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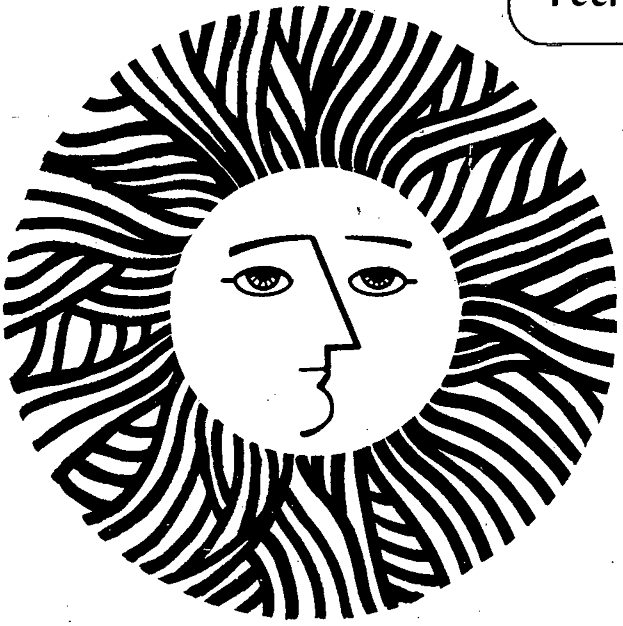

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ESTUARINE IMPACTS OF FOSSIL FUEL-BASED ENERGY TECHNOLOGY: A CASE STUDY

R. Ritschard, V. Berg and M. Henriquez

INTRODUCTION

Coastal regions, particularly estuaries and salt marshes, are rich in life forms. Of all ecological zones, estuaries have the greatest natural rate of food production. At the same time, man often burdens these productive regions with energy-related environmentally disturbing activities, such as power plants, and refineries, and their accompanying terminals and storage tanks.

San Francisco Bay, the largest estuary on the West Coast, is an example of a marine ecosystem that is impacted by numerous fossil fuel-based energy activities, especially in the upper reaches of the Bay, which holds more than 70% of the electrical generating capacity. Furthermore, most of the additional electricity generating facilities proposed for the Bay Area are planned for upper San Francisco Bay.

Man's past activities have already altered the Bay. Hydraulic mining of gold in the Sierras contributed large sediment loads; water flow in the Delta has been controlled and reduced by storage reservoirs, irrigation withdrawals, and diversions to southern California; the marshes in the Delta have been diked for agriculture; the periphery has been filled for urban development; various exotic species, such as striped bass and certain ship-fouling organisms have been introduced, both accidentally and on purpose; and a huge volume of municipal and industrial wastes is discharged daily into the Bay. Such wastes are the main impact of energy-related facilities.

The purpose of this study is to investigate the cumulative ecological effects of fossil fuel-based technologies on a specific estuarine system, namely the San Francisco Bay. The upper reaches of the Bay are used as a case study, since the majority of such activities occur in this region. The report is organized into three major parts. In the first, we describe the San Francisco Bay and Estuarine system, biologically, chemically, and physically; outline the boundaries of the study area; and summarize the existing energy facilities and those that are proposed for the future.

The second major section contains the effluent data that were collected, collated, and computerized for use in the study. Included in this information are oil spill data from the U.S. Coast Guard (1978-1980), and the most recent (1978) data for existing energy facilities (power plants and refineries) from the San Francisco Regional Water Quality Control Board. For comparison, these data are organized by zones (according to longitude and latitude). We also estimate the possible discharges from proposed power plants in the study area.

The final section contains a discussion of the possible ecological impacts to the upper Bay system from fossil fuel-based technologies. These impacts are discussed in light of both nonenergy activities, such as the proposed Valley Drain and Peripheral Canal, and the relationship of energy facilities to other activities in the Bay system. Political decisions and referenda on proposed activities, both energy-related and nonenergy will have major significance for the future health of this fragile ecosystem.

SAN FRANCISCO BAY ESTUARINE SYSTEM

Bay Ecosystem

San Francisco Bay is the largest estuary on the west coast. It has an area of 1,026 square kilometers at mean low tide, and 1,191 square kilometers at mean higher high tide. Extensive intertidal mudflats, encompassing an area of 166 square kilometers, are exposed at low tide.[1] The Bay is has two arms or reaches (Figure 1). The northern reach includes an extensive Delta that receives water from the Sacramento and San Joaquin Rivers, it accounts for 90% of total freshwater inflow to the Bay. The Sacramento River contributes about 80% of the freshwater entering the Delta, the San Joaquin River about 15 percent; the remaining 5% is from smaller streams entering the eastern Delta. The southern reach receives only local runoff, which amounts to less than 10% of the total volume of freshwater entering the system.[2] Thus, the southern reach lacks enough freshwater inflow to drive strong circulation essential to a typical estuarine system.

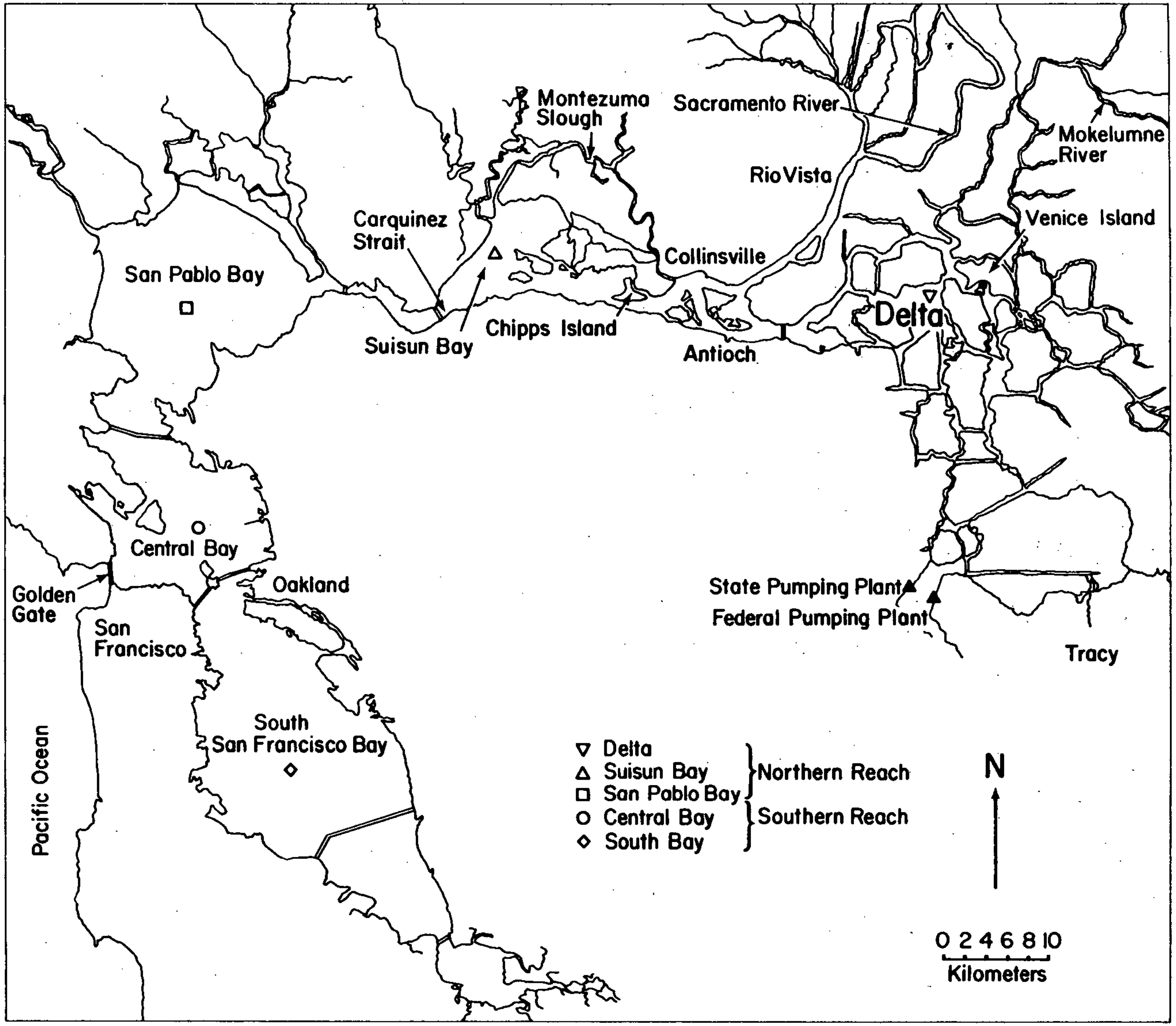

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Figure 1. San Francisco Bay Estuarine System

Freshwater Inflow and Circulation.

It is difficult to estimate the exact inflow into San Francisco Bay because of the tidally reversing flow and complicated topography near the Delta. Two indices, the Delta outflow index of the U.S. Water & Power Resources Service and the U.S. Geological Survey measurements of net Delta outflow are used to calculate the net outflow from the Delta. The average Delta outflow (1921-1976) is 21 million acre-feet per year (MAF). In the drought year of 1977, the Bay received only 3.7 MAF.[3] At the level of upstream development and diversion projected for the next two decades, the Delta outflow will average about 5.5 MAF during normal precipitation years.[3]

The circulation of water in San Francisco Bay is of primary importance for many of man's uses of the Bay. Water movements disperse and eventually transport sewage and toxic materials out of the system. Freshwater inflow and salinity control the distribution of sport fish (striped bass and salmon) and waterfowl. High salinity in the southern reach has given rise to a major salt production industry, while low salinity in the Delta has allowed the development of agriculture on reclaimed Delta marshlands. Some of this marshland, however, has been flooded (perhaps permanently) in the past few years.

Bay water is circulated by three main forces: tides, estuarine circulation and wind mixing. Tidal motion disperses material in the Bay, but does little to carry it out. Net transport into and out of the Bay is primarily through the estuarine circulation created by freshwater inflow from the Sacramento River system. Estuarine circulation is driven by the density difference between fresh and salt water and its magnitude is controlled by the amount of river water entering an estuary. An increase in river outflow increases the down-estuary flow at the surface; at the same time it increases the landward (up-estuary) flow of salt water near the bottom. Because of its dependence on river flow, estuarine circulation varies greatly with the season. Water residence time for the northern reach is about two weeks in the winter, but as long as two months in the summer. In the southern reach, it is about two months in winter and five months in summer.[2] The third factor, wind mixing, contributes greatly to local mixing and dispersion, but very little to net flow out of the Bay.

Sea water entering the Bay at the Golden Gate typically has a salinity of about 30 parts per thousand (ppt). The distribution of salinity with the Bay, particularly the northern reach, dependents on the amount of freshwater entering through the Delta. High freshwater during the winter decreases salinity in the northern reach, This causes salinity stratification to develop low-salinity water flows out on the surface and ocean water flows in at depth. The southern reach maintains near oceanic salinity throughout the year except when a major storm causes Delta freshwater to intrude.[4] During the summer the Bay is isohaline (same salinity from top to bottom at a given point in the Bay), because of the greatly reduced inflow from the Delta and because of strong tidal and wind mixing.[2]

Nutrients and Particulates

The main sources of oxygen in San Francisco Bay are oxygen production by plants and oxygen from the atmosphere, introduced by wind, waves, and tides.[5] Bay water is well oxygenated (greater than 90% of the saturation level), except that levels are reduced to about 70% saturation in the extreme southern end of the Bay during summer.[2]

The major nutrients essential for the growth of phytoplankton are nitrogen (primarily nitrates and ammonium), phosphates, and silicates. In the northern reach, Delta outflow is the major nutrient source and there is a marked seasonal variation in silicate and nitrate distribution.[2] During the winter, high Delta outflows provide large amounts of nutrients, but low sun angles, short days, and large amounts of suspended sediments in the water keep light levels low, so phytoplankton growth is limited. Large supply and low utilization result in high nutrient levels during the winter. In summer, Delta outflow is low and so, therefore is nutrients and suspended particulate matter. The seasonally higher sunlight results in high phytoplankton growth, which can deplete both nitrogen and silicates to near limiting levels.[6]

In the southern reach, nutrients are supplied primarily by sewage discharges and to a lesser extent by storm runoff and atmospheric fallout. There is a small seasonal variation in silicates and phosphate distribution, with higher concentrations in summer than in winter. The extreme southern end of the Bay is characterized by high nitrate, phosphate, and ammonium concentrations (20 times the normal Bay-wide value); however, euthrophication is not presently considered a problem in the Bay.[2]

The major sources of suspended particulates (less than 0.1 mm in diameter) in the Bay are Delta outflow, local surface runoff, sewage inputs, resuspension of sediments from the bottom by waves, and phytoplankton growth. Breakdown of marsh plants and benthic algae may also contribute a substantial amount of particulate organic detritus. Knowledge of the composition, distribution, and process affecting suspended particles is important because they adsorb and concentrate trace contaminants (such as trace metals and synthetic organic compounds), provide food for planktonic and benthic filter-feeders and substrates for bacteria. Together with dissolved material, suspended particulates attenuate light and thereby limit photosynthetic activity.

Delta outflow is the major source of particulates in the northern reach and is reported to reach 4 million metric tons per year.[7] Sediment loads increase as flows increase, and consequently 80% of the sediment load is received in the winter. The two-layered estuarine circulation in the northern reach traps suspended particulates in the null or entrapment zone (an area where suspended particles reach peak concentration as a result of two-layered flow circulation).[8] Net upstream transport of particulate materials that settle into the bottom current is nullified by net downstream transport of materials in the Delta outflow. As a result, certain suspended materials (including certain biota) concentrate in this null zone. As fresh and salt water mix, particles tend to flocculate and aggregate, increasing their settling rate.

Maximum concentration of suspended particles is in waters of 1 to 6 ppt salinity. Particle concentration in the null zone is 20 to 40 times the upstream or downstream concentration. Daily, the null zone moves with the tide (3 to 10 km/day); in summer it moves tens of kilometers upstream toward the Delta as freshwater inflow decreases.[8]

The concentration of suspended particles is higher in the northern reach in winter because of the material carried by the Delta outflow, and it is correspondingly reduced when the outflow decreases in summer. In the southern reach, by contrast, the concentration peaks in the summer. The major source of suspended particles is resuspension of sediments from the shallow bottom. The gradient of the southern reach and its sluggish circulation imply that, overall, particles introduced here are diffused northward (to the Central and San Pablo Bays) by tidal-current and wind mixing. Long-term sediment records indicate that not only does the southern reach accumulate little new sediment, but in the past several decades it has actually lost sediment to the northern reach.[7]

Phytoplankton and Null Zone

Planktonic algae affect the concentration of dissolved gases (oxygen and carbon dioxide), the concentration of dissolved inorganic substances, and pH. Photosynthetic fixation of inorganic carbon by plankton also offers a source of organic carbon and energy for higher trophic levels and ultimately determines the success of fisheries, both commercial and recreational. In the the southern reach, phytoplankton are dominated by small flagellates. A bloom occurs in March and April and is associated with the salinity stratification that develops when low-salinity water intrudes during peak Delta outflow.[9] This stratification allows the phytoplankton to stay near the surface and obtain adequate sunlight for rapid growth. Since nutrients are in abundant supply throughout the year, light depth controls phytoplankton growth except during the stratified spring period.[9] Phytoplankton populations, however, are relatively small in the southernmost part of San Francisco Bay.

In the Central Bay, the maximum standing stock of phytoplankton occurs between March and June. The spring maximum likely results from the dispersion of planktonic diatoms (Nitzschia seriata is the dominant neritic diatom) into San Francisco Bay from offshore blooms during the upwelling season.[9]

The northern reach is a partially to well-mixed estuary comprising a deep central channel and two shallow isolated embayments--San Pablo Bay and Suisun Bay. There is a spring bloom (March and April) in San Pablo Bay, composed primarily of marine diatoms (Skeletonema costatum).[9] These phytoplankton rapidly disperse over tidal flats because of the null zone and multiply rapidly because of shallow depths. The null zone is usually located near San Pablo Bay during the spring, when Delta outflow is high.

Later in the season, as the null zone moves upstream with decreased Delta outflow, a bloom typically develops in July and August in Suisun Bay.[10] Here, large standing stock provides the most dramatic feature of phytoplankton dynamics in the San Francisco Bay system. Its the summer bloom is 10 times greater than those found in the other segments of the Bay. Although the standing crop is high, productivity is generally lower than in other parts of the Bay because of increased turbidity. The most numerous and frequently occurring phytoplankton species during the bloom is the diatom Thalassiosira excentrius.[11]

Fauna

Many commercial and sport fish (salmon and striped bass) eat zooplankton in the early stages of their life cycle and other fish as adults. Fish such as anchovies and herring feed primarily on zooplankton. In the southern reach, the most abundant species is the copepod Acartia clausi, but there are many microzooplankton that feed on microflagellates, the dominant form of phytoplankton[12]. The mysid shrimp (Neomysis mercedis) is the dominant form in the northern reach. Neomysis is an important food source for young of the year striped bass and is 10 to 250 times more concentrated in the null zone than upstream or downstream.[8,13] Its primary food is diatoms though detritus and small zooplankton may also be taken. Neomysis migrates vertically possibly via the two-way estuarine flow in the null zone[13]. They are most abundant at salinities up to 10 ppt and are almost never found at salinities greater than 20 ppt.[8] In the Delta and Suisun Bay there are two other copepods that are abundant. Acartia clausi occurs at salinities greater than 10 ppt and Eurytemora hirundoides is abundant at salinities from less than 10 ppt in the null zone.

Since the Bay is shallow, much of the organic matter produced in the surface layers reaches the bottom and provides food for a rich benthic fauna. Organic matter from sewage and from material carried in by Delta outflow, especially during winter floods, are also important food sources for benthic organisms. The benthos of San Francisco Bay are comprised mostly of opportunistic species, which repeatedly colonize disturbed areas.[14] The greatest number of species is found in the Central Bay. This diversity is owning to the proximity of the Central Bay to the coastal ocean and to the relatively stable sediments in this deep part of the Bay. The fewest species and the lowest biomass are found in the northern reach, probably because of the strong seasonal variation in salinity.[14] Those that are found are the young of opportunistic species. In the southern reach, the diversity is intermediate, but the biomass level is the highest. Sediment instability is important in controlling the distribution of benthic organisms in the shallow parts of San Pablo Bay and the northern reach. The most important human impact on the benthos of San Francisco Bay has been the introduction over the past 130 years of approximately 100 species of benthic organisms.[15]

Man's use of the Sacramento River system and the Bay has taken a heavy toll on fish stocks. Upstream hydraulic gold mining, dams and diversions of river water, filling, dredging, and water pollution, and overfishing have all affected the Bay fisheries. Most commercial fishing in the Bay has been banned since 1957; herring (for food) and anchovies and ghost shrimp for bait in sport fishing, in addition to trolling for salmon outside the Golden Gate are the only legal commercial fisheries.[16] Sport fishing, continues to flourish.

Several fish and shellfish species use the Bay system during at least part of their life cycle, including chinook salmon, striped bass, American shad, sturgeon, Pacific herring, northern anchovy, starry flounder, clams, oysters, and mussels. Each will be discussed briefly below.

Salmon. The chinook salmon (Oncorhynchus tshawytscha) is native to the Sacramento-San Joaquin River systems. About 80% of all chinook salmon landings originate from stocks in this system.[16] Chinook salmon are anadromous fish that spawn on gravel beds in clear water systems. Three stocks of adult fish (spring, fall and winter) occur from San Francisco Bay. Most of the spring run fish spend the summer in deep pools and do not spawn until fall. The fall run is the largest.[16] The young migrate to the ocean to live for two to four years before reaching maturity. Mature fish return to their native streams and then die.

Bass. The striped bass (Morone saxatilis) was introduced from estuaries of the East Coast. Most of West Coast striped bass production occurs in the San Francisco estuary. Spawning takes place from early April to mid-June in two areas: the San Joaquin River between Antioch Point and Venice Island (Fig. 1) and the Sacramento River (about 250 km upstream).[17] Striped bass spend most of their adult life in the northern reach, Central Bay and Pacific Ocean within 32 km of the Golden Gate. Young bass abundance is greatest in the null zone (the principal nursery for many fishes) where they feed chiefly on Neomysis (shrimp) and Eurytempora (copepod).[17] Striped bass populations have shown a continuing decline over the past decade. Adults are parasitized by tapeworms, bear external lesions, and have high body burdens of various toxic chemicals.[18]

Herring. The Pacific herring (Clupea harengis pallasi) lives as both juvenile and adult in the coastal ocean. Adults enter the Central Bay to spawn each year from November through March. They lay their eggs on rocks and seaweed in the intertidal and shallow subtidal areas near Sausalito and Tiburon.[16] Adult fish and eggs are subject to heavy predation from sea birds, fishes and sea lions. Only Pacific herring is the commercially fished in San Francisco Bay at present.

Shad. America shad (Alosa sapidissima) is another species transplanted from the Atlantic Coast. It is an anadramous fish that spends most of its life at sea but spawns from April to June in the Sacramento River system.[16] Most young fish leave the Delta and pass through San Pablo Bay from September to November. Legislation prohibiting gill netting in inland waters was enacted in 1958 and the shad fishery was closed. Recreational fishing for shad, however, has since become popular.[19]

Sturgeon. Two species are found in San Francisco Bay: white sturgeon (Acipenser transmontanus) and green sturgeon (Acipenser medirostris). Females of both species reach maturity in about 12 to 15 years (approximately 125 to 140 cm in length), males in 10 to 12 years (112 to 125 cm in length).[17] Both species eat invertebrates such as clams, small crabs, and bay shrimp, but during the winter herring runs, 20% to 80% of their food is herring eggs. The white sturgeon spends summer, fall, and winter in the lower bays and Delta and migrates upstream in early spring to spawn. The green sturgeon is believed to spend more time in the ocean. For various reasons, including overfishing and hydraulic gold mining operations, the fishery was closed in 1917. Sturgeon were opened to sport fishing in 1954.[19]

Anchovy. Northern anchovy (Engraulis mordax) is probably the most abundant species of fish in the Bay. It has a maximum life span of about 7 years although individuals rarely exceed 4 years of age. Anchovies are found in the Bay throughout the year, but a large influx occurs in May and this higher abundance persists through September.[16] It is probably the most important forage fish in the Bay for salmon, jacksmelt, and striped bass. Anchovies are currently preserved and packaged as frozen bait for sport fishing.

Flounder. Starry flounder (*Platichtys stellatus*) is one of the most important sport fish along the Pacific Coast. It is a euryhaline species that is commonly found in estuarine areas and sometimes in freshwater, especially in soft sandy habitats. The starry flounder spawns in December and January as the adult fish migrate to shallower waters.[16] Only a few eggs, larvae, and juveniles have been taken in the Bay, so its life cycle within the Bay and Delta system is still unknown.

Oysters. San Francisco Bay was once one of the major landing areas for oysters and clams. The industry began declining after 1900; the oyster industry collapsed in the late 1930's and the soft shell clam industry in the late 1940's.[19] Three species of oyster have been harvested from the Bay in the past: the native species (*Ostrea lurida*), the eastern form (*Crassostrea virginica*), and the Pacific oyster (*Crassostrea gigas*). The latter two species were introduced for holding and fattening seed culture; neither have reproduced sufficiently in the Bay for commercial use.[19]

Clams and mussels. The three most abundant species of clams and mussels are not native, but were accidentally introduced.[15] They are the soft shell clam (*Mya arenaria*), the ribbed or horse mussel (*Ischadium demissium*), and the Japanese littleneck clam (*Tapes japonica*). The bay mussel (*Mytilus edulis*) is indigenous. Soft shell and Japanese littleneck clams are abundant in the Bay. Intensive sport clamming in Foster City and Berkeley continues despite warnings of the State Public Health Department of high bacterial levels in the clams.

Shrimp. There are three native species: *Crangon franciscorium* (the largest and most abundant), *C. nigricanda*, and *C. nigromaculata*. The Korean shrimp (*Palaemon macrodactylus*) was introduced accidentally in the early 1950's.[16] Shrimp are important forage for sport and market fisheries (sturgeon and striped bass). Eggs hatch in water of high salinity; larval stages are planktonic until reaching 6 to 7 mm in length, when they settle to the bottom and move toward shallower water of reduced salinity. As the shrimp develop and spawning season approaches, they move back into deeper, cooler, and more saline waters. Spawning occurs from December to May or June (*C. franciscorium*).[16] Bay shrimp are short-lived, with large fluctuations in abundance from year to year. They are particularly sensitive to the effects of oil and chemical spills.

Delta Outflow: The Controlling Factor

The importance of the relationship between Delta outflow and the health of Bay ecosystem must be re-emphasized. the Delta provides 90% of the freshwater received by the Bay. This inflow fluctuates seasonally and is influenced by the operations of state and federal water projects.

The Delta outflow, in turn, is the major source of suspended particulates in the Bay system. Because of the two-layered estuarine circulation in the northern reach, these suspended particulates are trapped in the null or entrapment zone. In fact, concentrations of suspended particles are 20 to 40 times greater in the entrapment zone than upstream or downstream. As mentioned before, the entrapment zone retreats toward the Delta, especially Suisun Bay, with the summer drop in Delta outflow. One study found that low outflows of 3.6 to 6.2 MAF/yr are required to maintain the entrapment zone in the Suisun Bay vicinity.[11]

It has also been shown that phytoplankton standing crops are highest when the entrapment zone is adjacent to the expansive shallows of Suisun Bay. Phytoplankton is 5 to 20 times more concentrated in this area than upstream or downstream. The phytoplankton standing crop in Suisun Bay can also be regulated, within water availability limits, by manipulating Delta outflow to optimize the entrapment zone location.

Zooplankton, especially the mysid shrimp (Neomysis), is 10 to 250 times more concentrated in the entrapment zone. Further, juvenile striped bass, which eat zooplankton at this stage in their life cycle, abound in the entrapment zone. The concentration of juvenile bass is 200 to 600 times greater here than upstream or downstream.

Reduction in duration and frequency of freshwater flow into and out of the Delta (caused by increasing demands for agricultural industrial and domestic uses) will probably affect other anadramous fish stock. The proposed water projects are expected to cause a gradual decline in Delta outflow, and this decline can affect salinity regions, which can change the distribution of certain species and possibly the migratory habits of anadromous fishes and salinity-regulated shrimp (*Crangon sp.*) that are important for sport and commercial fisheries.

Thus, the health of San Francisco Bay and estuary is related not only to energy facilities, as emphasized in this study, but also to Delta outflow, and future water diversions, and municipal discharges from the 7 million people who live in and are dependent on this ecosystem. Our report emphasizes the potential cumulative ecological impacts to the Bay system resulting from existing and proposed fossil fuel energy facilities. These impacts, however, must be considered along with the other activities that have altered the Bay system.

Table 1. Geographic boundaries of estuary study area zones

Zone	Name	North	South	East	West
--	Entire Area	38 45´	37 52´30"	121 00´	122 37´50"
1	Sacramento & Channel	38 45´	38 15´00"	121 00´	121 45´00"
2	Delta & Stockton	38 15´	37 52´30"	121 00´	121 45´00"
3	Pittsburg & Antioch	38 15´	37 52´30"	121 45´	121 55´00"
4	Suisun & Carquinez	38 15´	37 52´30"	121 55´	122 14´00"
5	San Pablo Bay	38 15´	38 00´00"	122 14´	122 37´30"
6	Richmond & Marin	38 00´	37 52´30"	122 14´	122 37´30"
7	Napa & Northeast	38 45´	38 15´00"	121 45´	122 37´30"

Estuarine Study Area

The estuarine study area includes the northern reach of the San Francisco Bay-San Joaquin River estuarine system. As shown in Figure 2., the study area is subdivided into seven zones; the latitudes and longitudes of their boundaries are listed in Table 1.

The study area was divided into zones based on geographic and hydrologic characteristics. The boundary between zones 1 and 2 is approximately the southern end of the Sacramento ship channel. Zone 2 includes Stockton and most of the Delta area, and is bounded on the west by the Antioch Bridge over the San Joaquin River. The Sacramento and San Joaquin Rivers converge in zone 3, whose eastern boundary is at Chipps Island, west of Pittsburg. Zone 4 includes Suisun Bay, Honker Bay, Grizzly Bay, and the Carquinez Strait. The zone extends eastward to the Carquinez Bridge. San Pablo Bay comprises zone 5, which extends south to Pinole Point and Point San Pedro. Zone 6 is the area between Richmond and Marin County, south to about Tiburon. Zone 7 is the remainder of the study area, including parts of the Napa and Sacramento Valleys.

Existing Facilities

Industrial and Military Facilities

The coastline of the study area is one of the major military and industrial areas of northern California (Table 2). Some of the larger industrial facilities include: the world's largest sugar refinery (C&H sugar, in zone 4); the U.S. Steel mill at Pittsburg, in zone 3; Domtar Gypsum America Inc., a gypsum distributor, at Antioch in zone 3; a Crown Zellerbach paper mill in Antioch; the Port Costa Products Company in zone 5, northern California's largest brick manufacturer; the Concord Naval Weapons Station (zone 4), where six ammunition ships are based; and the Mare Island Naval Shipyard in zone 5.

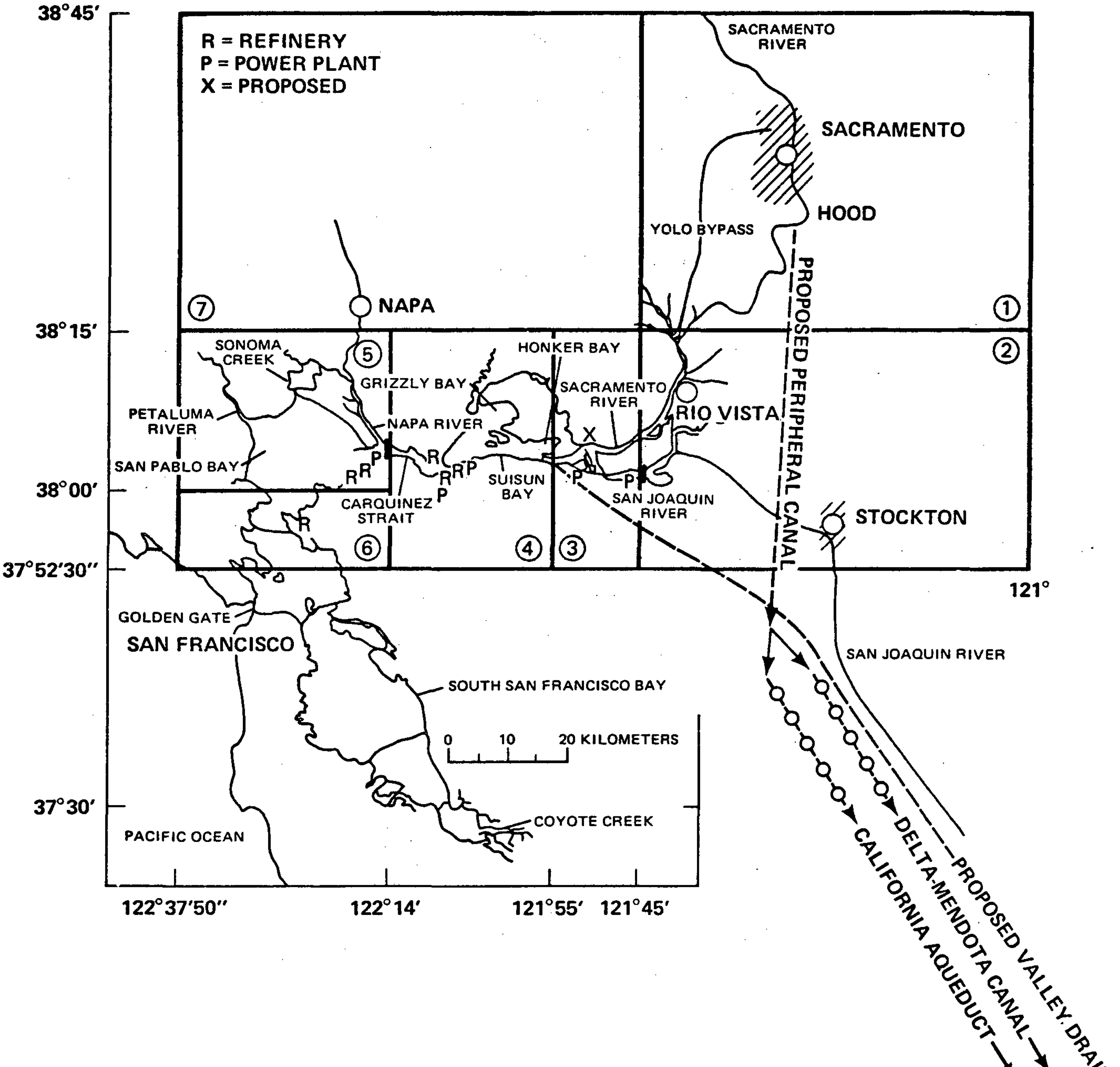

Figure 2. Estuarine Study Area.

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Table 2. Major industrial facilities in estuary study area.

Facility	Function	City	Zone
Kellman Steel Co.	Bulk Facility	Sacramento	1
Sacramento Northern RR	Fueling Area	Sacramento	1
Western Pacific RR	Railroad	Stockton	2
Borges Clarksburg	Private Airport	Stockton	2
Crown Zellerbach	Paper Mill	Antioch	3
Domtar Gypsum America	Distributor	Antioch	3
Imperial West Chemical Co.	Sulfuric Acid	Antioch	3
Kerley Chemical Corp.	Manufacturing	Antioch	3
Diablo Service Corp. Wharf	Coke, Caustic Soda	Pittsburg	3
Dow Chemical	Manufacturing	Pittsburg	3
U.S. Steel	Manufacturing	Pittsburg	3
Concord Naval Weapons Station	Military	Port Chicago	4
Bird & Son Inc.	Asphalt Roofing	Martinez	4
C & H Sugar	Sugar Refinery	Crockett	4
Louisiana Pacific Co.	Wood products	Antioch	4
Port Costa Products	Brick manufacturing	Port Costa	5
Western Asphalt Service	Storage		5
Point Molate	Naval Fuel Depot	Richmond	6

Source: Ref. 20.

Energy Facilities

The highest tonnage import to the area is crude oil, and oil refining and distribution is the largest industrial activity. Six refineries are located in the study area, concentrated between Richmond and the Carquinez Strait (Table 3). The Chevron USA refinery at Richmond is by far the largest of the six, followed by Tosco, Union Oil, Shell, and Exxon. The Pacific Refining Company refinery at Hercules is the smallest, and specializes in heavy crudes.

Other facilities receive, store, and transport petroleum products. For example: the Ozol Oil wharf at Martinez (zone 4), where jet fuel and other petroleum products are received and shipped to Air Force facilities; a Navy fuel supply depot at Point Molate, near Richmond (zone 6); a Tosco Corporation subsidiary in Pittsburg (zone 3) that ships agricultural products, including fertilizers; and several, bulk oil storage facilities, distribution centers, and fueling stations.

Pacific Gas and Electric Company (PG&E) operates five power plants along the Contra Costa County shoreline. They were located here for easy shipment of fuel and availability of cooling water. All of the existing plants can be fired by either natural gas or oil. Some of the older plants are fairly small, but the units at Pittsburg and Contra Costa are significant components of the PG&E generating system. Table 4 lists the power plants that are sited in the study area and summarizes their cooling water source, fuel, and capacity.

Proposed New Facilities:

Several facilities have been proposed for construction or major modification in the study area. Some may affect water quality and ecosystems in the Bay by routine release of effluents, some by potential accidental spills of damaging substances, and others by changes in the flow regime of the estuary.

New or Expanded Refineries

It is quite unlikely that any new refining capacity will be added in zone 4 in the forseeable future. Because of current fuel use trends, the existing refineries are operating below their optimum capacity. Pacific Refining Company the smallest one, is at only 50% of capacity at this time. A few years ago, Exxon considered adding 45,000 barrels per day to the capacity of its Benicia refinery but, the expansion was cancelled when the company decided it was unneeded. The Union Oil Company proposed a small (10,000 barrels per day) refinery near Martinez, but allowed its permits to expire because the project is not economical.

Instead of expansion, some of the refineries are undertaking major modernization and improvement projects.[22] Shell is spending $300 million to modernize its Martinez refinery. New units are being added that can use 100% Alaskan and Californian crudes as feedstock, but they will not increase capacity. New docks are being built with additional safeguards against oil spills, and there will be wastewater recycling facilities. The Tosco refinery at Avon is receiving $110 million worth of improvements, including better facilities for air and water quality protection. The Chevron refinery in Richmond is being modernized at a cost of $400 million. Its lube plant, which produces over 1,500 products, will operate on high-sulfur crude oil.

New Power Plants

Pacific Gas and Electric Company is planning to add two new turbines to the seven already in use at its Pittsburg plant in zone 3. It is uncertain at present whether the new units will be fired with oil or with some other fossil fuel source, such as gasified coal, or methanol.

PG&E has also received approval for construction of a coal-fired power plant at Collinsville (Fossil 1 and 2), across the river from the Pittsburg plant. The proposed plant would have two 800-megawatt steam turbines, fueled by Utah coal. Since load growth in the utility's service area has slowed considerably in recent years, Fossil 1 and 2 have been delayed until 1993.

Table 3. Refinery Capacities in Estuary Study Area.

Company and Location (zone)	Crude Capacity		Production Capacity, (b/sd)					
	(b/cd)	(b/cd)	Alkylation	Aromatics-isomerization	Lubes	Asphalt	Hydrogen (MMcfd)	(t/d)
Tosco Corp.-Avon (4)	126000	NR	10500	1800	100	---	60.0	1200
Shell Oil Co.-Martinez (4)	104000	107000	8000	---	4500	13000	65.0	---
Exxon Co.-Benicia (4)	103000	108000	12000	---	---	---	104.0	1000
Union Oil Co.-Rodeo (5)	111000	117000	---	---	4400	---	70.0	1850
Pacific Refining Co.-Hercules (5)	NR	85000	---	---	---	---	---	---
Chevron USA Inc.-Richmond (6)	365000	NR	9200	2000	5670	11000	135.0	---
Total (thousands)*	809	417	39.7	3.8	14.67	24	.502	4.05
Total California (thousands)*	2634	2770	95.6	10.5	21.6	82.1	.8377	16.6
Percent of State Output*	30.7	15.06	41.5	36.2	68.0	29.2	59.9	24.3

* Some values not reported. Interpret numbers with caution.

Abbreviations: b/cd, barrels per calendar day; b/sd, barrels per stream day;
MMcfd, million cubic feet per day; t/d, tons per day.

Source: Reference 21.

Table 4. Pacific Gas and Electric Company power plants in study area.

Name	Zone	Cooling Source	Capacity (MW)	Fuel	Date
Contra Costa 1-7	3	San Joaquin R.	1260	Oil/Gas	1951-64
Pittsburg 1-7	3	Suisun Bay	2002	Oil/Gas	1954-72
Avon Steam	4	Canal	46	Oil/Gas	1940
Martinez	4	Canal	46	Oil/Gas	1941
Oleum Steam 1 & 2	5	San Pablo Bay	87	Oil/Gas	1942-43
*Pittsburg 8 & 9	3	Suisun Bay	??	Oil/Gas	
*Fossil 1 & 2 (Montezuma)	3	Sacramento R.	1600	Coal	

* Proposed power plants.

Proposed Coal Export Terminal

Export demand for coal from the western U.S. has been increasing recently. The only feasible sites for coal export in the San Francisco Bay area are near Martinez, Port Costa, and Selby.[23] The Wickland Oil Company is considering construction of a coal export terminal at a 300-acre site it owns at Selby on San Pablo Bay.[24] Coal would be transported from the Rocky Mountain states and across the Benicia-Martinez Bridge on the Southern Pacific main line. It would then be dumped from cars into hoppers, and conveyor belts would load the coal into ships. The export terminal would probably have a capacity of about 15 million tons per year, or about six 80-car trains per day. This compares to the 5 million tons per year (2 trains per day) for the postponed Fossil 1 and Fossil 2 power plants. A major environmental concern would be with fugitive dust and particulate emissions. Leaching controls would probably need to be installed around an old lead-smelting slag pile on the site.

New Port Facilities

The Port of Richmond, Contra Costa County's only public port, has the capacity to expand into a major container shipping facility. The first container berth was opened in 1980, and land is available for a total of six berths in the future. The president of the County's Development Association says, the Port of Richmond is considered "the single most important economic project in this county. It has tremendous potential as a job producer."[25]

Channel Dredging

A major navigational improvement project is partially underway in the study area. The Baldwin Ship Channel Project of the Army Corps of Engineers may eventually make it possible for deep-draft ships to travel all the way from the Golden Gate through the estuary to the Port of Stockton, in zone 2.

The several parts of this project are in varying stages of completion. The first section, from the Golden Gate to the area south of Richmond, has been completed. The next section, from there through San Pablo Bay, is proposed for construction in fiscal year 1983. This section is particularly important, because it will increase safety and decrease the likelihood of accidental oil spills. Currently, large oil tankers must anchor in San Francisco Bay south of the Bay Bridge and transfer part of their cargo to shallower-draft barges before they can dock. These transfers increase the hazard of spillage or collisions. The completion of the channel and an associated turning basin will help alleviate those problems. The section from Point Edith (near Avon, zone 4) up to Stockton will be constructed in fiscal year 1982.

Dredging through the Carquinez Strait and Suisun Bay, probably the most controversial part of the project, is still in the planning stage because of the possibility that it may increase salt water intrusion in the Delta. This possibility is being studied, and a submerged concrete sill has been suggested as a solution; the sill would prevent salt water from moving upstream underneath the Delta outflow.[27] In any case, several agencies will be evaluating this section of the channel before construction is permitted.

Peripheral Canal

The Peripheral Canal is one of the most controversial issues in California politics. The federal Central Valley Project and the State Water Project both export water from the Delta area southwest of Stockton to the agricultural San Joaquin Valley and southern California. Water from the Sacramento River flows through the meandering channels in the Delta to the massive pumps near Tracy. The size and flow patterns of the Delta channels and the necessity of preventing salt water intrusion into the Delta limit the amount of water that can be pumped. The proposed Peripheral Canal and associated facilities would bypass the Delta and permit a larger volume of water to be exported. A 43-mile, unlined channel would carry water from the Sacramento River near Hood to the Tracy pumps. Since 80% of the flow through the Delta comes from the Sacramento River, some water in the canal could be released to Delta channels to maintain downstream flows in summer. Some water could also be moved to the San Joaquin River to prevent salt intrusion there.[25]

The many controversial aspects of the Peripheral Canal project include the general issue of water exports to the south, salt intrusion into agricultural water in the fertile Delta area, possible changes in water quality and Delta outflows in Suisun Bay, and effects on municipal water supplies, including those of the large Contra Costa County Water District.

A major water development bill (S.B. 200), including authorization for the Peripheral Canal, was approved in 1980 by the California legislature. Later, a proposition passed but not enacted by California voters in November 1980 set standards for Delta water quality. Enough signatures were gathered on petitions to force a referendum election on S.B. 200; the election is scheduled for June 1982. The results of the referendum will determine whether or not the Peripheral Canal will be built.

Valley Drain

Build-up of salt in their soils has increasingly concerned farmers in the San Joaquin Valley. All irrigation water contains some salt, which builds up in the soil through evapotranspiration. The salt must be leached out and removed if irrigated agriculture is to continue. The problem affects over 400,000 acres of irrigated farmland in the San Joaquin Valley, and over a million acres may ultimately be affected.

The San Luis Drain currently carries irrigation return water from parts of the valley to Kesterson Reservoir in Merced County. This reservoir cannot handle all of the area's drainage. A 295-mile canal has therefore been proposed that would drain a much larger area of the valley and carry the water north to the Bay. The brackish water would be discharged into Suisun Bay at Millard Slough, across from Chipps Island between zones 3 and 4. Some expected water quality parameters for the drain water are listed in Table 5. The combined effect of reduced outflows from the Peripheral Canal and additional brackish water from the Valley Drain could have major impacts on water quality in the estuary, especially in the Suisun Bay area (zone 4). Authority for permitting construction of the drain has been shifted from the Regional Water Quality Control Boards to the state board because of the importance of the drain to water quality in the estuary.

Table 5. Expected constituent concentrations and flow rates in agricultural drainage water entering the proposed Valley Drain. (Concentrations may change in transit through reservoirs and marshes).

Salts (mg/l)	1985	2000
Calcium and Magnesium (Ca + Mg)	460	470
Sodium (Na)	910	970
Potassium (K)	3.8	5.3
Bicarbonate (HCO_3)	270	350
Sulfate (SO_4)	1580	1750
Chloride (11)	560	660
Arsenic (As)	0.0	0.05
Boron (B)	9.7	10.2
Nutrients (mg/l)		
Nitrate as N	21.0	21.0
Phosphate as P	0.06	0.31
Input flow (acre-feet/yr.)	57,000	518,000

Source: Ref. 25.

POLLUTANT LOADINGS

Accidental Spills of Oil and Hazardous Substances

Crude oil and distilled products, as well as hazardous chemicals, are occasionally released into San Francisco Bay. These spills and their cleanup are monitored by the U.S. Coast Guard, and data on locations, quantities spilled, and pollution effects are recorded.[28] The data are stored in a central data base called the Pollution Incident Reporting System.[29]

The sources of oil and hazardous substance spills in the study area are listed in Table 6. Appendix A contains a more complete set of oil spill data. Because most discharges are accidental, there is great variability in time and place of spills. Some general trends can, however, be discerned. The total number of spills has declined over the past three years, from 128 in 1978 to 80 reported spills in 1980. the greatest decline occurred in zones 5 and 6. The number of spills in zones 1 through 3 is not high in any of the three years, while zone 4 had an intermediate number.

At first glance, the total volume of oil and hazardous substances spilled seems to have risen dramatically, from 36,654 gallons in 1978 to 451,242 gallons in 1980. These figures may be misleading. The volume data are heavily influenced by a few large spills.

Table 6. Oil and hazardous substance spills in each zone, 1978-1980.

		Number Spills	Total Gallons	Vessel	Cargo Transfer	Bulk Facility	Oil Refinery	Power Plant	Industrial Plant	Land Transport	Other and Unknown
Entire Area	1978	128	3,6654	26,254	25	30	2351	0	241	7,376	377
	1979	110	6,4623	4,3436	236	50	270	336	16030	3,671	594
	1980	80	451,242	1,134	343,759	75	104,837	2	0	543	892
Zone 1	1978	0	0	--	--	--	--	--			
	1979	2	892	--	--	--	--	--	--	882	10
	1980	1	5	--	--	--	--	--	--	--	5
Zone 2	1978	6	1,340	110		30	--	--	--	100	200
	1979	6	125	20	--	--	--	--	--	--	105
	1980	8	343,751	5	353,741	--	--	--	--	--	4
Zone 3	1978	3	305	--	--	--	--	--	200	100	5
	1979	3	542		200	--	--	336	--	--	6
	1980	2	2	--	--	--	--	2			
Zone 4	1978	34	29,392	24,989	23	--	2351	--	1	1900	128
	1979	42	17471	66	5		20		16000	1064	316
	1980	20	33,592	146	10	--	33345	--	--	1	90
Zone 5	1978	21	538	267	1	--	--	20	250		
	1979	15	896	375	--	--	250	--	30	204	37
	1980	10	674	71	--	75	85	--	--	143	300
Zone 6	1978	64	5,079	888	1	--	--	--	20	4126	44
	1979	42	44,697	42,975	31	50	--	--	--	1521	120
	1980	39	73,218	912	8		71,407	--	--	399	492

Dashes indicate no data or no reported spills.
* Data are gallons spilled less amount recovered.
No spills were reported from zone 7.

Source: Reference 28.

The six spills listed in Table 7 represent 96% of the total volume released in the 1978-1980 period. The single largest spill was of jet fuel in the port of Stockton. Much of that evaporated before it could be cleaned up. The predominance of these large, rare spills makes it difficult to tell whether the volumes released are actually increasing overtime. That depends on the frequency of those large spills.

Figure 3 illustrates the number and volume of spills in each zone. The very high volume released in zone 2 reflects the large jet fuel spill. Otherwise, the volumes roughly parallel the number of spills. In zones 4 and 6, the average release is about 840 gallons, whereas in the other zones the mean size ranges from 45 to 300 gallons.

The substances spilled in each zone are listed in Table 8. They include all the major products in today's petroleum economy, such as crude oil, gasoline, jet fuel, diesel oil, and fuel oil. Several other hazardous substances were also released. Most incidents occurred in zones 4 and 6.

Table 7. Major oil spills in study area.

Zone	Date	Gallons	Substance	Source
2	10-10-80	343,741	Jet fuel	Cargo transfer
4	3-25-78	22,638	Gasoline	Barge
4	12-10-75	16,000	Fuel Oil	Industrial Plant
4	1-13-80	35,000	Heavy Crude	Refinery
6	4-12-79	42,000	Gasoline	Barge
6	12-9-80	71,400	Heavy diesel	Refinery

Source: Ref. 28.

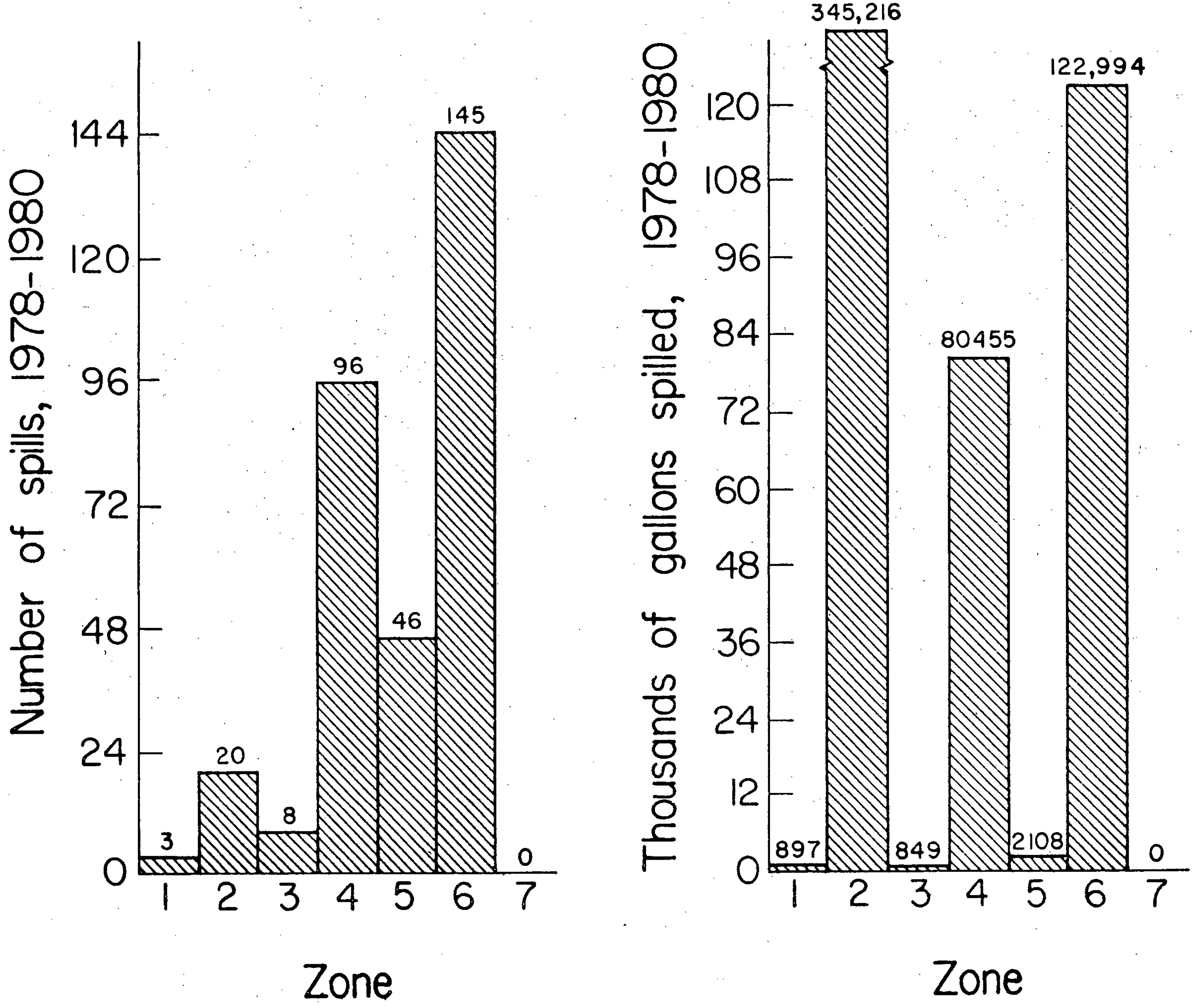

Figure 3. Number and volume of oil spills in each study zone (1978-80).

Table 8. Types of oil and hazardous substances spilled in each zone, 1978-1980 (Number of gallons spilled less amound recovered).

	Entire area	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Light Crude Oil	577--	--	--	27	250	300	
Heavy Crude Oil	34622	--	--	--	33335	642	645
Cashinhead Gasol.	1				1		
Avi./Auto Gasol.	71557	882	1000		27222	268	42185
Jet Fuel	343741		343741				
Other Dist. Fuel	70				58		12
Naptha	3						3
Other Pet. Solv.	25						25
Light Diesel Oil	1479	10	10	100	92	384	883
Heavy Diesel Oil	71815					135	71680
#4 Fuel Oil	88			2	86		
#5 Fuel Oil	2244				2234		10
#6 Fuel Oil	16372			336	16016		20
Asphalt/Road Oil	27					7	20
Animal Oil	241						241
Vegetable Oil 1860						1860	
Waste Oil	496		100	6	82	138	170
Lube Oil	262		35	200	17	2	8
Hydraulic Fluid	208					136	72
Lacquer Paint	22				22		
Mixture Pet. Prod.	720		110		308	111	191
Unid. Light Oil	366	5	70		214	5	72
Unid. Heavy Oil	426				106		320
Other Oil	141				106		320
Acetone	440				440		
Benzene	5						5
Chlorosulf. Acid	4000						4000
Hydrochl. Acid	23				23		
Phenol	20						20
Phosphoric Acid	100						100
Toluene	3						3
Other Haz. Subst.	150		150				
Sewage Sludge	3						3
Chemical Wastes	86				86		
Coke	207			200	7		
Other Material	87				52		35
Unknown Material	32			5	27		

Dashes indicate no data or no reported spills. Source: Ref. 28.

Energy Facility Discharges

Discharge data on the major energy facilities in the northern reach of the Bay were obtained from the San Francisco Bay Regional Water Quality Control Board (Region 2). The information in these files is not reported in a uniform fashion from year to year or from facility to facility. The effluent reporting program is voluntary, and each facility or discharger can report on effluents as it wishes or on only those effluents specified in the original discharger permit. Furthermore, some dischargers did not report for 1978, which is the year that otherwise has the most complete data. Thus, in many instances, data are missing. Four of the five power plants are included, but only one refinery had data available for 1978.

Table 9 lists the average annual discharges reported in 1978 for the major energy facilities in the study area. Appendix B provides a more complete set of energy facility data. Except for flow, which is reported in thousands of gallons per day, the values are in kilograms of effluent per day (kg/day). In some cases, the maximum values were so high because of a system anomaly that they are listed as well. The major pollutants from the reported data are total suspended solids (TSS), oil and grease, and copper (Cu). Since there was such a paucity of information, it was difficult to compare power plant effluents with refinery discharges. In fact, only the Pacific Refinery, which has the smallest capacity but specializes in heavy crude oils, reported its discharges for 1978.

Table 9. Major energy facility effluents - 1978 (annual average kg/day).

Facility	Zone	Flow*	Biological oxygen demand	Total suspended solids	Total settleable material	Oil and grease	Ammonia nitrogen	Total chromate	Total sulfide	Cl	Cr	Cu	Fe	Zn
PG&E Pittsburgh	3	209	180.9	-	-	18.596	-	-	-	-	-	0.208	-	-
		19**	-	-	-	0.997	-	-	-	-	-	0.581	0.101	-
		764**	-	-	-	-	-	-	-	-	-	168.7	-	-
PG&E Martinez	4	0.5	-	-	-	0.13	-	-	-	0.0	-	0.2	-	-
PG&E Avon	4	216	-	-	0.0 (38.1)	0.08 (10.3)	-	-	-	37	-	-	-	-
Pacific Refinery	4	-	-	33.1 (234)	38.8	7.71 (29.9)	118.114 (120.2)	0.013 (0.099)	0.034 (0.399)	37	0.0	0.2 (0.38)	-	0.72 (0.472)
PG&E Oleum	5	159	-	10.8 (128.0)	-	0.1 (14.2)	-	-	-	-	-	4.5 (69.1)	0.06 (2.6)	-

* Flow reported in thousands of gallons per day.
\- indicates data not reported.
() indicates quantities are maximum values.
** more than one discharge point.

Source: San Francisco Bay Regional Water Quality Control Board files.

Other authors have attempted to estimate the pollutant loadings on the San Francisco Bay ecosystem.[30,31] One study divided the Bay into six pollution-receiving water zones for discussion and comparison.[30] The major outfalls discharging into Suisun Bay, a zone extending from the Carquinez Bridge to Chipp´s Island, west of Pittsburg, totaled 22 (10 municipal and 12 industrial). This area corresponds to zone 4 in our study. The estimated average daily discharges into Suisun Bay (1975-1977) are listed in Table 10, along with the estimates of the total effluents discharged into the Bay. The bulk of the effluents listed in Table 10 are attributed to municipal souces rather than to industrial discharges.[30]

Table 10. Effluent discharges (1975 1977), in Kilograms per day

Effluent	Suisun Bay*	Estimated Bay Total
Oil/Greases	6655.1	33042.7
Zinc	18.2	429.8
Copper	17.3	1478.4
Chromium	9.0	182.3
Lead	16.7	128.0
Nickle	3.2	103.8
Cadmium	4.3	23.8
Mercury	<0.1	20.5
Arsenic	1.0	62.0

* Zone extends from the Carquinez Bridge to Chipps Island, west of Pittsburg.

Source: Estimates based on data in Ref. 30.

To compare the effluent loadings from municipal sources with those from energy facilities in the study area, we obtained data for 1978 from the San Francisco Bay Regional Water Quality Control Board. Table 11 summarizes the pollutants discharged from major municipal dischargers in zones 3, 4, and 5. If the values in Table 11 are compared with those for discharges from energy facilities (Table 9), we find that municipal sources are much more significant contributors to pollutant loadings than energy facilities in spite of the magnitude of energy-related activities in the Bay area. Municipal sources clearly exceed energy facilities in the volume of waste flows and in the levels of biological oxygen/demand, total suspended solids, and oil and grease. In trace metals reported however, the energy facility discharges are somewhat higher, especially copper.

Effluents from Proposed Energy Facilities

Effluent discharge limitations have not yet been prescribed for the Fossil 1 or 2 and the Pittsburg 8 and 9 power plants. However, the Environmental Protection Agency has promulgated "Standards of Performance of New Sources" applicable to steam electric power plants. Maximum concentration limits for waste constituents are listed in Table 12. Mass emission rates for oil and grease require that 95% of those residuals be removed prior to discharge. Federal thermal pollution standards have not yet been approved.

The new power plants would also have to comply with state standards. California requires that dissolved oxygen levels in receiving waters not fall below 5 mg/l in warm water, and 7 mg/l in cold water or spawning habitats. The normal temperature of the receiving water cannot be altered without approval of the Regional Water Quality Control Board. The state limits effluent pH to the range of 6.5 to 8.5, which is more restrictive than the federal standard.[32]

Table 11. Municipal discharge loadings in study area - (1978 kg/dy).

Facility	Zone	Flow*	Biological oxygen demand	Total suspended solids	Total settleable material	Oil and grease	Ammonia nitrogen	Total chromate	Total sulfide	Cl	Cr	Cu	Fe	Zn
Contra Costa Sanitary District SD5	3	-	45 (50)	-	0.4	-	-	-	-	0.81 (1.88)	-	-	-	-
City of Pittsburgh Camp Staneman	3	1450 1148	715 (1555)	- (402)	-	-	-	-	0.32	- (57)	-	-	-	
City of Pittsburgh Montezuma	3	1400	434 (771)	201 (454)	-	-	-	-	-	0.0	-	-	-	-
Crokett Valonoma Sanitary District	4	0.280	242.2 (573.4)	67.1 (158.8)	-	14.96 (36.28)	18.14 (20.9)	-	-	-	-	-	-	-
Benicia Sanitary District	4	-	-	-	-	-	-	-	-	-	2.9 (4.74)	0.95 (.43)	-	1.7 (2.8)
Contra Costa Sanitary District 7A	4	750	497 (699)	377 (755)	-	106.8 (174)	-	-	-	9.4 (66.8)	-	-	-	-
Rodeo Sanitary District	5	719	-	-	-	-	-	-	-	-	0.08	0.028	-	0.75

* Flow reported in thousands of gallons/day.
\- indicates data not reported.
() indicates quantities are maximum values.

Source: San Francisco Bay Regional Water Quality Control Board files.

Table 12. EPA limitations on power plants effluents.

All Discharges	
pH	6.0-9.0
Polychlorinated Biphenyls	none

Low Volume Sources	Maximum for Any One Day (mg/l)	Average for 30 Consecutive Days (mg/l)
TSS (Total Suspended Solids)	100	30
Oil and Grease	20	15
Bottom Ash Transport Water		
TSS	100	30
Oil and Grease	20	15
Metal Cleaning Wastes and Boiler Blowdown		
TSS	100	30
Oil and Grease	20	15
Total Copper	1	1
Total Iron	1	1
Cooling Tower Blowdown		
Zinc	N.D.A	N.D.A
Chromium	N.D.A	N.D.A
Phosphorus	N.D.A	N.D.A
Other Corrosion Inhibitors	0.5	0.2

N.D.A. - No Detactable amount.

Source: Reference 32

POTENTIAL ECOLOGICAL IMPACTS

A previous section presented the available data on which estimates of impact must be based. These include both data on routine discharges from power plants and refineries, and oil spills from petroleum transporting, handling or storage. For both plant discharges and oil spills, zone 4 is a highly impacted region of the Bay. In fact, in 1978, 29 thousand gallons of petroleum from 34 spills -- about 30 kg/day. of oil and grease -- and over 170 kg/day of copper were reported to have entered this zone. Because not all dischargers are required to monitor for all effluent constituents, it is difficult to obtain a complete picture of the total level of effluents reaching the Bay. In addition, it is best to interpret the values reported as low estimates of discharges into the Bay system, since data on surface runoff have not been included.

As we suggested earlier, energy-related discharges as well as other industrial wastes may not be the most significant contributors to pollutant loading of the Bay. Municipal outfalls -- only briefly mentioned in this study -- and Delta outflow are more important to the well-being of the Bay ecosystem, at least volume and mass loading of different effluents.

A study based on field monitoring and computer modeling was conducted by the Association of Bay Area Governments (ABAG) as part of federally funded water quality planning.[31] Annual loads of biochemical oxygen demand (BOD), nutrients (total nitrogen and phosphorus), heavy metals, and total suspended solids (TSS) were estimated for San Francisco Bay for each source category (municipal, industrial, non-point, and Delta outflow).

The ABAG study reported that municipal wastewaters were the largest contributors of BOD (57%), nitrogen (58%), and phosphorus (79%).[31] Elevated BOD levels decrease dissolved oxygen the presence of which is essential for fish, shellfish, and other aquatic animals. Nitrogen and phosphorus are plant nutrients and are responsible for nuisance blooms of algae. Compliance with current water quality standards will cause a decrease in certain pollutant loads from both municipal and industrial sources as well. These new treatment programs will decrease BOD loadings to the Bay, but will not greatly affect the nitrogen or phosphorus inputs. The proposed Valley Drain, which would take agricultural wastewater from the San Joaquin Valley, could increase nitrogen concentrations, especially in the zone 4.

Delta outflow is responsible for much of the pollutant loading within San Francisco Bay. It contributes to the level of TSS (77%), heavy metals (56%), nitrogen (33%), phosphorus (17%), and BOD (26%). Delta outflow also fluctuates in response to storms and to the level of diversions by the state and federal water projects. Delta outflow for the next two decades as a result of upstream development and diversions is projected to average about 5.5 MAF during normal precipitation years.[3] This level is compared to 3.7 MAF during the 1977 drought and a typical present outflow of about 12 MAF per year.

It seems well established that there is a direct relationship between the level of Delta outflow and the health of part of the Bay ecosystem. Suspended particulate materials carried by the Delta outflow are trapped in the null or entrapment zone of the northern reach, which is also the area where phytoplankton standing crops are the highest. Both the entrapment zone and the phytoplankton standing crop can be regulated, in turn, by manipulating the Delta outflow. Zooplankton, especially Neomysis, and juvenile striped bass are also concentrated in the entrapment zone.

The relationship can be further illustrated by examining low flow conditions. When the outflow is low, the null zone migrates from Suisun Bay to deep, narrow channels upstream that do not support phytoplankton production and where the standing crop is thus low. Under these conditions, there is also a reduction of the mysid shrimp to about 25% of its normal population and of young striped bass population to about 10% of normal. Therefore by controlling the Delta outflow, the entrapment zone, the phytoplankton standing crop, and the population of zooplankton, shrimp and juvenile striped bass are also regulated.

If a water policy decision is made to maintain entrapment zone within the Suisun Bay through July (most of the summer) to protect the striped bass population, this same assemblage of organisms will be exposed for a longer period of time to effluents from the energy facilities (power plants and refineries) and to municipal outfalls in zone 4. The consequences of this interaction are unknown at this time, but they will have to be considered in the future.

The major pollutants reported as discharges from energy-related facilities are oil and other petroleum products (oil/grease), total suspended solids (TSS), and copper (see Table 9). These pollutants also make up a significant portion of the municipal discharges and the load in the Delta outflow. In addition, we have shown that a considerable amount of oil and other hazardous substances are spilled each year in the Bay system.

Fuel and crude oil generally contain toxic materials that are harmful to estuarine life even at very low concentrations. Their effect may also be accentuated through synergistic interactions. Oil damage in many regions can be persistent, sometimes lasting for years or decades, particularly if the oil becomes incorporated into bottom sediments. The impact of low-level, chronic oil discharges on organisms is still a debated scientific issue.

Total suspended solids such as silt, clay and organic particles can affect water transparency, which in turn, may limit the amount of light available to aquatic producers, i.e., phytoplankton, and disrupt the base of the estuarine food chain. Furthermore, much of the heavy-metal load of any estuary, as well as other toxicants, has been found to be associated with suspended solids. If the Delta outflow, the major contributor of TSS to the Bay, decreases over the next two decades because of additional federal and state water diversions, such as the Peripheral Canal, the level of TSS should also be expected to decline.

Heavy metals, such as copper, in sufficient concentrations can have damaging effects on aquatic organisms. These chemicals can also interact with other substances to create synergistic or antagonistic responses. A recent study of clams in the southern reach reported a four-fold variation in copper levels over time.[33] This observation was related to Delta outflow and local stream runoff. Since freshwater flushes high concentrations of metals out of organisms, such as clams, the future levels of Delta outflow will be an important consideration. Striped bass in the Bay have been reported to be heavily burdened with copper and zinc.[34] This increased pollutant burden in the adult bass is believed to be at least partly responsible for the unhealthy state of the striped bass fishery.

A paucity of data is available on the pollutant loadings in the Bay. In addition, much of the existing data are of limited value because there is little or no mention of the sampling techniques or sample variability. Natural variability caused by physical, chemical and biological disturbances may be great enough to mask many effects of man's activities. It is therefore recommended that integrated ecosystem-type studies be conducted to properly assess the pollution impacts related to other activities in the system. Furthermore, these studies should use improved sampling techniques and an intercalibration of methods between research laboratories.

In the northern reach of San Francisco Bay the impact of power plants and refineries is extremely site-dependent. These impacts include the routine introduction of pollutants into the aquatic environment, entrainment (passage of small organisms through the cooling water system), impingement (impaction of larger aquatic species on water intake screens), and the possibility of thermal pollution. Entrainment and impingment may be very important at power plants using once-through cooling systems. However, in relation to other major activities in the Bay system, such as the outflow of municipal discharges and Delta outflow, these effects may seem minimal. If we consider energy facilities in conjunction with other contributory factors, the health of the Bay may be at stake.

Major activities of the Bay that must be included in a systemwide assessment are: (1) the Peripheral Canal, which will divert large quantities of freshwater from the Bay; (2) the Valley Drain, which if built will become a significant contributor of algae-producing nitrogen to the study area; and (3) the proposed Baldwin Ship Channel, which could allow more salt water to intrude into important spawning and nursery areas.

As we have pointed out in this study, estuarine ecosystems are highly dynamic and, at times, unpredictable. Estuaries are also associated with marshes or wetlands, which serve as intermediate zones between the marine and terrestrial environments. Wetlands are highly productive, serve as a reservoir and buffer for nutrients, and are nursery areas for juveniles of many species.

Therefore, even though a technical evaluation of man's impact on estuaries is a complex and difficult task, it should be conducted in a more systematic and comprehensive fashion. This holds true not just for the San Francisco Bay system, but for estuaries located anywhere in the country, and in the world for that matter. Our modest effort here has attempted to develop this new paradigm. Studies in the future should monitor the health of the <u>entire ecosystem</u>, particularly species that man uses for food or that are considered as the most sensitive indicators of environmental health. Finally, these studies should take account of all aspects of the environment--biological, chemical and physical--and should address all sectors of the economy--municipal, industrial and agricultural. Only an analysis of this kind will be useful to policy makers who control the destiny of such fragile ecosystems.

SUMMARY

Estuaries have long been important to many of man's activities. This condition is especially relevant in terms of planned energy development, where estuarine sites for power plants and refineries become increasingly favored over freshwater alternatives. While estuarine sites are attractive, they also are areas with formidable environmental, economic and institutional constraints to energy development.

The purpose of this study is to assess the potential cumulative ecological impacts on an estuarine ecosystem resulting from fossil fuel technologies, both operating or proposed. San Francisco Bay is used as an example of such a system, since it is impacted by several fossil fuel-based activities in addition to other major actions, such as water flows and diversions, municipal and industrial discharges, and bay dredging, diking, and filling.

The available data on oil spills, energy facility discharges, and municipal outflows are examined. It is concluded that routine discharges from energy-related activities as well as other industrial sites may not be the most significant contributors to pollutant loadings of the Bay. Municipal outfalls and Delta outflow are more important in terms of volume and mass loading of different effluents.

Energy facilities do routinely discharge major pollutants, such as suspended solids, trace metals, and oil products. Major oil spills are always a concern and must be prevented. However, chronic low level discharge of oil from energy facilities including ships can pose a more serious problem to the ecosystem. The combination of effluents from energy-related activities can interact with each other and with other chemicals to create synergistic responses.

The question of siting more energy facilties within the Bay ecosystem is dependent on a more intensive site-specific analysis, which is beyond the scope of this study. If the proposed new facilities become operable the potential impacts on certain parts of the Bay, especially zone 4, will be increased. Zone 4 is already the site of several energy facilities as well as the primary location of the entrapment zone. Furthermore, if the entrapment zone is maintained Suisun Bay (zone 4) during the summer to protect the phytoplankton, zooplankton and juvenile striped bass populations, these organisms will be exposed for a longer period of time to the energy facility effluents.

The pollution from fossil fuel energy facilities must be considered in conjunction with that from other sources such as municipal waste discharge and Delta outflow. In addition, other future projects like the Peripheral Canal, the Valley Drain, and the Baldwin Ship Channel must be included in an ecological assessment of the Bay ecosystem. If all of these activities are considered, the health of the Bay may be at stake.

We recommend that a comprehensive study be conducted of the entire Bay ecosystem, one that considers all aspects of the environment and addresses all sectors of the economy. Furthermore, we recommend that such an integrated ecological study include improved sampling techniques and an intercalibration of methods between researchers. Finally, we recommend that a more complete, better organized, and readily accessible data base on the pollutant loadings in the Bay be constructed. If all these recommendations are followed, a sound understanding of how the Bay ecosystem functions in relation to its multiple uses will be gained. An assessment of this nature will be a useful tool to decision-makers throughout the country who are responsible for estuaries.

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APPENDIX A: OIL AND HAZARDOUS SUBSTANCES SPILL DATA

The tables in this appendix summarize the data used in the text for oil and hazardous-substances spills. Original data were obtained from the U.S. Coast Guard Pollution Incident Reporting System. The 1980 data used were considered to be still incomplete at the time.

Table A.1 is a summary of all spills in the entire study area from 1978 through 1980. Tables A.2 through A.7 are summaries of the data for each zone; each of those tables lists the data for each year separately.

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LBL ESTUARY ENERGY FACILITY PROJECT.

OIL AND HAZARDOUS SUBSTANCES SPILLS IN THE ENTIRE ESTUARY AREA

Table A.1

LATITUDE 3752 TO 3845, LONGITUDE 12100 TO 12238
YEARS 78 79 80

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE ENTIRE ESTUARY AREA (1978-1980)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE- LINE	LAND+ HIGH- WAY	RAIL- ROAD	OTHER+ UNKNOWN
LIGHT CRUDE OIL	7	577	327	0	0	0	0	0	0	250	0	0	0	0	0	0
HEAVY CRUDE OIL	13	34622	746	0	0	0	0	0	0	33325	0	0	1	0	0	550
CASINGH. GASOL.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
AVI/AUTO GASOL.	31	71557	64640	0	0	90	2	0	0	2350	0	0	0	4450	0	25
JET FUEL JP1-5	5	343741	0	0	0	0	0	343741	0	0	0	0	0	0	0	0
OTHER DIST FUEL	8	70	22	0	0	12	0	0	0	36	0	0	0	0	0	0
NAPHTHA	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER PET SOLV.	2	25	5	20	0	0	0	0	0	0	0	0	0	0	0	0
LIGHT DIESL OIL	51	1479	7	0	605	242	0	27	0	15	0	0	0	468	0	115
HEAVY DIESL OIL	10	71815	240	10	0	0	0	8	75	71400	0	0	0	80	0	2
"4 FUEL OIL	6	88	84	0	0	0	0	0	0	0	2	0	0	2	0	0
"5 FUEL OIL	5	2244	2242	0	0	0	0	2	0	0	0	0	0	0	0	0
"6 FUEL OIL	9	16372	10	20	0	6	0	0	0	0	336	16000	0	0	0	0
ASPHLT/ROAD OIL	2	27	0	0	0	0	0	0	0	0	0	20	0	0	0	7
ANIMAL OIL	2	241	42	0	0	0	0	0	0	0	0	0	0	199	0	0
VEGETABLE OIL	7	1860	360	0	0	0	0	0	0	0	0	0	0	0	1500	0
WASTE OIL	24	496	183	0	1	18	0	21	50	0	0	0	0	0	0	223
LUBE OIL	16	262	6	5	0	2	0	13	30	2	0	200	0	4	0	0
HYDRAULIC FLUID	8	208	10	0	0	58	0	0	0	0	0	0	0	100	0	40
LAQUER BASE PNT	4	22	0	20	0	2	0	0	0	0	0	0	0	0	0	0
MIXTUR PET PROD	24	720	151	0	50	89	0	0	0	80	0	30	200	100	0	20
UNID. LIGHT OIL	25	366	60	20	0	5	0	0	0	0	0	0	0	1	0	280
UNID. HEAVY OIL	11	426	127	226	0	0	0	4	0	0	0	1	0	25	0	43
OTHER OIL	8	141	0	0	0	10	0	0	0	0	0	20	0	0	0	111
ACETONE	1	440	0	0	0	0	0	0	0	0	0	0	0	440	0	0
BENZENE	1	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0
CHLOROSULF ACID	1	4000	0	0	0	0	0	0	0	0	0	0	0	4000	0	0
HYDROCHLOR ACID	1	23	0	0	0	0	0	0	0	0	0	0	0	0	0	23
PRCHLOROETHLENE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHENOL	1	20	0	0	0	0	0	0	0	0	0	0	0	20	0	0
PHOSPHORIC ACID	1	100	0	0	0	0	0	0	0	0	0	0	0	0	0	100
TOLUENE	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER HAZ SUBST	1	150	0	0	0	0	0	0	0	0	0	0	0	0	0	150
DREDGED SPOIL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SEWAGE SLUDGE	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
CHEMICAL WASTES	1	86	0	0	0	0	0	0	0	0	0	0	0	0	0	86
COKE	6	207	0	5	0	0	0	202	0	0	0	0	0	0	0	0
OTHER MATERIAL	4	87	35	0	0	0	0	0	0	0	0	0	0	0	0	52
UNKNOWN MATRIAL	16	32	0	0	0	0	0	0	0	0	0	0	0	0	0	32
SOURCE TOTALS	318	552519	69303	331	656	534	2	344018	155	107458	338	16271	201	9889	1500	1863

Table A.2

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE SACRMENTO+ CHNL AREA (zone 1, 1978)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
SOURCE TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE SACRMENTO+ CHNL AREA (zone 1, 1979)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
AVI/AUTO GASOL.	1	882	0	0	0	0	0	0	0	0	0	0	0	882	0	0
LIGHT DIESL OIL	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10
SOURCE TOTALS	2	892	0	0	0	0	0	0	0	0	0	0	0	882	0	10

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE SACRMENTO+ CHNL AREA (zone 1, 1980)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
UNID. LIGHT OIL	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5
SOURCE TOTALS	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE DELTA + STOCKTN AREA (zone 2, 1978)

Table A.3

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
AVI/AUTO GASOL.	1	1000	0	0	0	0	0	0	0	0	0	0	0	1000	0	0
LUBE OIL	1	30	0	0	0	0	0	0	30	0	0	0	0	0	0	0
MIXTUR PET PROD	2	110	0	0	50	60	0	0	0	0	0	0	0	0	0	0
UNID. LIGHT OIL	1	50	0	0	0	0	0	0	0	0	0	0	0	0	0	50
OTHER HAZ SUBST	1	150	0	0	0	0	0	0	0	0	0	0	0	0	0	150
SOURCE TOTALS	6	1340	0	0	50	60	0	0	30	0	0	0	0	1000	0	200

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE DELTA + STOCKTN AREA (zone 2, 1979)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
WASTE OIL	1	100	0	0	0	0	0	0	0	0	0	0	0	0	0	100
LUBE OIL	1	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0
MIXTUR PET PROD	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UNID. LIGHT OIL	3	20	0	15	0	0	0	0	0	0	0	0	0	0	0	5
SOURCE TOTALS	6	125	0	20	0	0	0	0	0	0	0	0	0	0	0	105

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE DELTA + STOCKTN AREA (zone 2, 1980)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
JET FUEL JP1-5	3	343741	0	0	0	0	0	343741	0	0	0	0	0	0	0	0
LIGHT DIESL OIL	4	10	0	0	0	5	0	0	0	0	0	0	0	0	0	5
UNKNOWN MATRIAL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOURCE TOTALS	8	343751	0	0	0	5	0	343741	0	0	0	0	0	0	0	5

Table A.4

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE PITTSBURG- ANT. AREA (zone 3, 1978)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE- LINE	LAND+ HIGH- WAY	RAIL- ROAD	OTHER+ UNKNOWN
LIGHT DIESL OIL	1	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
LUBE OIL	1	200	0	0	0	0	0	0	0	0	0	200	0	0	0	0
UNKNOWN MATRIAL	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5
SOURCE TOTALS	3	305	0	0	0	0	0	0	0	0	0	200	0	100	0	5

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE PITTSBURG- ANT. AREA (zone 3, 1979)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE- LINE	LAND+ HIGH- WAY	RAIL- ROAD	OTHER+ UNKNOWN
#6 FUEL OIL	1	336	0	0	0	0	0	0	0	0	336	0	0	0	0	0
WASTE OIL	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	6
COKE	1	200	0	0	0	0	0	200	0	0	0	0	0	0	0	0
SOURCE TOTALS	3	542	0	0	0	0	0	200	0	0	336	0	0	0	0	6

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE PITTSBURG- ANT. AREA (zone 3, 1980)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE- LINE	LAND+ HIGH- WAY	RAIL- ROAD	OTHER+ UNKNOWN
#4 FUEL OIL	1	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0
#6 FUEL OIL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOURCE TOTALS	2	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0

Table A.5

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE BAYS+ CARQ STRT AREA (zone 4, 1978)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
LIGHT CRUDE OIL	3	22	22	0	0	0	0	0	0	0	0	0	0	0	0	0
HEAVY CRUDE OIL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CASINGH. GASOL.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
AVI/AUTO GASOL.	6	26790	22638	0	0	0	2	0	0	2350	0	0	0	1800	0	0
JET FUEL JP1-5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER DIST FUEL	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
LIGHT DIESL OIL	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
"4 FUEL OIL	1	84	84	0	0	0	0	0	0	0	0	0	0	0	0	0
"5 FUEL OIL	2	2232	2232	0	0	0	0	0	0	0	0	0	0	0	0	0
WASTE OIL	3	70	0	0	0	0	0	20	0	0	0	0	0	0	0	50
LUBE OIL	1	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0
MIXTUR PET PROD	1	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
UNID. LIGHT OIL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UNID. HEAVY OIL	3	3	1	0	0	0	0	1	0	0	0	1	0	0	0	0
PRCHLOROETHLENE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DREDGED SPOIL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COKE	2	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0
OTHER MATERIAL	1	52	0	0	0	0	0	0	0	0	0	0	0	0	0	52
UNKNOWN MATRIAL	3	25	0	0	0	0	0	0	0	0	0	0	0	0	0	25
SOURCE TOTALS	34	29392	24984	5	0	0	2	21	0	2351	0	1	0	1900	0	128

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE BAYS+ CARQ STRT AREA (zone 4, 1979)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
LIGHT CRUDE OIL	1	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0
HEAVY CRUDE OIL	2	35	15	0	0	0	0	0	0	20	0	0	0	0	0	0
AVI/AUTO GASOL.	4	427	2	0	0	0	0	0	0	0	0	0	0	400	0	25
OTHER DIST FUEL	1	21	21	0	0	0	0	0	0	0	0	0	0	0	0	0
LIGHT DIESL OIL	2	70	0	0	0	0	0	0	0	0	0	0	0	20	0	50
"4 FUEL OIL	1	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0
"5 FUEL OIL	1	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0
"6 FUEL OIL	5	16016	10	0	0	6	0	0	0	0	0	16000	0	0	0	0
WASTE OIL	4	12	5	0	0	0	0	1	0	0	0	0	0	0	0	6
LUBE OIL	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
LAQUER BASE PNT	1	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0
MIXTUR PET PROD	5	205	0	0	0	0	0	0	0	0	0	0	200	0	0	5
UNID. LIGHT OIL	5	204	0	0	0	0	0	0	0	0	0	0	0	1	0	203
UNID. HEAVY OIL	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
OTHER OIL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACETONE	1	440	0	0	0	0	0	0	0	0	0	0	0	440	0	0
HYDROCHLOR ACID	1	23	0	0	0	0	0	0	0	0	0	0	0	0	0	23
COKE	2	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0
UNKNOWN MATRIAL	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
SOURCE TOTALS	42	17471	58	0	0	8	0	5	0	20	0	16000	200	864	0	316

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE BAYS+ CARQ STRT AREA (zone 4, 1980)

Table A.5 (cont.)

MATERIAL	NO. OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
HEAVY CRUDE OIL	1	33300	0	0	0	0	0	0	0	33300	0	0	0	0	0	0
AVI/AUTO GASOL.	2	5	0	0	0	5	0	0	0	0	0	0	0	0	0	0
OTHER DIST FUEL	4	36	1	0	0	0	0	0	0	35	0	0	0	0	0	0
LIGHT DIESL OIL	2	20	0	0	0	10	0	0	0	10	0	0	0	0	0	0
LUBE OIL	3	11	0	0	0	0	0	10	0	0	0	0	0	1	0	0
LAQUER BASE PNT	1	20	0	20	0	0	0	0	0	0	0	0	0	0	0	0
MIXTUR PET PROD	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
UNID. LIGHT OIL	2	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0
UNID. HEAVY OIL	1	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0
CHEMICAL WASTES	1	86	0	0	0	0	0	0	0	0	0	0	0	0	0	86
COKE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UNKNOWN MATRIAL	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
SOURCE TOTALS	20	33592	11	120	0	15	0	10	0	33345	0	0	0	1	0	90

Table A.6

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE SAN PABLO BAY AREA (zone 5, 1978)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
AVI/AUTO GASOL.	2	25	0	0	0	5	0	0	0	0	0	0	0	20	0	0
LIGHT DIESL OIL	8	302	0	0	0	101	0	1	0	0	0	0	0	200	0	0
HEAVY DIESL OIL	1	30	0	0	0	0	0	0	0	0	0	0	0	30	0	0
WASTE OIL	2	138	138	0	0	0	0	0	0	0	0	0	0	0	0	0
LUBE OIL	1	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0
HYDRAULIC FLUID	1	10	0	0	0	10	0	0	0	0	0	0	0	0	0	0
MIXTUR PET PROD	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
UNID. LIGHT OIL	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER OIL	2	30	0	0	0	10	0	0	0	0	0	20	0	0	0	0
SOURCE TOTALS	21	533	139	0	0	128	0	1	0	0	0	20	0	250	0	0

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE SAN PABLO BAY AREA (zone 5, 1979)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
LIGHT CRUDE OIL	1	250	0	0	0	0	0	0	0	250	0	0	0	0	0	0
HEAVY CRUDE OIL	2	337	336	0	0	0	0	0	0	0	0	0	1	0	0	0
AVI/AUTO GASOL.	1	200	0	0	0	0	0	0	0	0	0	0	0	200	0	0
LIGHT DIESL OIL	5	37	0	0	0	9	0	0	0	0	0	0	0	3	0	25
HEAVY DIESL OIL	1	30	30	0	0	0	0	0	0	0	0	0	0	0	0	0
ASPHLT/ROAD OIL	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	7
MIXTUR PET PROD	1	30	0	0	0	0	0	0	0	0	0	30	0	0	0	0
UNID. LIGHT OIL	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5
UNKNOWN MATRIAL	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOURCE TOTALS	15	895	366	0	0	9	0	0	0	250	0	30	1	203	0	37

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE SAN PABLO BAY AREA (zone 5, 1980)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE-LINE	LAND+ HIGH-WAY	RAIL-ROAD	OTHER+ UNKNOWN
HEAVY CRUDE OIL	2	305	0	0	0	0	0	0	0	5	0	0	0	0	0	300
AVI/AUTO GASOL.	2	43	0	0	0	0	0	0	0	0	0	0	0	43	0	0
LIGHT DIESL OIL	2	45	0	0	0	45	0	0	0	0	0	0	0	0	0	0
HEAVY DIESL OIL	1	75	0	0	0	0	0	0	75	0	0	0	0	0	0	0
HYDRAULIC FLUID	2	126	0	0	0	26	0	0	0	0	0	0	0	100	0	0
MIXTUR PET PROD	1	80	0	0	0	0	0	0	0	80	0	0	0	0	0	0
SOURCE TOTALS	10	674	0	0	0	71	0	0	75	85	0	0	0	143	0	300

Table A.7

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE RICHMOND- MARIN AREA (zone 6, 1978)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE- LINE	LAND+ HIGH- WAY	RAIL- ROAD	OTHER+ UNKNOWN
LIGHT CRUDE OIL	2	300	300	0	0	0	0	0	0	0	0	0	0	0	0	0
HEAVY CRUDE OIL	3	59	59	0	0	0	0	0	0	0	0	0	0	0	0	0
AVI/AUTO GASOL.	6	103	0	0	0	3	0	0	0	0	0	0	0	100	0	0
JET FUEL JP1-5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER PET SOLV.	2	25	5	20	0	0	0	0	0	0	0	0	0	0	0	0
LIGHT DIESL OIL	8	67	0	0	5	20	0	1	0	0	0	0	0	25	0	16
HEAVY DIESL OIL	3	12	0	10	0	0	0	0	0	0	0	0	0	0	0	2
"4 FUEL OIL	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
"6 FUEL OIL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASPHLT/ROAD OIL	1	20	0	0	0	0	0	0	0	0	0	20	0	0	0	0
VEGETABLE OIL	4	290	290	0	0	0	0	0	0	0	0	0	0	0	0	0
WASTE OIL	6	16	0	0	0	8	0	0	0	0	0	0	0	0	0	8
LUBE OIL	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
HYDRAULIC FLUID	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LAQUER BASE PNT	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MIXTUR PET PROD	4	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0
UNID. LIGHT OIL	5	12	0	0	0	5	0	0	0	0	0	0	0	0	0	7
UNID. HEAVY OIL	1	126	0	126	0	0	0	0	0	0	0	0	0	0	0	0
OTHER OIL	4	11	0	0	0	0	0	0	0	0	0	0	0	0	0	11
CHLOROSULF ACID	1	4000	0	0	0	0	0	0	0	0	0	0	0	4000	0	0
OTHER MATERIAL	3	35	35	0	0	0	0	0	0	0	0	0	0	0	0	0
UNKNOWN MATRIAL	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOURCE TOTALS	64	5079	689	156	5	38	0	1	0	0	0	20	0	4126	0	44

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE RICHMOND- MARIN AREA (zone 6, 1979)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE- LINE	LAND+ HIGH- WAY	RAIL- ROAD	OTHER+ UNKNOWN
HEAVY CRUDE OIL	1	336	336	0	0	0	0	0	0	0	0	0	0	0	0	0
AVI/AUTO GASOL.	3	42077	42000	0	0	77	0	0	0	0	0	0	0	0	0	0
OTHER DIST FUEL	1	10	0	0	0	10	0	0	0	0	0	0	0	0	0	0
NAPHTHA	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
LIGHT DIESL OIL	11	94	5	0	0	40	0	25	0	0	0	0	0	20	0	4
HEAVY DIESL OIL	1	210	210	0	0	0	0	0	0	0	0	0	0	0	0	0
"4 FUEL OIL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANIMAL OIL	1	42	42	0	0	0	0	0	0	0	0	0	0	0	0	0
VEGETABLE OIL	3	1570	70	0	0	0	0	0	0	0	0	0	0	0	1500	0
WASTE OIL	4	79	25	0	1	0	0	0	50	0	0	0	0	0	0	3
LUBE OIL	4	4	0	0	0	0	0	3	0	0	0	0	0	1	0	0
HYDRAULIC FLUID	2	22	0	0	0	22	0	0	0	0	0	0	0	0	0	0
LAQUER BASE PNT	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MIXTUR PET PROD	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10
UNID. HEAVY OIL	2	129	126	0	0	0	0	3	0	0	0	0	0	0	0	0
BENZENE	1	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0
PHOSPHORIC ACID	1	100	0	0	0	0	0	0	0	0	0	0	0	0	0	100
TOLUENE	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
SEWAGE SLUDGE	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
UNKNOWN MATRIAL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOURCE TOTALS	42	44697	42820	5	1	149	0	31	50	0	0	0	0	21	1500	120

SUMMARY OF OIL AND HAZARDOUS SPILLS IN THE RICHMOND- MARIN AREA (zone 6, 1980)

Table A.7 (cont.)

MATERIAL	NO.OF SPILLS	TOTAL GALS.	TANK VESSLS	DRY CARGO VESSLS	TUG/ TOW BOATS	OTHER VSSLS/ FACIL.	FUELNG	CARGO TRNSFR	BULK STORGE FACLTY	OILGAS PROD+ REFI.	POWER PLANT	INDUST PLANT	PIPE- LINE	LAND+ HIGH- WAY	RAIL- ROAD	OTHER+ UNKNOWN
HEAVY CRUDE OIL	1	250	0	0	0	0	0	0	0	0	0	0	0	0	0	250
AVI/AUTO GASOL.	3	5	0	0	0	0	0	0	0	0	0	0	0	5	0	0
OTHER DIST FUEL	1	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0
LIGHT DIESL OIL	6	722	0	0	600	12	0	0	0	5	0	0	0	100	0	5
HEAVY DIESL OIL	3	71458	0	0	0	0	0	8	0	71400	0	0	0	50	0	0
"5 FUEL OIL	2	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0
"6 FUEL OIL	1	20	0	20	0	0	0	0	0	0	0	0	0	0	0	0
ANIMAL OIL	1	199	0	0	0	0	0	0	0	0	0	0	0	199	0	0
WASTE OIL	3	75	15	0	0	10	0	0	0	0	0	0	0	0	0	50
LUBE OIL	2	3	1	0	0	0	0	0	0	2	0	0	0	0	0	0
HYDRAULIC FLUID	2	50	10	0	0	0	0	0	0	0	0	0	0	0	0	40
MIXTUR PET PROD	6	179	150	0	0	27	0	0	0	0	0	0	0	0	0	2
UNID. LIGHT OIL	3	60	50	5	0	0	0	0	0	0	0	0	0	0	0	5
UNID. HEAVY OIL	3	65	0	0	0	0	0	0	0	0	0	0	0	25	0	40
OTHER OIL	1	100	0	0	0	0	0	0	0	0	0	0	0	0	0	100
PHENOL	1	20	0	0	0	0	0	0	0	0	0	0	0	20	0	0
SOURCE TOTALS	39	73218	236	25	600	51	0	8	0	71407	0	0	0	399	0	492

APPENDIX B: AVERAGE MONTHLY WATER DATA FOR SELECTED ENERGY FACILITIES

Average monthly data (1978) were obtained for several energy facilities. Only the three parameters--flow, pH, and temperature--were available. The only peculiarity noted in the data is the fluctuation of temperature from 145° F early in the year to about 70° F later on at one facility. No explanation was given for this large fluctuation.

Table B.1. Average monthly flow rates from selected energy facilities -- 1978 (mgd).

	Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Martinez PG&E Avon	4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.3
PG&E Martinez	4	0.3	0.2	0.3	0.3	0.2	0.3	o.2	0.3	0.2	0.3	0.2	0.2
Rodeo PG&E Oleum	5	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2
Benicia Exxon Refinery	4	3.2	2.9	3.1	2.6	2.5	1.3	2.2	1.7	2.3	2.1	2.1	2.1
Richmond Standard Oil Refinery	6	18.1	16.8	20.4	17.5	15.1	13.6	12.8	18.8	14.3	13.0	13.0	12.9

Source: San Francisco Regional Water Quality Control Board files.

Table B.2. Average monthly pH values from selected energy facilities -- 1978.

	Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Martinez PG&E Avon	4	7.3	8.8	7.7	8.3	8.9	7.6	7.9	8.1	7.8	7.2	7.5	7.2
PG&E Martinez	4	--	--	--	--	--	--	--	--	--	--	--	--
Rodeo PG&E Oleum	5.	7.4	7.8	7.9	8.1	8.0	7.8	7.8	7.7	7.8	7.7	7.8	7.7
Benicia Exon Refinery	4	6.9	7.0	7.0	7.7	7.7	7.5	7.5	7.3	7.7	7.5	7.3	6.9
Richmond Standard Oil Refinery	6	8.0	8.0	8.2	8.2	8.0	8.8	8.8	8.2	8.3	7.9	8.4	8.2

(--) indicates no data available.
Source: San Francisco Regional Water Quality Control Board files.

Table B.3. Average monthly temperature from selected energy facilities -- 1978 (Degrees Fahrenheit).

	Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Martinez PG&E Avon	4	145	145	140	140	66	65	67	74	75	77	67	71
PG&E Martinez	4	78	81	86	83	78	79	79	85	85	78	73	63
Rodeo PG&E Oleum	5	55	54	59	63	65	67	66	70	69	68	64	51
Benicia Exon Refinery	4	61	64	70	72	75	73	75	73	75	65	61	60
Richmond Standard Oil Refinery	6	72	72	77	78	82	81	82	80	83	80	72	68

Source: San Francisco Regional Water Quality Control Board files.

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