associated with the near-bottom turbidity plume described below.

The primary factors controlling the bioavailability of contaminants will be the redox potential, pH, and salinity of water on-site. Oxygen levels in site water that are higher than in the disposed sediment would promote some oxidation of substances in disposed material, which would in turn promote the adsorption and desorption of chemical contaminants from particulates. The typically higher pH of San Pablo Bay waters compared to dredged material would also promote desorption of contaminants. However, higher salinity on occasion would serve to increase adsorption of contaminants onto particulates (U.S. Navy 1990).

Table 4.3-8. Dissolved Water Quality Parameters near the San Pablo Bay Disposal Site

Parameter	***Dissolved Concentrations***	
PH	7.6 - 7.8	
Ammonia	1.06 - 7.29	µM
Ag	1.34 - 4.76	ng/l
As	1.57 - 2.34	µg/l
Cd	29.23 - 91.63	ng/l
Cr	0.14 - 0.22	µg/l
Cu	1.3 - 2.54	µg/l
Hg	1.21 - 3.34	ng/l
Ni	1.35 - 3.73	µg/l
Pb	10.27 - 21.31	ng/l
Se	0.15 - 0.22	µg/l
Zn	0.41 - 0.78	µg/l
PAHs	2,783	pg/l
PCBs	171.78	pg/l
Pesticides	1,642	pg/l
Source: SFEI 1994.		

Although there have been no detailed studies conducted on changes in water quality parameters at the San Pablo Bay site, it is expected that changes would be similar to those measured within Central Bay (see discussion of Pollutants under section 4.3.1.2), except that the tendency of saline waters to increase adsorption of trace metals to particulates would be lower because salinities within this embayment are lower. The overall impacts of short-term increases of pollutant levels in the water column would depend on background concentrations, whether water quality objectives are exceeded, and the extent of the volume of water within which concentrations are elevated above ambient levels.

SEDIMENT CHARACTERISTICS. The characteristics of the natural sediment at the San Pablo Bay disposal site vary seasonally, ranging from pockets of sand, to a mixture dominated by silt and clay (roughly 60 percent) and sand. Dredged material disposal affects these natural characteristics. However, at recent disposal volumes, most dredged material effectively disperses from this site each year, and no significant mounding problem has been observed like that found at the Alcatraz disposal site.

SEDIMENT QUALITY. Table 4.3-9 summarizes bulk chemistry data for sediment from the San Pablo disposal site, obtained from several recent permit applications (MEC and ABT 1994; ABT 1994a; ToxScan 1993; MEC 1993a).

The average concentrations of pollutants observed in these San Pablo Bay disposal site samples are generally within ranges found throughout the main embayments in the Estuary. As in other areas, fine sediments at this site contain higher concentrations of pollutants (e.g., organotins, pesticides, and heavy metals) than coarser sediments. Average values across the four studies shown in Table 4.3-9 for arsenic, mercury, lead, nickel, and silver fell within the middle of background sediment quality levels reported throughout the Estuary. Average cadmium and chromium concentrations fell near the high end of the same distribution.

Table 4.3-9. Summary of Bulk Chemistry in Sediments at the San Pablo Disposal Site

Parameter	*Source (1) Fine*	*Source (2)*	*Source (3) Sand*	*Source (4)*
Grain Size (percent)				
Gravel	1.2	4.5	0.9	0.2
Sand	30.8	57.8	37.8	95.0
Silt	29.7	14.3	28.1	1.5
Clay	38.3	23.4	33.2	3.3
Total Organic Carbon (percent)	1.0	0.673	0.92	0.19
Solids (percent) (Dry wt.)	52	64.6	58.5	76
Organic Contaminants (μg/kg)				
Tributyltin	6	<1.5	<10	ND
Dibutyltin	8	<1.5	<10	ND
Monobutyltin	ND	<1.5	<10	ND
Oil and Grease (mg/kg)	140			
TRPH (mg/kg)	87	4.5	<50	ND
DDT and metabolites	50	ND	4	ND
Pesticides	ND	ND	ND	ND
total PCBs	ND	ND	ND	ND
total PAHs	ND	103.1	393	ND
total Phthalate Esters	ND	188.9	400	ND
Metals (mg/kg)				
Arsenic	10	7.12	8.5	5.7
Mercury	0.29	0.183	0.24	0.04
Selenium	0.2	0.443	<0.5	ND
Cadmium	0.23	0.15	0.2	0.06
Chromium	150	58.8	75.6	44.3
Copper	42	26.3	35.9	11.7
Lead	25	13.8	22.7	13.7
Nickel	66	56.3	70.6	63.6
Silver	0.2	<0.124	0.2	0.05
Zinc	100	67.2	93.4	53.9

Notes: All chemical concentrations are in dry weight unless noted.
Averages calculated assuming value was 1/2 of detection limit where reported.
Sources: (1) Pinole Shoal Maintenance Dredging Study from ToxScan (1993)
(2) San Rafael Rock Quarry Dredging Study from ABT (1994)
(3) Larkspur Ferry Terminal Dredging Study from MEC and ABT (1994)
(4) Bahia Lagoon Dredging Study from MEC (1993)

TOTAL SUSPENDED SOLIDS AND TURBIDITY. Turbidity levels at the San Pablo Bay disposal site vary considerably depending on season and are often much higher that TSS levels in the Central Bay. TSS concentrations measured at a nearby monitoring station in 1993 ranged from a low of 7.2 mg/l during a period of high riverine flow to a high of 190.7 mg/l during the summer months when wind-generated currents resuspend significant amounts of material in the embayment.

AQUATIC RESOURCES. The primary aquatic resources within the boundaries of the San Pablo Bay disposal site that could potentially be affected by dredged material disposal are those associated with the benthic community. Other resources such as phytoplankton, zooplankton, pelagic fish, and wildlife are more appropriately considered in the following section addressing the broader context of the embayment.

Environmental Characteristics of San Pablo Bay Outside the Disposal Site Potentially Affected by Dredged Material Disposal

WATER QUALITY. In general, water quality parameters such as pH, DO, ammonia, salinity, and pollutant levels are affected by disposal of dredged material, but these changes are only expected to be short-term and localized within a limited volume of water generally located within the boundaries of the disposal site. Water quality within San Pablo Bay is expected to only be marginally affected by disposal, presuming disposal events are much less frequent than the time it takes a disposal sediment plume to fully diffuse (less than 1.5 hours).

SEDIMENT CHARACTERISTICS. San Pablo Bay is a very shallow embayment where the substrate is predominantly Bay mud. This material is cut by channels, the deepest of which runs from the western edge of Carquinez Strait to the southern boundary of the embayment. The substrate in the main channel is predominantly sand, surrounded by a broader band of silt and clay extending northwest and southeast into the lower energy mudflat reaches. The character of the surficial sediments in the vicinity of the channel also varies according to season.

SEDIMENT DYNAMICS. Transport of suspended material in the shallow areas and channels of San Pablo Bay is governed by two different sets of factors. Within the channels, tidal currents and gravitational circulation dominate the movement of suspended material. In the shallow areas, wind-driven currents dominate material suspension and movement. Also, during periods of high riverine flow, fine-grained material is resuspended from Suisun Bay and deposited in San Pablo Bay. As flows decline, this material is gradually resuspended and transported away from San Pablo Bay (Nichols and Pamatmat 1988).

Sedimentation rates in San Pablo Bay have varied substantially over the years, largely due to the varying rate of water flow from the Delta. For example, as a direct result of gold mining in the Sierra foothills in the second half of the 1800s, approximately 300 million cy of debris was deposited in San Pablo Bay, filling the Bay by, on average, 1 meter. Sedimentation continued, but at a much slower rate, until the middle of this century. Beginning in 1951, the Bay lost sediment, possibly as a result of upstream flood control and water distribution projects that reduced peak flows (conditions when the most sediment is transported) which, in turn, decreased the sediment supply. Tidal mudflats grew due to the sedimentation, but they eroded with the reduced influx of debris. In the years that the Bay experienced a net loss in sedimentation, the mudflats eroded at a rate of approximately 90 acres per year. Therefore, the changes in sedimentation have directly affected the creation and erosion of tidal mudflats (USGS 1997).

SEDIMENT QUALITY. Representative sediment quality data from two years of monitoring at two sites in San Pablo Bay is presented in Table 4.3-10. Generally, contaminant concentrations in these sediments are similar to those observed at the San Pablo disposal site with the exception of zinc and total PAHs, which are frequently higher at the monitoring sites than at the disposal site.

Table 4.3-10. Summary of Bulk Chemistry in Sediments from Monitoring Stations in San Pablo Bay (1993-1994)

Parameter	***BD22***	***BD31***
Fines (percent)	30	66
Total Organic Carbon (percent)	1.2-1.3	1.3-1.9
Organic Contaminants (µg/kg)		
DDT and metabolites	0.9-2.6	2.0-5.3
Total Pesticides	2.8-3.2	5.0-5.8
total PCBs	7.1-9.9	18-26
total PAHs	3,100-7,461	646-1,080
Metals (mg/kg)		
Arsenic	10-19	10-20
Mercury	0.4	0.2-0.4
Selenium	0.1-0.9	0.2-0.9
Cadmium	0.2-0.3	0.3-0.4
Chromium	69-80	83-100
Copper	48-53	49-62
Lead	16-30	25-36
Nickel	67-92	80-110
Silver	0.2-0.3	0.3-0.5
Zinc	111-121	120-148

Note: * Data not reported due to QA problem.
Sources: SFEI 1994 and 1995

TOTAL SUSPENDED SOLIDS AND TURBIDITY. TSS levels in San Pablo Bay are naturally often greater than those of the Central Bay. Recent data on suspended solids taken off Point San Pablo indicate mean TSS concentrations of 90.9 mg/l near the bay floor (65.3 mg/l median; 31.5 mg/l lower quartile, 121 mg/l upper quartile) and 87.9 mg/l at 13 feet above the Bay floor (70.4 mg/l median; 37.4 mg/l lower quartile; 114 mg/l upper quartile) (Buchanan and Schoellhamer 1994).

BENTHOS. San Pablo Bay possesses an invertebrate fauna somewhat different from other regions of the Bay. The native Baltic clam (*Macoma balthica*) predominates in the intertidal mudflats of San Pablo Bay. Mollusks such as the soft shell clam *Mya arenaria* and *Gemma gemma* prefer the fine silt and clay bottoms of San Pablo Bay, but are sensitive to variations in salinity. The snail *Ilyanassa obsoleta*, a number of amphipods, and many polychaete worms that are found in other North American estuaries are also abundant. The Asian clam *Potamocorbula amurensis* has quickly become abundant in San Pablo Bay. As noted earlier, with the possible exception of *Macoma balthica*, all the species listed above were introduced.

Important crustacean species of San Pablo Bay include the Dungeness crab and several species of bay shrimp (*Crangon* spp.). These crustaceans are native species. Red rock crab (*Cancer productus*) and brown rock crab (*Cancer antennarius*) are found throughout San Pablo Bay during their entire life cycles, inhabiting rocky, nearshore habitats. Grass shrimp, California bay shrimp, blacktailed shrimp populations respond predominately to outflow and salinity (SFEP 1992a). During late winter to July, larval and post-larval stages of Franciscan bay shrimp are found in San Pablo Bay, while juveniles are most abundant from April to August.

EELGRASS HABITATS. Eelgrass (*Zostera*) beds are found only in the shallow areas in the southern portions of San Pablo Bay near Central Bay (where the substrate is mud or mixed mud and sand). The eelgrass grows in low-energy areas and serves to stabilize sediment, providing a substrate for epiphytes, producing organic matter, exporting detritus, and attracting crabs, shrimp, and skates. Eelgrass also provides forage, spawning, and nursery substrate for numerous species of fish. A 1987 aerial survey found a single bed of 50 ha directly north of Point San Pablo (Echeverria and Rutten 1989).

FISH AND SHELLFISH RESOURCES. The fish assemblage of San Pablo Bay varies seasonally as a result of reproductive cycles and the volume of freshwater inflow. The most abundant species in the embayment is the northern anchovy. The abundance of other marine fishes (e.g., white croaker, bay goby, jacksmelt, and the shiner perch) appears to be restricted to summer months, when salinities are highest in the extensive shallow areas in this embayment. Estuarine species include starry flounder, longfin smelt, staghorn sculpin, and the striped bass. Other species found in San Pablo Bay include the Pacific herring, yellowfin goby, and the English sole. Saltponds of San Pablo Bay support species such as topsmelt, yellowfin goby, threespine stickleback, and Pacific staghorn sculpin. (SFEP 1992a).

Because San Pablo Bay is located between the ocean and the San Joaquin and Sacramento rivers, it is used as a seasonal migration corridor for several species of anadromous fish such as the striped bass, chinook salmon, steelhead trout, American shad, and the white and green sturgeon. These species may utilize San Pablo Bay as seasonal habitat and/or a migration route during upstream spawning or downstream migrations of adults or juveniles. The abundances of many of the estuarine species that inhabit San Pablo Bay (striped bass, sturgeon, longfin smelt, starry flounder, and staghorn sculpin) have decreased substantially in recent years, apparently as a result of reduced freshwater inflow. This decrease in estuarine species has coincided with increases in some marine species, such as white croaker and queenfish.

The primary concerns regarding disposal of dredged material at the Carquinez or San Pablo Bay designated sites and aquatic species are related to migrating special status species and a sensitive life stage of Dungeness crabs.

WILDLIFE RESOURCES. Important shore- and waterbirds in San Pablo Bay include black-necked stilts, dowicher, dunlin, eared grebes, egrets, greater yellowlegs, lesser yellowlegs, herons, northern pintail, canvasback, scoters, scaups, long-billed curlew, American avocet, western and least sandpiper, killdeer, the marbled godwit, northern shovelers, red necked phalaropes, terns, and the western medowlark. Rocky shore habitat also supports the black turnstone, brown pelican, cormorants and western gulls.

Marine mammals of the open water and rocky shore habitat include the California sea lion and the harbor seal. The seal uses the mudflats to haul out during low tide.

SPECIES OF SPECIAL CONCERN. The species of special concern identified in San Pablo Bay include the chinook salmon, Sacramento splittail, coho salmon, longfin smelt, Dungeness crab, and recreational marine fishes. Generally, disposal could result in direct effects to chinook salmon adults and juveniles due to disruption of migration patterns and degradation of water quality. Coho salmon, if present, would also be susceptible to the same direct effects. Disposal may also degrade the habitat of marine recreational fishes in the area. However, these species are expected to be able to avoid effects from disposal operations provided that the disposal site is located in a broad water body and disposal events do not occur at high frequences over extended periods. Thus, disposal at the San Pablo Bay site is not expected to result in direct effects on these species of special concern.

Other special concern species that occur in San Pablo Bay include the peregrine falcon, brown pelican, western snowy plover, California clapper rail, California least tern, and salt marsh harvest mouse.

Existing Monitoring Programs

Existing monitoring programs of dredging and dredged material disposal that occur in the San Pablo Bay are discussed above in section 4.3.2.1.

Summary of Environmental Characteristics of San Pablo Bay Potentially Affected by Dredged Material Disposal

Table 4.3-11 summarizes the resources at the San Pablo Bay disposal site (SF-10) and within San Pablo Bay embayment that may be affected by dredged material disposal. The magnitude of potential impacts depends on the overall amount of material directed to San Pablo Bay over the course of the next 50 years and on the development and implementation of policies that will serve to limit adverse environmental effects of disposal.

4.3.2.3 Carquinez Strait

The narrow, 12-mile long Carquinez Strait joins San Pablo Bay with Suisun Bay. The Strait is characterized by primarily deep water habitat and a variable salinity regime resulting from fluctuations in fresh water flow from the Sacramento-San Joaquin river system. The mean depth of the Strait is 29 feet (SFEP 1992a). In periods of high Delta outflow, the most landward zone of gravitational circulation (the null zone) is located in the vicinity of Carquinez Strait. While San Pablo Bay is the deposition site for many of the fine-grained sediments carried out of the Delta, the deeper Carquinez Strait is characterized by strong currents and consequently most of the bottom is a sandy substrate.

Table 4.3-11. Summary of Resources of Concern at San Pablo Bay Dredged Material Disposal Site and San Pablo Bay

Resource	***On Site***	***Embayment***
Water Quality		
Dissolved oxygen	X	
Ammonia	X	
Pollutant levels	X	
Toxicity	X	
Sediment		
Characteristics	X	
Bathymetry/dynamics	X	
Quality	X	X
Total Suspended Solids/Turbidity	X	
Aquatic Resources		
Habitats		
Benthos	X	
Eelgrass		X
Migratory corridor		X

This section first describes the environmental conditions at the Carquinez disposal site itself, followed by a discussion of environmental parameters within the broader Strait that may be affected by dredged material disposal at the Carquinez site.

Environmental Characteristics of the Carquinez Strait Disposal Site

The Carquinez Strait disposal site (known as “SF-9”) is a 1,000-foot by 3,000-foot rectangle located 0.9 miles west of the entrance to Mare Island Strait in eastern San Pablo Bay (see Figure 2.2-1 and Figure 4.3-16). The bulk of the material disposed at this site has been dredged from the Mare Island Ship Channel. The COE and BCDC records indicate historic disposal quantities ranged from a low of approximately 200,000 cy in 1977 to a high of over 2.5 mcy in 1986 (Figure 4.3-17). The current disposal volume limitation on this site is 2 to 3 mcy/yr, depending on whether the year is a “normal or “wet” year, respectively. Monthly information on disposal volumes at this site is presented in Figure 4.3-18.

The Carquinez site acts as a disperal site for the dredged sediments disposed there. A large-scale tracer study was performed at the site in the mid-1970s to examine the fate of dredged materials. The results of this study showed that approximately 10 percent of iridium-tagged sediment disposed at the site recycled back into Mare Island Strait and the rest settled across a large portion of San Pablo and Suisun bays (USACE 1976b).

SALINITY. Salinity levels at the Carquinez Strait disposal site vary considerably according to season. Data from a nearby monitoring station at Davis Point show levels ranging from 8.43 to 19.98 ppt with higher salinities during periods of low riverine flow. There is also a significant salinity gradient with depth at this site that also varies by season. Sampling during 1993 showed the strongest gradient during periods of high riverine flow and low surficial salinities (levels increased from roughly 2 ppt to 25 ppt with increasing depth). The gradient was much less pronounced during periods of low riverine flow when salinities rnaged from approximately 12 ppt at the surface to 20 ppt near-bottom.

Disposal of sediment dredged from channels in the Estuary may cause short-term, localized changes in

Figure 4.3-16 Carquinez Strait Open Water Disposal Site SF-9

Figure 4.3-17 Annual Disposal Volumes at Carquinez (1975-1994)

Figure 4.3-18 Monthly Disposal Volumes at Carquinez (September 1993 — September 1994) salinity at the Carquinez disposal site, but these changes are expected to be marginal.

DISSOLVED OXYGEN. The disposal of dredged sediment has the potential to affect levels of dissolved oxygen at each disposal site, particularly in waters near the Bay floor. Short-term depressions in dissolved oxygen levels were measured in waters immediately adjacent to this site during disposal of material from the Mare Island Strait in 1973. Levels of dissolved oxygen near the Bay floor declined from 80-85 percent to 20-30 percent saturation within several minutes after material was released from the barge, but recovered to ambient levels within 10 minutes.

PH, UN-IONIZED AMMONIA, AND POLLUTANTS. Water quality parameters measured in 1993 at a monitoring station near to the Carquinez disposal site are summarized below in Table 4.3-12.

The magnitude and extent of changes in pH, ammonia levels, and pollutant concentrations, associated with dredged material disposal are not known for the Carquinez disposal site. Changes in these water quality parameters are expected to occur, but to be of short duration and primarily limited to the immediate vicinity of the disposal site. The primary factors controlling the bioavailability of contaminants will be the redox potential, pH, and salinity of water on-site.

Table 4.3-12. Dissolved Water Quality Parameters near the Carquinez Disposal Site

Parameter	***Concentrations***	
pH	7.7 - 8.0	
ammonia	2.43 - 6.89	µM
Ag	1.09 - 4.00	ng/l
As	1.48 - 2.41	µg/l
Cd	33.04 - 97.03	ng/l
Cr	0.14 - 0.36	µg/l
Cu	1.82 - 2.36	µg/l
Hg	0.82 - 2.45	ng/l
Ni	1.43 - 3.75	µg/l
Pb	8.49 - 62.88	ng/l
Se	0.14 - 0.27	µg/l
Zn	0.51 - 0.98	µg/l
PAHs	6,269	pg/l
PCBs	100	pg/l
Pesticides	3,684	pg/l
Source: SFEI 1994.		

Oxygen levels in site water that are higher than in the disposed sediment would promote oxidation of substances in disposed material, which would in turn, promote the adsorption and desorption of chemical contaminants from particulates.

SEDIMENT CHARACTERISTICS. Sediment characteristics at the Carquinez disposal site vary according to season and use, but are on average approximately 7 percent gravel, 44 percent sand, 21 percent silt, and 28 percent clay material.

SEDIMENT QUALITY. Contaminant levels measured at the site generally fall within ranges reported for sediment concentrations throughout the Estuary (see Table 4.3-13) (ABT 1994b, 1994c, 1995).

TOTAL SUSPENDED SOLIDS AND TURBIDITY. Levels of TSS at the site vary according to season and riverine outflow. Levels measured at a nearby monitoring station (near-surface) in 1993 ranged from 13.2 to 40.7 mg/l with increasing levels as riverine flows decreased. The COE has monitored turbidity plumes associated with disposal at the Carquinez Strait site. Turbidity was highest immediately after disposal in waters close to the bottom but returned to background levels after 10-25 minutes (USACE 1976c).

AQUATIC RESOURCES. The primary aquatic resources within the boundaries of the Carquinez disposal site that could potentially be affected by dredged material disposal are those associated with the benthic community. Other resources such as phytoplankton, zooplankton, pelagic fish, and wildlife are more appropriately considered in the context of the embayment.

BENTHOS. The most abundant species found in the vicinity of the Carquinez disposal site in soft sediments were amphipods *Ampelisca abdida* and *Grandidierlla japonica* and the clam *Mya arenaria*. In 1989, the soft-bottom benthic community had shifted to being dominated by the introduced Asian clam, *Potamocorbula amurensis* and the polychaete worm, *Tharyx* sp. Abundance of these two species typically increases during spring and summer recruitment periods (Chambers Group 1994).

The most abundant epiphaunal species found near the Carquinez disposal site (near the Unocal marine

Table 4.3-13. Physical and Chemical Parameters Measured in Sediments from the Carquinez Disposal Site

Parameter	***Source (1)***	***Source (2)***	***Source (3)***
Grain Size (percent)			
Gravel	4	1.8	7.9
Sand	42.2	56.3	69.9
Silt	22.1	18.9	6.9
Clay	31.7	23.0	15.3
Total Organic Carbon (percent)	0.94	0.5	0.495
Solids (percent) (Dry wt.)	50.1	63.6	59.4
Organic Contaminants (μg/kg)			
Tributyltin	<2.0	<1.6	<1.7
Dibutyltin	<2.0	<1.6	<1.7
Monobutyltin	<2.0	<1.6	<1.7
TRPH (mg/kg)	33.1	10.1	98.5
DDT and metabolites	ND	ND	ND
Pesticides	ND	ND	ND
total PCBs	ND	ND	ND
total PAHs	ND	ND	569.6
total Phthalate Esters	180.5	ND	961
Metals (mg/kg)			
Arsenic	8.58	10.3	6.06
Mercury	0.303	0.162	0.343
Selenium	<1.99	<0.78	<0.84
Cadmium	<0.31	0.212	0.215
Chromium	70.7	67.6	51.9
Copper	46.3	34.9	35.0
Lead	19.2	39.9	12.1
Nickel	77.0	70.1	64.0
Silver	0.798	<0.06	<0.14
Zinc	103	81.8	75.1

Notes: All chemical concentrations are in dry weight unless noted.
Sources: (1) ABT 1994b (Benicia Industries).
(2) ABT 1995 (Exxon Loading terminal study).
(3) ABT 1994c (Wickland Oil study).

terminal) were cranganid shrimp, commonly known as bay or grass shrimp. Dungeness crab was also abundant throughout the sampling area, accounting for nearly 8 percent of the crustacean catch in 1989. The same sample also included several rock crabs such as *Cancer productus and C. antennarius* (Keegan et al. 1989).

The coarse shifting sand at the edge of the J.F. Baldwin ship channel contained only a few individuals of two amphipod species, *Ampelisca abdida* and *Sinelobus sanfordi*, both of which are adapted to invading disturbed areas and persisting in stressful environments (Chambers Group 1994).

Environmental Characteristics of Carquinez Strait Outside the Disposal Site Potentially Affected by Material Disposal

The Carquinez Strait disposal site is characteristically highly dispersive; disposed material has been shown to disperse rapidly into a widespread area both upsteam and downstream of the site (Sustar 1982). The environmental resources in both San Pablo and Suisun bays therefore have the potential to be affected by dispersed sediment from the Carquinez site (see sections 4.3.2.2 and 4.3.2.4). This section focuses on environmental resources potentially affected within the Carquinez Strait.

WATER QUALITY. In general, water quality parameters such as pH, DO, ammonia, salinity, and pollutant levels are affected by disposal of dredged material, but these changes are only expected to be short-term and localized within a limited mixing zone. That zone is generally located within the disposal site. Water quality within the Carquinez Strait is expected to only be marginally affected by disposal, presuming disposal events are much less frequent than the time it takes the plume to diffuse.

SEDIMENT CHARACTERISTICS. Carquinez Strait is a narrow channel that is scoured by strong tidal currents and riverine flows. The sediment is predominantly rock and sand with fine silt and clay forming classic Bay mud in the lower energy areas off the main channel (such as Southhampton Bay). The deep channel shoreline is characterized by rocky shores and developed waterfront areas, consisting of intertidal riprap, gravel beaches, and subtidal fine sand (ENTRIX 1991; Robilliard et al. 1989).

SEDIMENT DYNAMICS. Sediment dynamics within the Strait are dominated by riverine outflow and gravitational circulation. Sediment transported through the Strait appears to enter the overall sediment cycle in the Bay, and can ultimately distribute widely throughout the Estuary. See Chapter 3 (section 3.2.2 and Figure 3.2-3) for a more detailed discussion of general patterns of sediment movement in the Bay.

SEDIMENT QUALITY. Representative sediment quality data from two years of monitoring at one site at the edge of Carquinez Strait as well as data from stations associated with recent COE studies are presented in Table 4.3-14. Generally, contaminant concentrations in overall Carquinez Strait sediments are similar to, if

Table 4.3-14. Sediment Quality in Carquinez Strait

Parameter	***Source (1)***	***Source (2)***	***Source (3)***
Grain Size (percent)			
Gravel	2-3	NR	0-4
Sand	73-81	NR	4-94
Silt	6-9	NR	3-51
Clay	10-17	NR	3-52
Total Organic Carbon (percent)	0.2-0.5	NR	0.4-2.2
Organic Contaminants (µg/kg)			
Tributyltin	NA	NR	0.6-29
Dibutyltin	NA	NR	1-12
Monobutyltin	NA	NR	0.7-4
Oil and Grease (mg/kg)		NR	9-111
TRPH (mg/kg)		NR	12-62
DDT and metabolites	0.7-1.2	23	ND
Pesticides	0.7-1.6	NR	ND
total PCBs	1.2-4.4	29	ND
total PAHs	116-389	1,100	26-392
Metals (mg/kg)			
Arsenic	5.7-7.4	NR	8.4-21
Mercury	0.1-0.2	0.13	0.06-0.45
Selenium	0.1-0.7	--	0.8-1.0
Cadmium	0.1	0.5	0.1-0.6
Chromium	67-81	193	164-269
Copper	18-29	63	17-67
Lead	13-16	23	10-34
Nickel	62-74	--	81-120
Silver	0.05-0.1	0.2	0.03-0.3
Zinc	73-87	--	71-147

Notes: * Grain size data expressed as percent fines.
NA = not analyzed
NR = not reported

Sources: (1) Davis Point (BD40 and BD41) from SFEI (1994 and 1995)
(2) Sample Point from Long et al. (1988)
(3) Range of Carquinez Strait samples from Word and Kohn (1990)

not occasionally higher than, those observed in the vicinity of the disposal site (Word and Kohn 1990).

TOTAL SUSPENDED SOLIDS AND TURBIDITY (TSS). Levels of TSS in the Carquinez Strait vary according to season and riverine outflow. TSS concentrations measured at the surface at the western edge of the trait ranged from 13.2 to 40.7 mg/l while levels at the eastern edge of the Strait varied from 81.8 to 45.9 mg/l over the same time period. In special studies of disposal at Carquinez Strait site, the COE collected samples at four down-current stations prior to disposal. Maximum concentrations of suspended solids at these stations were up to 100 times higher in waters close to the bottom than in near-surface water. Elevated suspended solids concentrations were measured as far as 1,400 m down-current from the disposal site, but only lasted approximately 10 minutes (USACE 1976b).

BENTHOS. The benthic community in the main channel of the Strait is characterized by low diversity, dominated by opportunistic species such as the amphipods, *Ampelisca abdida* and *Sinelobus sanfordi*. Salinity of the area west of Carquinez Strait rarely falls below 5 ppt and the benthic community there is therefore dominated by salt-tolerant species and is more diverse than the benthic community of the eastern Strait and Suisun Bay. While Dungeness crab are primary found in the shallower areas of central and San Pablo Bay, they can are also found upstream depending on waterflows (Tasto 1983).

FISH AND SHELLFISH RESOURCES. Carquinez Strait is an important migratory corridor for many pelagic fish species. Striped bass, chinook salmon, American shad, Pacific herring, northern anchovy, white sturgeon and longfin smelt migrate through the area surrounding the vicinity of the Carquinez disposal site during one or more life stages. The starry flounder is a resident in the Carquinez Strait.

WILDLIFE RESOURCES. Shorebirds in Carquinez Strait include dunlin, northern pintail, canvasback, scoters, scaups, long billed curlew, American avocet, western and least sandpiper, killdeer, and the marbled godwit. The Carquinez Strait also supports the black turnstone, brown pelican, cormorants and western gulls.

SPECIES OF SPECIAL CONCERN. Resource agencies have identified the chinook salmon, delta smelt, longfin smelt, and Pacific herring as species of special concern along Carquinez Strait. Chinook salmon pass through Carquinez Strait on their migratory route. Both adults and juveniles may be directly affected by disposal at the Carquinez disposal site through interference with migration and the degradation of water quality. Juveniles may be affected by suspended sediment associated with the disposal of sediments interfering with their ability to forage in the Strait. Delta smelt primarily inhabit the shallow brackish sloughs and marshes of the Delta and Suisun Bay, but also occur downstream in the Carquinez Strait and elsewhere in the estuary, including the Napa River, where salinities are reduced by freshwater inflow. Longfin smelt are widely distributed in the northern part of the estuary from San Pablo Bay through the Carquinez Strait to Suisun Bay and the Delta. In addition, adult steelhead congregating at the mouth of the Napa River before high flow periods may also be affected by disposal at the Carquinez site.

Other special concern species that occur along the Carquinez Strait include brown pelican, California clapper rail, California least tern (which has nested at Port Chicago), and salt marsh harvest mouse.

Existing Monitoring Programs

Existing monitoring programs of dredging and dredged material disposal that occur in the Carquinez Strait are discussed above in section 4.3.2.1.

Summary of Environmental Characteristics of Carquinez Strait Potentially Affected by Dredged Material Disposal

Table 4.3-15 summarizes the resources within the Carquinez Strait that may be affected by dredged material disposal at SF-9 or other dispersive sites within or near this water body. The magnitude of potential impacts depends on the overall amount of material directed to SF-9 over the course of the next 50 years and on the development and implementation of policies that will serve to limit adverse environmental effects of disposal.

Table 4.3-15. Summary of Resources of Concern at Carquinez Strait Dredged Material Disposal Site and Carquinez Strait

Resource	***On Site***	***Embayment***
Water Quality		
Dissolved oxygen	X	
Ammonia	X	
Pollutant levels	X	
Toxicity	X	
Sediment		
Characteristics	X	
Bathymetry/dynamics	X	X
Quality	X	X
Total Suspended Solids/Turbidity	X	
Aquatic Resources		
Habitats		
Benthos	X	
Migratory corridor	X	X
Fish		
Steelhead		X
Special Status Species		
Chinook salmon		X

4.3.2.4 Suisun Bay

Suisun Bay is a shallow embayment between Chipps Island, at the western boundary of the Delta, and the Benicia-Martinez Bridge. Adjacent to this embayment is Suisun Marsh, the largest brackish marsh in the United States. Suisun Bay covers approximately 36 square miles, has a mean depth of 14 feet, and a mean salinity of approximately 7 ppt. Fresh water flowing from the Delta usually meets salt water from the ocean in the vicinity of Suisun Bay. Under moderate Delta outflow conditions, the location of the null zone is at the upstream end of Suisun Bay. The bottom of this embayment is primarily comprised of mud. During high flows, these fine sediments are deposited to San Pablo Bay. Under low-flow conditions, fine materials are deposited in Suisun Bay.

This section first describes the environmental conditions at the Suisun Bay disposal site. This is followed by a discussion of environmental parameters within the broader Suisun Bay embayment that may be affected by dredged material disposal at the Suisun Bay site.

Environmental Characteristics of the Suisun Bay Disposal Site

The Suisun Bay disposal site (known as “SF-8”) is a 500-foot by 11,200-foot rectangle located along the northern side of the Suisun Bay Channel (see Figure 2.2-1 and Figure 4.3-19). This site is currently limited to federal project use for materials that are at least 95 percent sand from the COE maintenance dredging of the Suisun Bay Channel. The COE and BCDC records indicate recent disposal quantities ranged from a low of 33,000 cy in 1992 and 1993 to a high of 125,000 cy in 1990. The site was not used in 1989 or 1991. Monthly information on disposal volumes at this site is presented in Figure 4.3-20. The current disposal volume limitation at the Suisun Site is 0.2 mcy/yr.

WATER QUALITY. The water quality characteristics at this disposal site resulting from the disposal of primarily sandy material are not expected to be significantly different than the immediate area. Studies conducted on the discharges from sand mining operations in Central Bay (MEC 1993b) demonstrated that unfiltered effluent from sand mining at Presidio Shoals and Point Knox had LC_{50} values of 60 percent and 34 percent unfiltered effluent while filtered effluent caused no toxicity. Chemical analysis of overboard effluent showed fairly high levels of particulate-bound metals within the plume and some changes in the gradient of metal concentrations with depth. While water quality at the Suisun Bay site has the potential to be affected by disposal of dredged sandy material, the effects are expected to be short term and limited to the site under the scenarios being considered under this programmatic EIS/EIR.

SEDIMENT COMPOSITION AND QUALITY. At the present time, the restrictions on use of this site to sandy material effectively prevent modification of the native sediment. Significant changes in sediment characteristics, dynamics, and quality are not expected with continued use of this site. Sediment chemistry (aside from grainsize analysis) is not available for the Suisun Bay disposal site. Past testing has demonstrated consistently low levels of contaminants in highly sandy sediments, eliminating the need for extensive chemical characterization of sediments from this disposal site.

TOTAL SUSPENDED SOLIDS AND TURBIDITY. As with the other designated disposal sites, it is expected that turbidity levels at the site will increase for a short period of time after release of dredged material and the greatest increase will occur in waters near the bay floor.

AQUATIC RESOURCES. The primary aquatic resources within the boundaries of the Suisun Bay disposal site

Figure 4.3-19 Suisun Bay Open Water Disposal Site SF-8

Figure 4.3-20 Monthly Disposal Volumes at Suisun Bay (September 1993 — September 1994) that could potentially be affected by dredged material disposal are those associated with the benthic community. This and other resources such as phytoplankton, zooplankton, pelagic fish, and wildlife are considered in the context of the embayment.

Environmental Characteristics of Suisun Bay Outside the Disposal Site Potentially Affected By Dredged Material Disposal

WATER QUALITY. In general, water quality parameters such as pH, DO, ammonia, salinity, and pollutant levels are affected by disposal of dredged material, but these changes are only expected to be short-term and localized within a limited volume of water generally located within the disposal site. Water quality within Suisun Bay is expected to be marginally affected by disposal, assuming disposal events are spaced to allow each plume to diffuse prior to beginning another event.

SEDIMENT CHARACTERISTICS. Suisun Bay is a shallow, brackish water embayment with a floor that is predominantly fine silt and clay, crossed by channels scoured by tidal and riverine flows. The surficial sediments around these channels change according to season. High riverine flows winnow the fine sediment of Suisun Bay and transport it downstream into San Pablo Bay. As a result, the ercentage of surficial sediments that are coarse-grained material in this embayment increases from roughly 5-10 percent to roughly 35 percent. As riverine flows decrease, silt again is deposited in Suisun Bay and the surficial sediments again become fine silt and clay (Nichols and Pamatmat 1988).

SEDIMENT DYNAMICS. Suspended sediment dynamics in Suisun Bay is governed by a complex series of factors. Riverine flows move suspended sediment westward and during high flow periods scour the substrate. Eastward flow of saline waters near the bottom of the Bay move descending particles back upstream. Continued disposal of sand material dredged from the main channel is not expected to affect either the sediment characteristics in Suisun Bay or the sediment dynamic patterns within the embayment.

SEDIMENT QUALITY. Representative physical and chemical data for various monitoring and dredging sites in Suisun Bay (both coarse and fine material) are presented below in Table 4.3-16. With the exception of chromium and nickel, contaminant concentrations in the finer sediments of Grizzly and Honker Bays is higher than in the sandy sediments of the navigation channel (Kohn et al. 1994).

PHYTOPLANKTON AND ZOOPLANKTON. Historically, the opossum shrimp have been abundant in the Suisun Bay; however, populations appear to have been impacted by altered flow and salinity conditions. *Acartia* is the most abundant copepod species in Suisun Bay. Generally, copepod and rotifer populations have drastically declined in this embayment, although water flea populations appear to be healthy (SFEP 1992a).

BENTHOS. Common benthic species in this area are those that are well-adapted to changing salinities. The asian clam, *Potamocorbula*, has reached its highest population densities in Suisun Bay and has caused significant changes in the structure of the benthic community. The situation appears not to have stabilized, and currently it is difficult to determine the nature of the benthic community in this body of water. Other common species include the following: the mollusks, *Macoma balthica*, *Mya arenaria*, and occasionally *Corbicula fluminea* when river flows are high; the amphipods, *Nereis succinea*, *Limnodrilus hoffmeisteri*, and occasionally *Ampelisca abdita*; and the polychaete, *Streblospio benedicti* that migrates upstream from more saline waters during periods of unusually low riverine flow (Nichols and Pamatmat 1988).

FISH AND SHELLFISH RESOURCES. The fish assemblage of Suisun Bay is markedly different from San Pablo Bay as a result of decreased salinity and different habitat structure. Changing salinity levels resulting from changes in freshwater outflow may alter the fish assemblage due to the differing salinity tolerance of the various species (Meng, Moyle and Herbold 1994). Typically, reduced salinity results in a decrease in the abundance and diversity of marine species such as northern anchovy, Pacific herring, white croaker, and jacksmelt which comprise a substantial portion of the fish assemblage. Species characteristic of Suisun Bay are striped bass, longfin smelt, yellowfin and chameleon goby and the northern anchovy. The abundance of many species have declined in recent years, including the striped bass, American shad, longfin smelt, delta smelt and starry flounder. Declines and changes in fish assemblages have been attributed to reduced Delta outflow and other anthropogenic impacts (Meng and Kanim 1994).

Table 4.3-16. Sediment Quality in Suisun Bay

Parameters	***Source (1) fine***	***Source (2) fine***	***Source (3) coarse***
Grain Size (percent)			
Gravel	0	0	0-1
Sand	1-2	1-3	80-97
Silt	31-36	28-31	0-12
Clay	62-68	66-72	2-8
Total Organic Carbon (percent)	1.4-1.5	1.6	0.11-0.3
Organic Contaminants (μg/kg)			
Tributyltin	NA	NA	ND
Dibutyltin	NA	NA	ND
Monobutyltin	NA	NA	ND
TRPH (mg/kg)	NA	NA	0-14
DDT and metabolites	3.9-10.4	4.4-7.0	ND
Pesticides	4-14	4-9	ND
total PCBs	8.1-17.8	8.0-13.0	ND
total PAHs	545-3,089	441-1,825	4-47
Metals (mg/kg)			
Arsenic	12.1-20.6	11.1-13.7	6.2-8.8
Mercury	0.2-0.4	0.3-0.4	0.01-0.03
Selenium	0.2-3.3	0.3-1.0	0.1-0.2
Cadmium	0.3	0.3-0.4	0.1
Chromium	70-105	107-125	230-334
Copper	52-67	68-72	17-29
Lead	20-27	23-24	7-12
Nickel	85-115	113-124	83-106
Silver	0.3	0.3-0.4	0.3-0.4
Zinc	124-151	131-164	72-77

Notes: * Grain size data expressed as percent fines.
** Data not reported due to QA problem.
NA Not analyzed
ND Not Detected
Sources: (1) Grizzly Bay (BF21) from SFEI (1994 and 1995)
(2) Honker Bay (BF40) from SFEI (1995)
(3) Sandy stations in Bulls Head Channel from Kohn et al. (1994)

Important crustacean species of Suisun Bay include two species of bay shrimp. California bay shrimp prefer the lower salinities that are common to Suisun Bay and blacktail shrimp are common and important food for striped bass, American shad, sturgeon and white catfish. Abundant and particular to Suisun Bay is the introduced shrimp *Palaemon macrodactylus* (SFEP 1992a); Nichols and Pamatmat 1988). Dungeness crab enter Suisun Bay when salinities are greater than about 10 ppt.

WILDLIFE RESOURCES. Birds common on the Suisun Bay are the wading birds, the great blue heron, great egret, snowy egret, American coot and Virginia rail. Migratory water fowl are the northern pintail, mallard, American widgeon, northern shovelers, Canada geese and cinnamon teal. The western sandpiper, dunlin, and long-billed dowitcher are abundant during spring migration. Marine mammals are generally not found in Suisun Bay.

SPECIES OF SPECIAL CONCERN. The species of special concern identified in Suisun Bay include the winter-run chinook salmon, delta smelt, Sacramento splittail, and the longfin smelt. Disposal in Suisun Bay is not expected to affect most migrating fish species because the site can be easily avoided. Species found in shallow channels are not expected to be affected because water quality changes are limited to an area immediately adjacent to the disposal site. Longfin smelt larvae cannot easily avoid specific areas such as the disposal site, and therefore may be affected by short-term changes in water quality on site and in the deeper channels.

Other special concern species that occur in Suisun Bay include brown pelican, California clapper rail, California least tern, and salt marsh harvest mouse.

Summary of Environmental Characteristics of Suisun Bay Potentially Affected by Dredged Material Disposal

Table 4.3-17 summarizes the resources within Suisun Bay that may reasonably be affected by dredged material disposal at the Suisun Bay disposal site, SF-9 or other dispersive sites within or near this water body segment. The magnitude of potential impacts depends on the overall amount of material directed to the Suisun Bay disposal site or to other nearby dispersive sites over the course of the next 50 years, and on the development and implementation of policies that will limit the adverse environmental effects of disposal.

Table 4.3-17. Summary of Resources of Concern for Suisun Bay Dredged Material Disposal Site and Suisun Bay

Resource	***On Site***	***Embayment***
Water Quality		
Dissolved oxygen	X	
Ammonia	X	
Pollutant levels	X	
Toxicity	X	
Sediment		
Characteristics		
Bathymetry/dynamics		
Quality	X	X
Total Suspended Solids/Turbidity	X	X
Aquatic Resources		
Habitats		
Benthos	X	
Fish		
Longfin smelt	X	X

4.3.2.5 South Bay

South San Francisco Bay includes all Bay waters south of the Oakland-San Francisco Bay bridge. The largest of the embayments, the South Bay covers 214 square miles and has a mean depth of 11 feet (SFEP 1992b). Salinites remain at near-ocean concentrations during much of the year although flushing of South Bay waters occurs during periods of high riverine flow. Consequently, the aquatic resources of the area are adapted to saline conditions.

The extreme southern edge of the South Bay south of the Dumbarton Bridge has historically been an area where water quality and associated beneficial uses have been impacted by sewage treatment facilities and industrial sources. Thus, while nutrient concentrations in other parts of the estuary vary seasonally, levels in the South Bay are relatively constant, being primarily a result of imputs from sewage treatment plants.

Material dredged from the ship channels and port facilities around the margin of the South Bay was historically disposed at many sites around the embayment. In 1972, the COE proposed using two sites, one off Hunter’s Point and one just off the San Mateo Bridge, for material disposal. In 1975, however, these sites were de-designated because monitoring information showed they were not dispersive and thus had a very limited capacity. Since that time, there has been no disposal of dredged material from the projects described in this analysis within this embayment. Material from South Bay dredging projects is instead taken to Alcatraz or upland disposal sites.

Currently, there are no plans to designate any multi-user disposal sites within the South Bay. Although the COE has included a generic consideration of the “Bay Farm Borrow Pit” site as a location for a potential confined aquatic disposal (CAD) site for NUAD material in several recent EIS documents — Oakland Harbor SEIR/S (USACE and Port of Oakland 1994), Richmond Harbor SEIS/EIR (USACE and Port of Richmond 1995), and the John F. Baldwin Ship Channel (USACE and Contra Costa County 1995) — no formal proposal has yet been made to designate this site. Any proposal to designate a new site would require a complete, site-specific environmental review (see section 5.1.3.3).

The following section describes the resources of the South Bay that could potentially be affected by designation of a new site and/or by material transported from a Central Bay disposal site(s). However, it is important to emphasize that this programmatic EIS/EIR does not propose or anticipate the designation of a new South Bay site.

On-Site Environmental Impacts that Should Be Addressed in the Event a South Bay Disposal Site is Considered

The following discussion is based on a hypothetical unconfined South Bay site located within the main embayment at a site where the currents are the strongest within this portion of the Estuary. The on-site impacts of unconfined diposal at shallower sites and/or those sites located in lower energy areas would generally be greater.

WATER QUALITY. The water quality characteristics within a South Bay site that would be potentially affected by dredged material disposal are the same as those affected by disposal at existing in-Bay sites. These impacts include short-term depressions in DO and changes in the DO depth gradient on site; short-term changes in pH, ammonia, and salinity within the plume; and associated changes in gradients of these parameters in ambient waters. In general, water quality characteristics within 1 to 2 meters of the Bay floor are most likely to be affected.

SEDIMENT. The disposal of dredged material at a hypothetical new South Bay site could significantly alter sediment charactertistics, particularly if the site were located in a region of shellfish beds or in a location characterized by coarser material such as found in the main navigation channels.

TOTAL SUSPENDED SOLIDS AND TURBIDITY. As was the case at the other designated disposal sites, turbidity levels in waters at a hypothetical South Bay site would be affected by dredged material disposal. Impacts would include short-term increases in turbidity, particularly in water near the bay floor. The rate with which this turbidity plume would dissipate would depend largely on current strength and the composition of the material disposed.

AQUATIC RESOURCES. The aquatic benthic resources would be most affected by the designation of a hypothetical South Bay disposal site. Disposal of material would bury benthic organisms. This impact is unavoidable and would likely result in colonization of the site by opportunistic species, thereby marking a significant change to the community composition.

Environmental Characteristics of South Bay Potentially Affected by Dredged Material Disposal

WATER QUALITY. Short-term increases in metal levels (particularly cadmium, copper, nickel, and lead) associated with the increase in suspended particulate material near the Bay bottom are also likely. Of particular concern within the South Bay are water column concentrations of copper and nickel. Ambient concentrations of these two metals have historically exceeded water quality critieria. Although discharge of these metals is gradually being reduced by the implementation of widespread point and nonpoint source control measures, past discharges have resulted in sediments acting as both a sink and source for these metals to the overlying water. Thus, even small increases in copper and nickel concentrations associated with dredged material disposal in an already affected system could potentially cause adverse effects in the water column. In contrast, similar discharges in other areas of the Estuary would be expected to have a less of an impact on water quality due to lower ambient concentrations of these metals.

TOTAL SUSPENDED SOLIDS AND TURBIDITY. Recent data on TSS concentrations in the waters of the South Bay is available for three monitoring stations: one located on the San Mateo Bridge on the eastern edge of the ship channel; one at Pier 23 off the Dumbarton Bridge; and one at Coast Guard Channel marker 17 in the central portion of the embayment south of the Dumbarton Bridge. Suspended solids levels were highest in the southernmost end of the embayment and varied from 52.8 mg/l to 153 mg/l at mid-depth and 67.1 to 197 mg/l at near-bottom. Average concentrations decreased northward, moving closer to the marine-influenced Central Bay. At a site at the boundary between Central and South bays (the Bay Bridge), the average suspended solid concentration was 36 mg/l near the bottom and 29 mg/l at mid-depth (Buchanan and Schoellhamer 1994).

SEDIMENT CHARACTERISTICS AND DYNAMICS. Sediment grain size in the northern part of the South Bay averages around 60-70 percent silt and clay, with higher concentrations of coarser sediments observable in early summer (Nichols and Pamatmat 1988). One distinguishing feature of sediments in the South Bay are the high concentration of shell fragments and remnants of shellfish beds found in mud along the eastern margin of the embayment. Sediment in the South Bay is resuspended two to five times before final burial, with the highest resuspension rates occurring during summer when wind-generated currents move across the embayment.

SEDIMENT QUALITY. Representative physical and chemical data from 1993-94 for three monitoring stations in the South Bay are presented below in Table 4.3-18.

Table 4.3-18. Sediment Quality in the South Bay

Parameters	*Oyster Point*	*Dumbarton Bridge*	*Extreme South Bay*
Grain Size			
Percent fines	34-36	74-77	72-76
Total Organic Carbon (percent)	0.7-1.4	0.7-1.4	0.8-1.5
Organic Contaminants (μg/kg)			
DDT and metabolites	1-3	2-6	2-3
Pesticides	2-7	2-9	4-12
total PCBs	9.9-24.8	2.6-36.5	16.7-32.4
total PAHs	1,407-4,022	2,095-4,232	1,707-7,632
Metals (mg/kg)			
Arsenic	9.7-14.2	9.7-13.1	9.8-12
Mercury	0.2-0.3	0.3-0.5	0.3-0.5
Selenium	0.3-0.7	0.2-0.5	0.3-1.3
Cadmium	0.05-0.3	0.04-0.2	0.04-0.2
Chromium	57-91	65-99	78-99
Copper	29-38	32-46	40-54
Lead	14-22	15-35	23-41
Nickel	60-86	48-103	70-100
Silver	0.3-0.5	0.3-0.5	0.4-0.6
Zinc	85-101	91-137	118-144

Notes: ** Data not reported due to QA problem.
Source: SFEI (1994 and 1995)

PHYTOPLANKTON AND ZOOPLANKTON. Phytoplankton productivity in the South Bay is high, contributing a significant amount of organic carbon to the Bay food chain. Productivity tends to increase with annual Delta discharges as higher outflows promotes stratification. Stratification then leads to higher growth rates and lower losses to suspension-feeding benthic macroinvertebrates. Conversely, decreased outflow from the Delta depresses phytoplankton productivity in the SF Bay. (SFEP 1992a). *Synchaeta* is the most common rotifer in the South Bay. Generally, rotifers are abundant in areas where there are high levels of chlorophyll *a*. Abundances of two copepod species, *Acartia californicus* and *Acartia calussi* vary seasonally (SFEP 1992a).

BENTHOS. Most of the South Bay is characterized by shallow water habitat. South Bay substrates are predominantly either soft mud or masses of shell fragments remaining from a previous commercial oyster industry. Shallow soft sediments are dominated by the large tube dwelling polychaete *Asychis elongata*. Other species present include large numbers of small clams (*Gemma gemma* and *Potamocorbula amurensis*), a tube-dwelling amphipod (*Ampelisca abdita)*, and the polychaete *Streblospio benedicti*. The molluscs *Mya arenaria* and *Macoma balthica* and the omnivorous mudsnail *Ilyanassa obsoleta* also are common on soft sediments. Shell deposits and areas with boulders, broken concrete, and cobbles, found particularly along the eastern and western margins of central South Bay, provide habitat for limpets (*Crepidula* spp.), predatory snails (*Urosalpinx cinerea*), ascidians (*Mogula manhattensis*), and molluscs (*Musculista* and *Tapes japonica*) (Nichols and Pamatmat 1988).

Several different kinds of crustaceans are found in the South Bay including Bay shrimp (*Crangon nigricauda* and *C. nigromaculata*) and brine shrimp, *Artemia salina*. The recently introduced green crab (*Carcinus maenas)* has also been observed in the South Bay.

Of the species listed above, only *Macoma balthica* may be native. The recently introduced Asian clam (*Potamocorbula amurensi)s* and green crab (*Carcinus maenas)* are changing the benthic community through their activities, as previously did other invasive species. The effects of *Potamocorbula* appear to be related to rapid population growth and its ability to filter large volumes of water as it feeds on suspended particles that include not only large numbers of phytoplankton, but the larvae of other invertebrates. *Potamocorbula* are tolerate salinities ranging from 1 to 33ppt (SFEP 1992a).

FISH. Northern anchovy, Pacific herring, shiner perch, jacksmelt and topsmelt dominate the species in the South Bay, however abundance is variable. The fishes of the South Bay are characteristic of a lagoon-type estuary where the salinity ranges are small. One area in the South Bay provides one of the few Pacific herring spawning sites in the Bay (LTMS 1994b). Longfin smelt, bat rays, walleye surfperch, brown smoothhound, and adult white croaker are also common in the South Bay.

Seasonal migration of marine fishes such as chinook salmon and American shad alter the composition of species in the South Bay. Bay gobies are often found in the South Bay on a seasonal basis (SFEP 1992a). Speckled sand dab, English sole, and staghorn sculpin vary in abundance. Fishes characteristic of shallow waters are less predictable in abundance than those found in the channels. In recent years, the species composition and overall fish abundance have remained fairly consistent except for an increase in the abundance of white croaker and plain midshipman that may be attributable to increased salinities.

WILDLIFE. The South Bay provides habitat for 60 percent of the shorebirds in San Francisco Bay (SFEP 1992b). Common birds in the South Bay include the western meadowlark, western sandpiper, and killdeer, dowitcher, and northern shoveler, white pelicans during their winter migration, and colonial waterbirds such as herons, terns, gulls, egrets and cormorants. Also found in the South Bay are scaups, scoters, northern shovelers, eared grebes, terns, red necked phalaropes, black-necked stilts, greater yellowlegs, lesser yellowlegs, and American avocets.

Harbor seals and the California sea lions haul out on the mudflats and intertidal salt marshes of the South Bay. Raccoons and striped skunks can be found in the mudflats areas. Red fox have also been observed in the South Bay.

SPECIES OF SPECIAL CONCERN. Species of special concern in the South Bay include the brown pelican, American peregrine falcon, California clapper rail, California least tern, western snowy plover, and salt marsh harvest mouse. Nesting colonies of the California least tern have been established at Alameda Naval Air station and the Oakland Airport. Federal species of concern in the South Bay are the Alameda song sparrow and the saltmarsh common yellowthroat. The San Francisco-Oakland Bay Bridge is an important nesting site to the double crested cormorants who are listed under CDFG species of special concern (SFEP 1992a). Alameda Naval Air Station provides a major roost for the endangered California brown pelicans.

The salt marsh wandering shrew, another federal species of concern, is limited to an small area in the southern part of the Bay. The endangered salt marsh harvest mouse also lives in the South Bay. Two varieties of bats that are species of concern (not endangered) and found in this area are the Pacific western big-eared bat and the greater western mastiff bat.

Summary of Environmental Characteristics of the South Bay Potentially Affected by Dredged Material Disposal

Table 4.3-19 presents the resources within the South Bay that may reasonably be affected by dredged material disposal at a theoretical disposal site or other dispersive sites outside this water body.

Table 4.3-19. Summary of Resources of Concern for the South Bay

Resource	***On Site***	***Embaymen t***
Water Quality		
Dissolved oxygen	X	X
Ammonia	X	
Pollutant levels	X	X
Toxicity	X	
Sediment		
Characteristics	X	X
Bathymetry/dynamics	X	X
Quality	X	X
Total Suspended Solids/Turbidity	X	X
Aquatic Resources		
Plankton		X
Habitats		
Benthos	X	X
Eelgrass		X

4.3.2.6 Delta

There are no aquatic dredged material disposal sites in the Delta and currently there are no plans to designated any aquatic disposal sites. However, dredged material disposal and reuse, primarily for levee stabilization projects, does occur in the Delta and may be expanded in the future. The Delta environment and resources at risk from dredged material placement are discussed below in section 4.4.