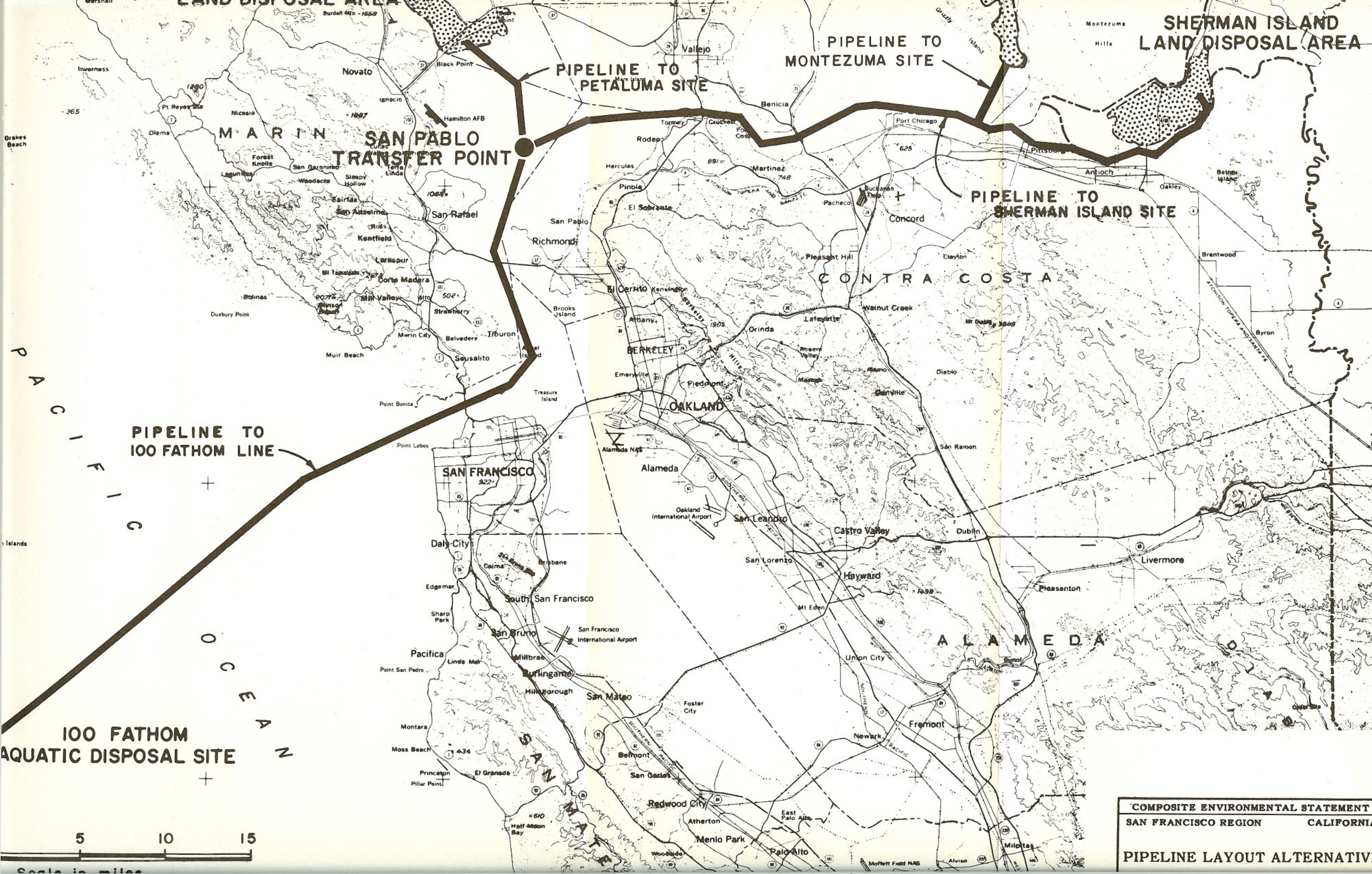


COMPOSITE ENVIRONMENTAL STATEMENT
SAN FRANCISCO REGION CALIFORNIA
PIPELINE LAYOUT ALTERNATIVE

6.052 The Petaluma and Sherman Island transfer points would act as a temporary retaining area to which the hopper and scow would unload the dredgings, and the material would eventually be transported to the ocean through the long-distance pipeline. Access to these areas by hopper would require some deepening and maintenance.

6.053 Although transport of dredged material through long pipelines is undoubtedly a possibility, it must be recognized that the alignment described for the self-contained system is conceptual, and that many technical, economic and environmental factors will have to be considered before such a system can be implemented or constructed.

2. Land Disposal

a. Introduction.

6.054 Potential land disposal sites around the Bay are being investigated by the San Francisco District as a part of its review of long-range alternative disposal methods and as a part of regional criteria. The intent of the study is to place this method of disposal in context with other disposal methods. Placing environmental constraints on the various potential sites, including the Corps policy regarding mean higher high water, is a judgment factor. Reviewing this judgment factor from the point of view of other regulatory agencies provides a basis for showing whether or not land disposal is really a viable alternative in a long-range disposal program for O & M dredging projects of San Francisco Bay. The basic data gathering and initial choices of potential sites were accomplished under contract by the International Engineering Company, and their findings are published in the Dredge Disposal Study (DDS), Appendix J (204).

6.055 The land disposal study described in Appendix J does not include value assessments in comparison to the present system of aquatic disposal. Land disposal has been objectively investigated for feasibility by itself as a future planning solution in the event that aquatic disposal is no longer permitted. Under the conditions of no aquatic disposal, land disposal would assume a possible role in sustaining O & M dredging in the Bay system. Out of all of the O & M projects, only 5 are anticipating land disposal. The total dredged material to be disposed on land from these five projects amounts to 5 percent of the sum total of the O & M projects.

6.056 Comments received from the U. S. Fish and Wildlife Service and California Fish and Game indicate that any areas below mean higher high water should not be considered for dredge disposal unless these areas have lost the potential for restoration to tidal marsh or that satisfactory mitigation measures can be implemented to offset the potential loss of restorable marsh.

6.057 Before briefly discussing the above study, it should be pointed out that the study is available to the public, and that specific comments on the study were asked from members of the Dredge Advisory Group (DAG)[1].

6.058 It should also be noted that, although this study consists of a long-range analysis, dredge disposal on upland areas is considered a limited or short-term solution. Once these designated areas are filled to their capacity the problem will again arise as to where to dispose additional material. This study has assumed a 20-year life of the disposal sites investigated. The sediment disposal sites as outlined in Appendix J of the DDS do not constitute a San Francisco District disposal program for either O & M dredging or new dredging projects. The following discussion briefly describes the land site selection process within the land disposal feasibility study.

b. Land Disposal Study.

6.059 At the onset of the feasibility study certain constraints in selecting potential upland sites were imposed by the Corps to reflect the environmental concerns of today and to realistically identify suitable sites within economic means of transporting the material there. The constraints were:

1. Areas must be larger than 200 acres. This was to identify and evaluate sites capable of accommodating disposal from dredging for 20 years.

1/DAG consists of representatives from EPA, U. S. Fish and Wildlife Service, National Marine Fisheries Service, Corps of Engineers, RWCQB, BCDC, State Fish & Game, State Lands Commission, C-MANC and Dredging Contractors Assn., who meet monthly to discuss dredge disposal issues. Meetings are open to the public.

2. Sites must not encompass public wildlife refuges, recreational areas or critical wildlife habitats (undiked marshes and mudflats).

3. Areas should be below the 50-foot mean sea level elevation and above mean higher high water:

- the upper elevation due to transportation economics;
- the lower elevation due to regulatory agency policies affecting such areas (Note: The lower elevation, as one will determine in the discussion, was not fully complied with because of lack of suitable sites above MHHW).

4. Areas with existing development should be excluded.

5. Areas should be within 60 miles of any dredging site.

6. Areas of excessive slope of those required for flood plain management should be excluded.

6.060 Rock quarries were considered but ruled out because of their small capacities. Sand and gravel quarries were eliminated because of potential contamination of groundwater by possible pollutants in the dredged material. All land areas within the above constraints were evaluated with respect to technical, environmental and economic considerations (detailed descriptions may be found in Appendix J):

6.061 (1) Technical Considerations. Several factors were investigated; among these were slope variability, bay mud physical characteristics, load capacity, subsidence, seismicity, drainage and site accessibility.

6.062 (2) Environmental Considerations. When considering potential sites based on environmental concerns there are several conditions that must be met. Regulations concerning water quality of effluent, noise and air pollution must be met. Geologic and hydrologic effects, aesthetics, and effects on adjacent vegetation and wildlife must also be weighed. In evaluating the long-range environmental effects future use of the disposal site should be considered. The site might be used to enhance the local area through increased flood protection, recreational and wildlife habitat protection and agricultural or industrial use. Long-range use could also cause adverse environmental effects. Landfill operations could materially and perhaps irretrievably change the characteristics and uses of such lands, eliminating the possibility of returning these lands to marsh.

c. Site Selection.

6.063 In addition to the constraints and considerations mentioned above, agencies and parties having interest in land disposal of dredged material were contacted to obtain further information. In the end, six general areas with 15 potential sites emerged from the selection process. These were:

South Bay

-Alviso-Milpitas
-South Fremont
-North Fremont
-Bair Island

Central Bay
-Bay Farm Island

North Bay
-Hamilton AFB South
-Hamilton AFB North

Petaluma-Sonoma-Napa
-Petaluma River Area
-Sonoma Creek Area
-Napa River

Suisun Bay-Delta
-Avon
-Montezuma
-Sherman Island

Fairfield-Dixon
-Thomassom
-Travis AFB

6.064 All of these potential sites are discussed in detail in Appendix J of the Dredge Disposal Study. Of the 15 individual sites, three were identified as possibly suitable for receiving dredged material from O & M projects and are briefly described as follows:

6.065 (1) <u>Petaluma River Area (Site No. 8, Plate VI-4)</u>. This site is composed of three sub-areas: (1) an area of 5,700 acres bounded on the east by the Lakeville Highway, on the west by the Petaluma River, and on the south of San Pablo Bay; (2) an area of 1,300 acres on the east side of Petaluma River between Petaluma and Lakeville, west of Highway 16; and (3) an area of 1,600 acres on the west side of Petaluma River around the Marin County Airport. The areas are protected by dikes and used for agricultural or grazing purposes. About 30 percent of the area is below MHHW. Total capacity is estimated at 139 million c.y. to elevation +10, uncompacted.

6.066 Sub-area (1) is probably one of the most promising for land disposal in the Bay area from the standpoints of location and size.

6.067 Site access could be via either dredged channel or pipeline with operations effluent returned to the Bay by the Petaluma River. Portions of this site are below MHHW while the remainder slopes upward to elevation +10 in the inland direction.

6.068 There is some potential for archaeological remains, although few have been found to date. Few other technical problems exist at this site given presently available information, particularly if adequate safeguards are employed with regard to control of surface water run-off from the site.

6.069 The site is in an active seismic area, being only 15 miles from the San Andreas fault and five miles from the Healdsburg-Rodgers Creek. Seismicity represents little hazard, if any, should this area be used for agriculture.

6.070 Despite the obvious technical and economic advantages of Petaluma sub-area (1), this site is highly questionable due to the potential environmental hazards. The site is adjacent to the San Pablo Bay National Wildlife Refuge which covers most of the northern San Pablo Bay. Land disposal operations could threaten wildlife at the Refuge and destroy portions of valuable marshland or potential marshland habitat.

6.071 Sub-area (2), in the same drainage area as the first, is adjacent to the Petaluma marsh and is protected by levees along the river. Technical and economic considerations are similar to those of the lower Petaluma River site, although costs would be higher because of the longer transport distance.

6.072 Sonoma County has considered both the upper and lower areas in a draft flood plain zoning plan (184). It was proposed that the upper area be zoned "F-1" (Primary Flood Plain) and the lower area "F-2" (Secondary Flood Plain). "F-1" zones cannot be obstructed if the flood hazard will be increased by so doing; "F-2" areas are subject to flooding but are not required to carry off or store flood waters. These definitions would tend to allow the use of the lower site for fill disposal but not the upper. The proposed flood plain zoning has not been adopted as of this writing, however.

6.073 The upper Petaluma site could be subject to additional criticism as a disposal site because of its proximity to the Petaluma Marsh.

6.074 Sub-area (3), in the Petaluma River drainage area, adjacent to the Marin County Airport, is low and flat, protected by levees, and traversed by several small creeks and ditches. It has moderate to high wildlife use. Technical considerations here are similar to the other Petaluma sites. There is a low to moderate potential for archaeological remains. The nearness of the site to U.S. 101 and the County Airport will affect ultimate land use, and put a premium on close coordination with those responsible for land use planning in the area. The primary disadvantage of this site is its small area and hence limited capacity for dredged material.

6.075 ABAG has designated most of the area as permanent open space with a small amount for controlled development. BCDC exerts control over the wetlands along the periphery of the sites, but has noted the potential for water-related industry for the area to the north of the Petaluma River mouth. The U.S. Fish and Wildlife Service feels that "major problems" would be associated with disposing of dredged material on any of the three Petaluma River sites and does not consider them suitable. (181)

6.076 (2) Montezuma Area (Site No. 12, Plate VI-5). One of the better sites from many aspects including size, location near a deep-water channel, flat topography, etc., is the Montezuma site. It is a diked agricultural area west of the town of Collinsville, bounded on the east by the 50-foot contour line and on the west by Montezuma Slough, which is adjacent to Suisun Marsh. About 80 percent is below MHHW. Construction of an exterior levee adjacent to Montezuma Slough reclaimed the site area from marshland. At the present time only a small amount of the site, principally in the south portion of the area, is used for farming with the remaining portions being used for cattle and sheet grazing. The site encompasses 3,000 acres and has a capacity for 44 million c.y. to elevation +10, uncompacted.

6.077 Solano County has designated a portion of this site as agricultural, grazing and watershed land, with the remainder as industrial (183). Their plan notes the importance of this area as one of the few remaining areas along the river where water-related industry can be located. A recent State Senate Bill (#1981) has created a buffer zone around the marsh area of Montezuma. ABAG designates the site as urban developed or controlled open space land, while BCDC's Bay Plans show the site potentially available to water-related industry. The U. S. Fish and Wildlife Service feels that disposing at Montezuma would pose major impacts on the high wildlife value in this area, and that area below MHHW could be readily restored to tidal action (181). The joint owners of this property are the Southern Pacific Railway Company and the National Steel Corporation.

6.078 The site has moderate to high wildlife use. It is adjacent to the Suisun game management area and to several waterfowl clubs. Portions of this area fall within jurisdiction of the Suisun Marsh Preservation Act of 1974. There is the potential for mudwave shallowing of the adjacent slough. Archaeologic potential is moderate. Effluent discharges to the slough and marsh areas nearby may produce negative environmental effects. In summary, the site poses considerable technical and environmental problems.

6.079 (3) Sherman Island Area (Site No. 13, Plate VI-5). The Delta Islands are prime sites for disposal of dredged material because of their size and proximity to water transport. Undesirable features are the great distances from dredged sites and possible foundation problems. The site totals 10,000 acres with a capacity for 317 million c.y. to elevation +10, uncompacted.

6.080 As a representative Delta Island, Sherman Island, the closest to the dredging sites, was chosen for analysis. Other adjacent islands, such as Jersey, Bethel, Bradford, Webb, Twitchell and Brannan, would be very similar but would require longer transport for the dredged material.

6.081 The soil of the Delta Islands is sediment and peat, and is productive agricultural land.

6.082 In addition to their high values from an agricultural viewpoint, the Delta Islands are a habitat for many forms of wildlife and are used extensively by hunters. The adjacent sloughs and rivers form an important fishery resource, and fishing, as well as other water-related activity, is an important attraction. The southwestern boundary of the site is adjacent to the State Game Management Area and consequently the effect of the project on wildlife values in the areas will have to be carefully evaluated.

6.083 Archaeologic potential of the site is low. Control of project water discharges to the adjacent river system will require careful study because of the adjacent wildlife areas and the importance of the fisheries resources of the Delta area.

6.084 The addition of the dredge spoil would reduce the danger of flooding by a simple increase in average elevation, since the island is presently entirely below MHHW. Deposition of the spoils would also probably result in a reduced rate of oxidation of peat deposits, with a consequent reduction in the rate of land subsidence.

6.085 BCDC and ABAG have no jurisdiction in the area. The Sacramento County Comprehensive Zoning Plan classifies Sherman Island as AG-20 and AG-80 (agricultural). There do not appear to be any administrative constraints to the use of the island for disposal of dredged fill.

6.086 The U. S. Fish and Wildlife Service states: "The proposal for a pipeline to site 13 on Sherman and Jersey islands has the most appeal to us because the spoils would be put to the beneficial use of raising the elevation of the sunken Delta lands" for use "as productive agricultural land" (181). They also indicate, however, that the area is valuable as a wildlife habitat and that it acts as a buffer zone to important fish and wildlife areas. Effects of disposal operations on adjacent fish and wildlife areas will have to be considered further.

d. Conclusions.

6.087 If dredged material can be considered a potentially useful resource as opposed to it being defined as a "spoil" or "waste," then land disposal of dredged sediments could become an attractive alternative. Land disposal sites could possibly be used for agriculture, recreation or for wildlife habitat.

6.088 For example, Murphy and Ziegler noted that dredged material could serve as a growing medium for many plants (118). They described practices of removing and stockpiling topsoil and subsequently replacing topsoil over dredged material; and improving the value of crop growing properties by mixing the dredged material with sand or humus. Surplus agricultural products could be utilized as admixtures to improve the quality of the dredge material; for example, rice hulls, which are a surplus commodity at the Port of Sacramento, could possibly be used.

6.089 However, land disposal would also involve undesirable environmental effects. Disposal at the Petaluma and Montezuma sites would adversely affect wildlife residing in these areas, and would virtually eliminate the possibility of restoring portions of these lowlands to intertidal marsh. For these reasons the U. S. Fish and Wildlife Service is strongly opposed to disposal in many lowland areas adjacent to or possessing wildlife habitats and suggests "substantial mitigation would be necessary for the loss of these important wildlife values" (181). In a recent letter they have stated their opposition to land disposal at the Petaluma and Montezuma sites (180). Similarly, the State Department of Fish and Game is strongly concerned with historic loss of marshes in the Bay area and would require "adequate mitigation" (82). EPA also has "very strong reservations" about use of the Montezuma site (40). On the other hand, the topography of the Sherman Island site offers the capacity for potential land disposal in an environmentally acceptable location (292). Both EPA and U. S. Fish and Wildlife Service consider Sherman Island to be among the more preferable of the potential land disposal sites.

6.090 The land disposal considerations discussed above are simply part of a preliminary overview. Due to the anticipated technical difficulties and adverse environmental effects which may be involved, extensive land disposal for O & M dredging projects does not appear to be a viable alternative to aquatic disposal at this time. However, since Sherman Island appears environmentally acceptable as a potential land disposal area and as an area for possible marsh restoration, technical and economic considerations such as site preparation and additional operations were included in the overall feasibility determination. The only O & M projects presently utilizing land disposal are San Rafael Creek, San Leandro Marina and Redwood City Harbor, where land disposal has historically been used. The Suisun Slough and New York Slough projects are anticipating land disposal.

6.091 3. Island Creation from Dredged Material. Wildlife habitats could also be created by construction of "spoil islands", and in several instances, disposal areas in other parts of the country are being used as recreational areas. Conditioned sediments could act as an engineered fill to be used for support of structures. Experience obtained at Redwood Shores in South Bay and elsewhere indicate that light construction can be accommodated on an engineered fill of bay mud. Effects of creating "spoil islands" on local sedimentation and circulation would have to be investigated for each potential site. Categorically, however, the creation of new land areas within the confines of San Francisco Bay would diminish water quality (reduction of tidal prism) and climate.

6.092 4. Delta Island Reclamation. The Delta levees were originally built to reclaim the rich Delta soil and to protect it from flooding. Presently, many miles of levees are in need of repair and rehabilitation. Land subsidence is continuing to lower many Delta Islands as well. The State Department of Water Resources has undertaken a Delta Levee Study and released an interim report, "Delta Levees -- What is Their Future?", September 1973, in which four alternatives were previewed. The Delta levees can be improved by raising, widening, and strengthening embankment as needed. The four alternatives proposed in the interim report are described briefly below:

a. No improvement.

b. Extensive improvement - 100-year flood protection for all leveed islands and tracts.

c. Moderate improvement - 50-year flood protection over 290 miles of levees.

d. Polders - development of five islands in addition to Sherman Island; 213 miles of levees would be improved to 50-year flood protection; 35 channel closures with 23 small craft locks to furnish access between the interior and exterior channels; 250 miles of channels now open to tidal action will become interior channels.

6.093 The State Department of Water Resources has completed its feasibility report in Bulletin 192, May 1975, in which a specific program for upgrading the Delta levees, both structurally and environmentally, was recommended based on the results of the five public meetings held in February 1974 (296). The recommended plan presented in Bulletin 192 is a compromise plan containing both 50- and 100-year flood protection to preserve open space and protect urban centers respectively. Based on best available data, an estimated 14 million cubic yards of material are required for the initial improvements. With detailed studies, an exact figure for required material will be determined. Quantities of material for expected maintenance work have not been estimated although maintenance cost figures have been shown in the bulletin. These cost figures are based on annual replacement costs to maintain levee stability at other locations. A construction period of approximately 20 years has been indicated to minimize environmental effects. This time frame is required for adding new material as settlement of the berms and levees takes place.

6.094 With respect to solid waste management, ABAG has proposed a preliminary plan to demonstrate recovery of resources from urban waste by mixing composted refuse with dredged material for island reclamation in the Delta (51). The concept of mixing dredged material with other component materials to produce a compound to rehabilitate the Delta levees has also been suggested in correspondence from the State Department of Water Resources (295). Prior to implementation of the proposed action, the State Legislature will decide the merits of the recommendations, and future program planning will be subject to review by agencies and the general public.

6.095 Important considerations in future studies would include methods of collection and transportation of dredged materials from O & M project locations to the Delta levees or mixing station, hauling and operating costs, and environmental concerns at the Delta levees and within the Delta channel system. With detailed investigation of technical, economic and environmental concerns and approval of a Delta levee improvement program by the State Legislature, the proposal to use dredged material could possibly become one of several long-range alternative disposal methods for O & M dredging.

5. Creation of Salt Marsh Habitat.

6.096 a. Justification. As dictated by the policy set forth in the regulations (236) providing guidance for the preparation and coordination of environmental impact statements, the District Engineer will develop, analyze, and adopt or utilize all practicable means and measures . . . which will enhance, protect and preserve the quality of the environment, restoring environmental quality previously lost . . . (emphasis added). In fulfillment of this requirement, the Corps of Engineers has for the past several years sponsored research to determine the feasibility and methods of salt marsh restoration using dredged material as a substrate.

6.097 The support of this work represents an important policy change from that used in the previous decades when dredged material was commonly deposited on existing marshlands, drastically altering their life support functions. This change has been brought about by a realization that the salt marshes provide food and spawning and nursery areas for most forms of life in the estuary, as well as contribute significantly to water quality by removing pollutants. Healthy marsh environments are necessary for production of many sport and commercial fish and shellfish, and are also valuable in preventing shoreline erosion. The total social value of salt marshes has been calculated to be $50,000-80,000/acre (65). It is now recognized that not only should existing marshes be preserved in their natural state, but that those areas of former marsh which are able to be reclaimed as marshland should be converted if feasible.

6.098 Reclamation of marshes is further justified by the long history of marsh destruction which has continued for more than a century in the Bay Area. Since the mid-1800's, more than one-half of the marshlands of the Bay system have been destroyed by filling to elevations above tidal influence or diking.

6.099 Additional justification for marsh creation is that it makes beneficial use of dredge material which must be disposed of and which has potential for creating environmental problems if improperly handled.

6.100 b. Background (Corps of Engineers - Marsh Research). Detailed research into the basic ecology of salt marshes began to receive emphasis during the early 1950's. These early studies demonstrated the importance of marshlands to the estuarine ecosystems, but until the late 1960's little information had been developed with respect to the artificial propagation of salt marshes.

6.101 (1) Coastal Engineering Research Center (CERC). In November, 1969 with the support of the U.S. Army Coastal Engineering Research Center (CERC), marsh propagation studies were begun at North Carolina State University in Raleigh. The primary investigators were Drs. W. W. Woodhouse, E. D. Seneca, and S. W. Broome, and the results of their studies, published in August 1974 (266) showed that cordgrass, *Spartina alterniflora*, can be successfully established on dredged material and eroding shorelines. Springtime propagation by seeds and rhizomes was occurring by fall. During the second growing season the site was almost stabilized and by the start of the third growing season, near full-growth productivity was obtained.

6.102 (2) Dredge Material Research Program (DMRP). In early 1973, the Waterways Experiment Station of the Corps of Engineers in Vicksburg, Mississippi began a long-range (5 year, 30 million dollar), comprehensive project known as the Dredge Material Research Program (DMRP). Designed to develop information on all aspects of dredge-disposal on a nationwide scale, the program has since grown to include over 100 separate research programs. Fifteen of these deal directly with artificial marshland island creation and another seven projects cover aspects of habitat development.

6.103 These projects, in various stages of completion, are providing detailed guidelines relative to deciding where or where not to build a marsh based on local environmental factors, the type of dredge substrate, other disposal alternatives and the type of marsh to be created. Procedures to make marsh creation more efficient and successful are being developed, tested and implemented on several different types of coastline. It is expected that this program will result in improved procedures for all Corps dredging and disposal programs across the nation.

6.104 (3) San Francisco Bay Marsh Development Study (MDS). In April 1972, the San Francisco District of the U.S. Army Corps of Engineers initiated a three and one-half year $2.9 million study to investigate the impacts of dredging and dredged material disposal operations on the San Francisco Bay and estuarine environment. The study is generating factual data, based on field and laboratory studies needed for Federal, State and local regulatory agencies to evaluate present dredging policies and alternative disposal methods.

6.105 The Marshland Development Study (MDS) is one of three studies which address specific alternatives to the present system of aquatic disposal in San Francisco Bay. The other two "alternative" studies are concerned with land and ocean disposal of dredged materials. The overall objective of the Marshland Development Study is to determine workable procedures for the development of marshlands upon dredge material substrates in the San Francisco Bay Area.

6.106 The MDS was conducted in two phases. Phase one, entitled the "Preliminary Investigation", was conducted between August 1973 and December 1973 to develop baseline physical and biological information at a project site, to formulate workable procedures for the artificial propagation of marshland plants, and to prepare plant materials for the second study phase. All three objectives were successfully completed.

6.107 Phase two, entitled, "Pilot Study', was initiated in May 1974 and will continue until May 1976. The primary objective of this study phase is to appraise the relative success of various planting procedures. Specific tasks included:

(a) planting 68 test plots and 10 linear transects in an unconfined dredge material disposal area along the north bank of the Alameda Creek Flood Control Project near Fremont (Alameda County);

(b) monitoring the growth and survival of test plantings;

(c) collecting and analyzing soil samples within the test area;

(d) collecting and analyzing invertebrate populations within the test area; and

(e) performing cursory laboratory studies relating to the physiology, anatomy, and genetic structure of intertidal flora.

6.108 Results of the first 1-1/2 years of this study will be included in Appendix K of the Dredge Disposal Study (230) to be released in the near future. Much of the following information is derived from the Marshland Development Study.

6.109 As a result of this research, other government and private agencies have become convinced of the feasibility of marsh creation. Currently in the Bay Area there are about 2,000 acres of previously-diked land which are scheduled for marsh creation. Three marshes, ranging in size from 2-10 acres, have already been created by the Corps in Maryland and Virginia.

c. Design and Construction Considerations.

6.110 (1) Environmental Requirements of Marshland Plants. In San Francisco Bay representatives of two plant genera, Spartina and Salicornia, are virtually the only inhabitants of the regularly flooded intertidal zone. Intertidal varieties of these genera are commonly referred to as "cordgrass" and "pickleweed", respectively, and are found in coastal bays and estuaries throughout the United States. In the eastern and gulf states, the variety is called "smooth cordgrass". The western coast variety is called "California cordgrass". In order to design new marsh areas with the use of dredged material, it is necessary to delineate the environmental requirements of these varieties. Tidal submergence, salinity and substrate are the most important environmental features to consider in the design and construction of a salt marsh.

6.111 (a) Tolerance to submergence. Submergence by the tides is probably the most important environmental factor affecting the distribution of intertidal plants. Several members of the Genus Spartina (cordgrass and others) are remarkably well adapted to withstand long periods underwater. Cordgrass survives lower in the intertidal zone than any other seed-producing plant but in the upper levels of the intertidal zone where tolerance to submergence is not as critical, cordgrass soon loses its competitive advantage and is crowded by the more aggressive, weedy plant varieties, principally pickleweed.

6.112 Woodhouse, Seneca and Broome concluded from their studies in North Carolina that smooth cordgrass will usually grow in any area, roughly between mean high water (MHW) and mean low water (MLW) for locations with low tidal fluctuations, and from MHW to mean sea level for higher tide ranges (266). They noted also that considerable variation may be found as a result of wave heights.

6.113 Several studies of smooth (eastern) cordgrass have identified tidal range and the lowest elevations where the plant survives (32,85). Assuming that in these studies cordgrass survived intertidal elevations equal to or greater than Mean high water, one may estimate that cordgrass populated 81 percent and 70 percent of the intertidal zone respectively.

6.114 Several measurements of the elevational distribution of California cordgrass have been made in central California:

	TIDAL RANGE	LOWEST SURVIVORS
Bolinas Lagoon, Marin County (Rowntree, 1975)	4.4 feet	2.1 feet (above MLLW)
Emeryville Crescent, near SF-Oakland Bridge tollgate (Harvey, unpublished)	6.4	3.3
Alameda Beach, near Bay Farm Island (Rowntree, 1975)	6.5	2.7
Alameda Creek, near mouth (DDS, Appendix K)	8.0	3.7
Palo Alto Marsh, near Palo Alto Yacht Harbor (Rowntree, 1975)	8.6	4.3

6.115 Assuming an upper survival range to the elevation of mean high water, cordgrass in and near San Francisco Bay populated only 52 percent, 48 percent, 58 percent, 53 percent and 50 percent of the intertidal zone. The lower growth range is approximately the level of mean tide.

6.116 Unlike cordgrass, pickleweed cannot store oxygen for respiration during long periods of submergence and therefore is not adapted to lengthy periods underwater. In general, pickleweed will be found dominant only above mean of the high waters where submergence occurs for only short periods of time.

6.117 Judging from this and other data, for all practical purposes, marsh creation efforts in the San Francisco Bay Area can use mean tide level (MTL) as the lower elevational extreme suitable for the propagation of marshland flora and mean higher high water (MHHW) as the upper extreme.

6.118 (b) Salinity. Salinity is another important environmental influence upon the distribution of salt marsh plant communities. Considerable research has been conducted with respect to smooth cordgrass concerning the question of salt requirements and/or tolerances. Studies which have subjected smooth cordgrass seeds to varying salinities indicate that freshwater is an impetus to germination. Mooring et al found that salinities above 6.0 ppt (parts per thousand) virtually prohibit germination in smooth cordgrass (115). Additional studies of the growth ot smooth cordgrass seedlings and mature plants, however, confirm that even in early development stages the plant prefers brackish water. Growth of smooth cordgrass seedlings is better in 5 and 10 ppt salinity than at zero salinity. Salinities above 40 ppt, however, seem to cause substantial reduction in growth potential. Growth of adult plants was found to be optimal at salinities from 10 to 20 ppt. In field studies smooth cordgrass has been observed tolerating salinities between 2.5 and 42.5 ppt (71).

6.119 Phleger subjected adult California cordgrass plants to nutrient solutions from zero to 41.2 ppt seawater (135). Growth and survival was best in solutions of 0.0 ppt salinity, indicating that California cordgrass may prefer brackish water. However, Phleger's experiment lasted only eight weeks and should not be considered conclusive. The transplanted adult plants certainly began the experiment with an accumulation of salt in plant tissues. In an unpublished report at San Jose State University, W.S. Chun was able to obtain 41 percent germination at zero salinity, 13 percent germination at 2.5 ppt salinity, and no germaination at salinities higher than 25 ppt, using California cordgrass seeds (35). Purer recorded California cordgrass in southern California growing in soil salinities between 22 ppt and 39 ppt in the field. From this scant evidence, it is impossible to postulate with any surety whether or not California cordgrass truly perfers brackish water like its Atlantic coast relative.

6.120 Pickleweed does prefer brackish water. It can be found generally in soils with mean annual salinities greater than 18 ppt and can survive in soils with salinities greater than 80 ppt. Competitive ability of pickleweed seems to increase rapidly where mean annual soil salinity exceeds 31 ppt. Stands of pickleweed growing in soils with salt concentrations above 70 ppt exhibit reduced growth. Pickleweed is virtually without a floral competitor along the shores of San Francisco Bay in soils with salinities between 35.5 and 81 ppt salinity (107).

6.121 The following is a general summary of salt tolerances of pickleweed and cordgrass, based on available literature:

0.0 - 5.0 ppt Germination of cordgrass seed - optimum.

5.0 - 10.0 ppt Seeding growth of cordgrass - optimum.

10.0 - 20.0 ppt Adult growth of cordgrass - optimum.

20.0 - 30.0 ppt Growth of pickleweed - lower limit.

30.0 - 40.0 ppt No data.

40.0 - 50.0 ppt Growth of cordgrass - retarded.

50.0 - 60.0 ppt Cordgrass - upper limit.

60.0 - 70.0 ppt Growth of pickleweed - retarded.

70.0 - 80.0 ppt Pickleweed - upper limit.

6.122 (c) Soils (Suitability of dredged material). Cordgrass has been variously reported surviving in a wide variety of substrates. Adams reports stands occurring in silt-clay substrate (1). Woodhouse et al reports the successful establishment of cordgrass in substrates containing from 76-97 percent sand in artificial propagation experiments (266). In general, intertidal marshes in San Francisco Bay are predominantly clay-silt in composition. Pestrong describes the sediments at the bayward edge of existing marshes in South San Francisco Bay as containing five percent sand, 15 percent coarse shell fragments and organic debris, 15 percent silt, and 65 percent clay (133).

6.123 In conjunction with the MDS, sediment samples were collected and analyzed in existing marsh areas, in a channel before dredging, in a confined disposal area one month after the completion of hydraulic dredging activities, and in an unconfined disposal area one year after clamshell dredging has ceased. The results of these comparisons are shown in Table VI-4. Salinity values are also given.

TABLE VI-4

COMPARISON OF CHEMICAL PROPERTIES OF MARSH SOILS
VS.
DREDGED MATERIAL

TYPE OF MATERIAL	INTERTIDAL ELEVATION	MOISTURE % WET WT.	SALINITY PPT	PHOSPHATE PPM	NITRATE PPM
MARSH SUBSTRATE	above MHHW	50	22	43	1
MARSH SUBSTRATE	below MHHW	58	24	20	1
CHANNEL SEDIMENTS	subtidal	40	12	18	6
HYDRAULIC DREDGED MATERIAL	limited tidal action	48	30	27	1
CLAMSHELL DREDGED MATERIAL	above MHHW	46	37	87	5
CLAMSHELL DREDGED MATERIAL	below MHHW	54	29	55	2

6.124 The salinity comparisons in the table are somewhat misleading. Salinity measurements in existing marsh substrates (22 and 24 ppt) were made in December when the salinity levels of the adjacent bay waters were seasonally low. Salinities in the unconfined disposal areas (37 and 29 ppt) were measured during May when water salinities are normally about 30 ppt in adjacent waters. Salinities in the confined disposal area (as abandoned salt pond) ranged from 22 to 40 ppt. This area is not exposed to tidal action. When the area is breached during 1975, additional soil samples will be taken in order to follows changes in salinity which occur as a result of tidal circulation. It is not believed that salinity levels in dredged material will prohibit revegetation of the dredged material substrates.

6.125 Phosphates and nitrates should not be a limiting factor in vegetative growth on dredged material. Phosphorus levels within the confined area will increase significantly when the area is exposed to tidal circulation.

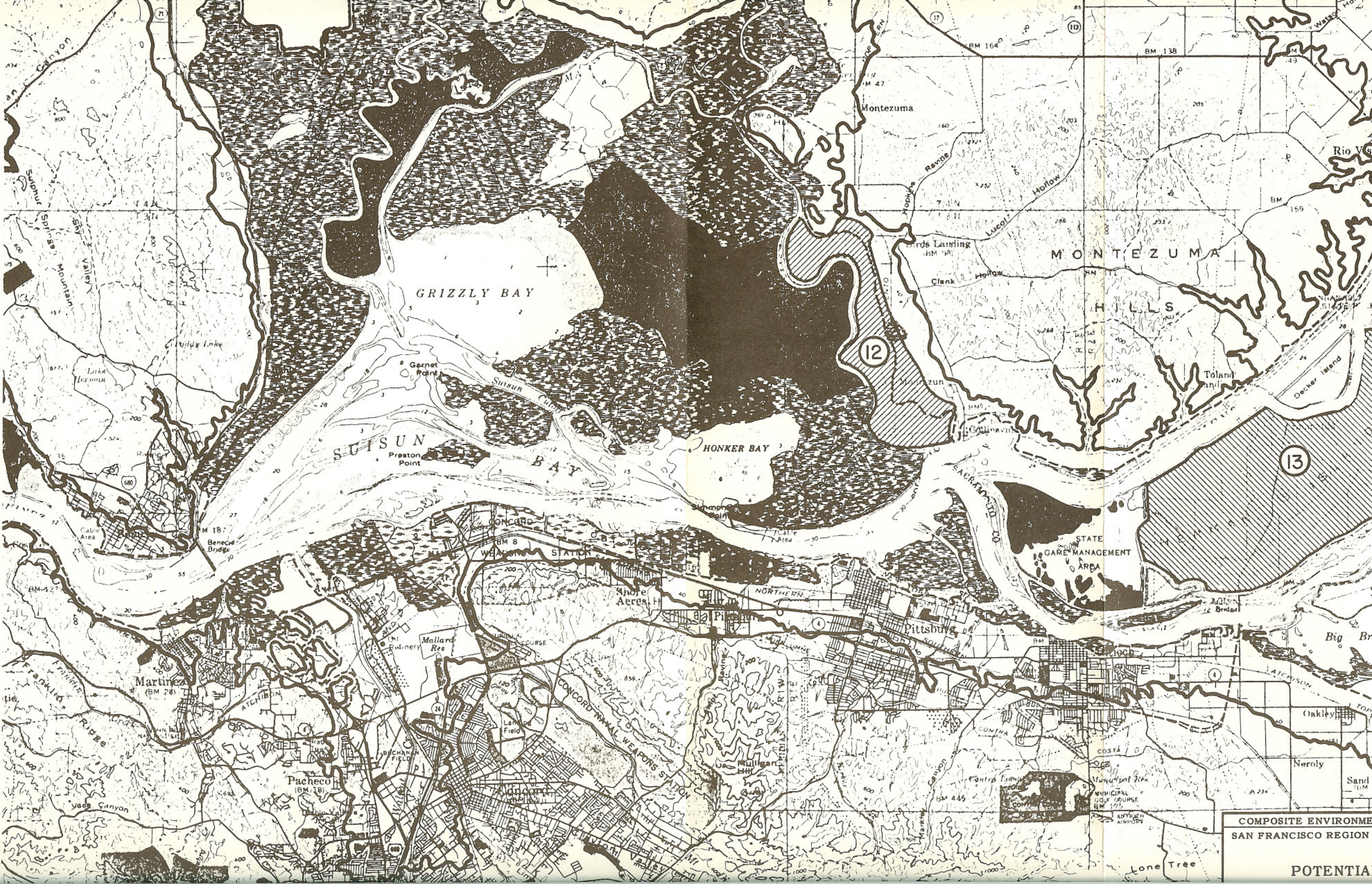
6.126 Adams reported that smooth cordgrass requires substantial levels of iron (/). Levels of iron in the dredged material sampled in both the condined and unconfined areas (150 to 1,400 ppm) were equal to or greater than those levels observed in existing marsh substrates (50 to 150 ppm).

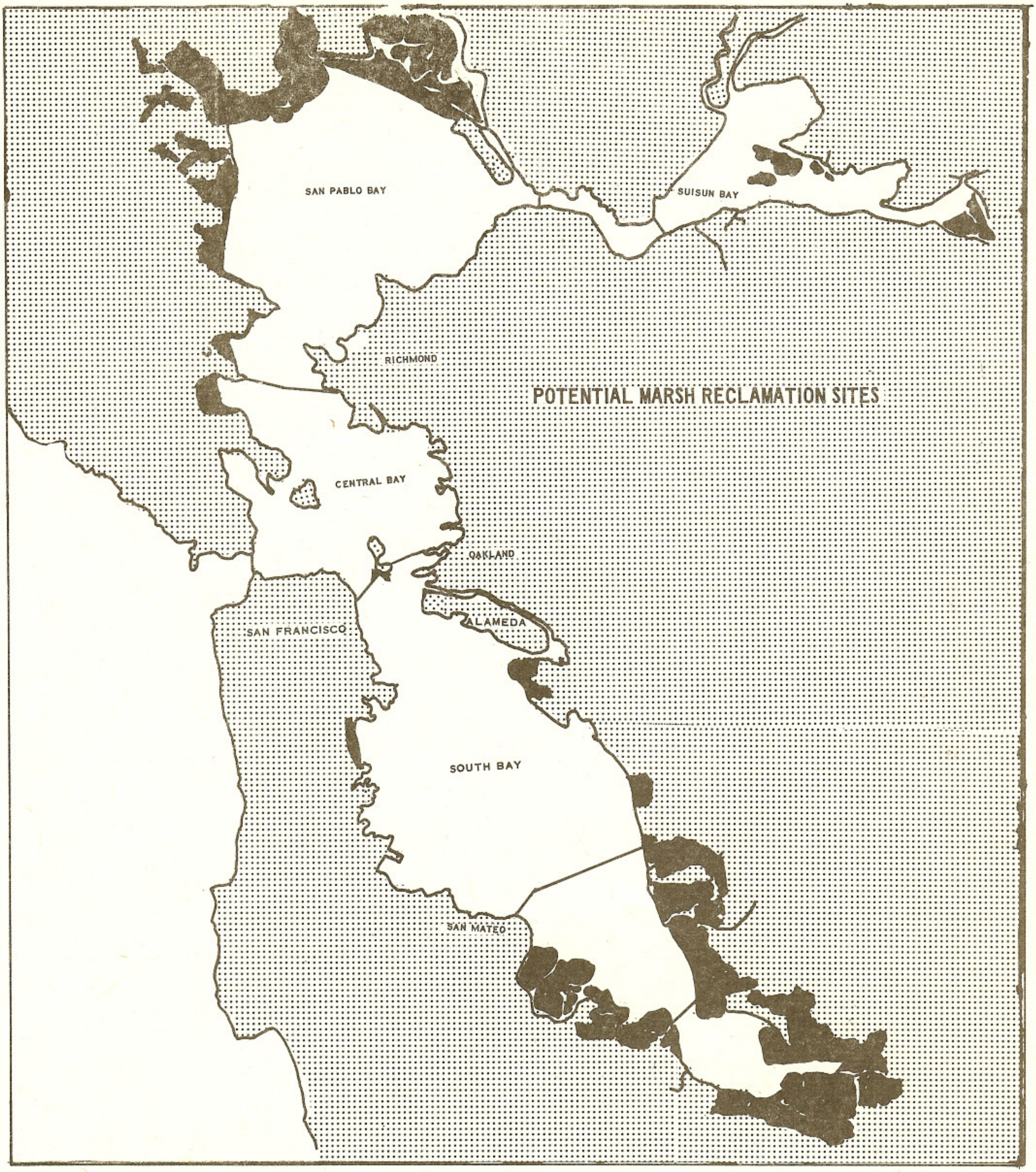
6.127 Results of test plantings in the unconfined disposal during 1974 and the above soil analysis support the conclusion that there are no excessive or limiting elements in the dredge material studied which adversely affects local marsh species.

(2) Engineering Considerations.

6.128 (a) Potential sites. Re-establishment of a salt marsh is best accomplished in areas which were formerly salt marsh (Plate VI-6). As previously mentioned, some 120,000 acres of historic marshland in the Bay have been diked for salt production, agriculture, and industrial and urban development. In South Bay alone there are more than 40,000 acres of salt ponds and in San Pablo Bay more than 35,000 acres of salt ponds and agricultural lands which are at an elevation lower than adjacent tides. As a result of subsidence (Plate VI-7) due to extensive groundwater depletion, wind erosion and consolidation,

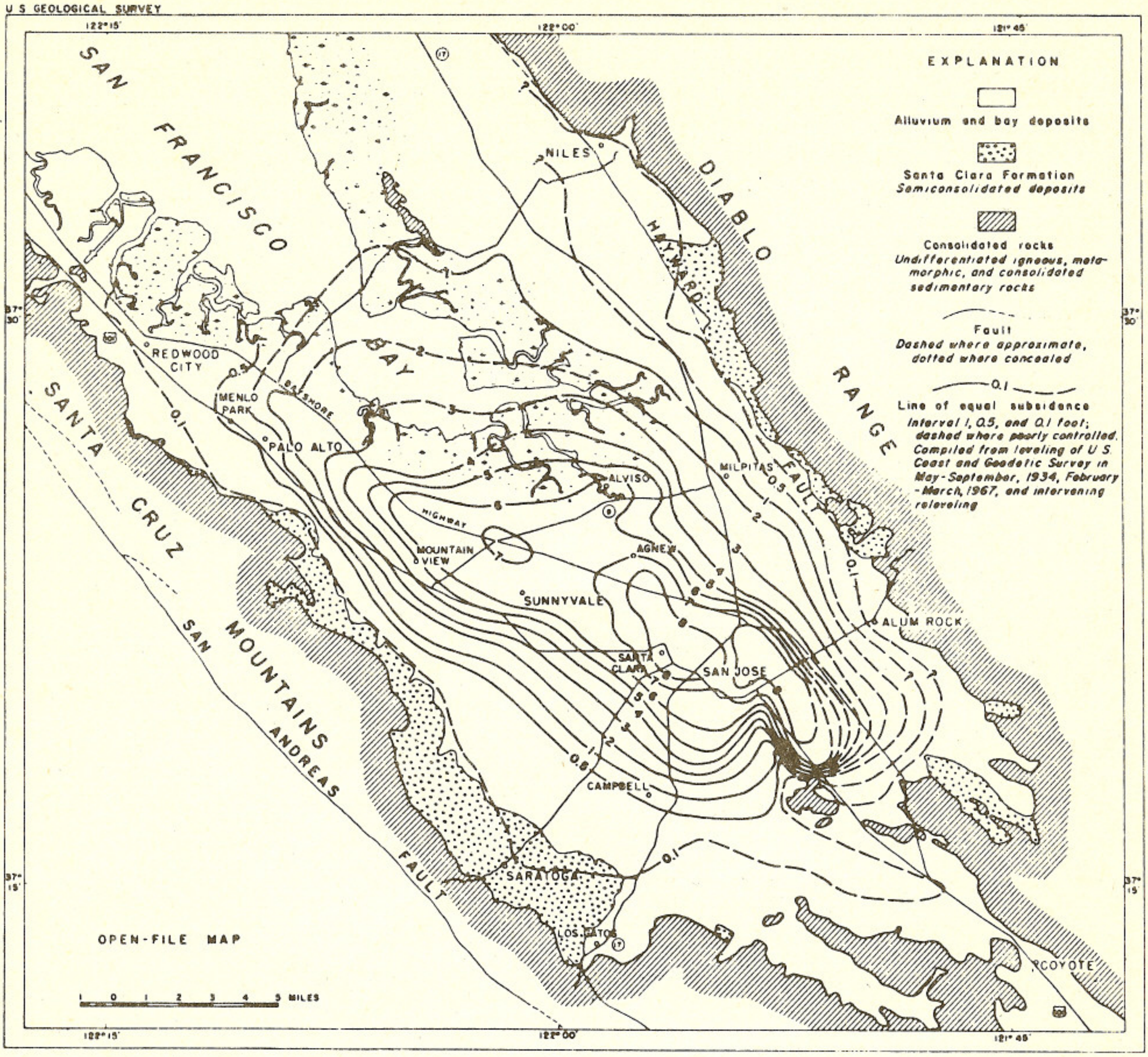

COMPOSITE ENVIRONMENTAL STATEMENT
SAN FRANCISCO REGION
CALIFORNIA
POTENTIAL LAND DISPOSAL SITES
EY
ONTOUR
HIGH WATER
FUGES
TIONAL
FUGE
Glen Ellen
Oak Knoll
Salvador
Napa
Boyes Hot Springs
El Verano
Sonoma
Buena Vista
Arrowhead Mtn
Milliken Peak
Browns Valley
Sugarloaf
Petaluma
Petaluma Adobe State Historic Mon
Sonoma Mtn
Hogback Mtn
Mt George
Vichy Springs
Napa Jct College
Cuttings Wharf
Salt Evaporators
Napa County Airport
Creston
Napa Junction
Elkhorn Peak
Wildcat Mtn
Sears Point
Burdell Mtn
Naval Reservation
Radio Towers
Russ Island
Island No
Knight Island
Island No 1
Napa River
Sonoma Mountains
Sonoma Valley
Southern Pacific
8


GRIZZLY BAY
SUISUN BAY
HONKER BAY
Garnet Point
Preston Point
Suisun Channel
Benicia Bridge
Martinez
Pacheco
Concord
CONCORD NAVAL WEAPONS STATION
Mallard Res
Shore Acres
Pittsburg
Montezuma
MONTEZUMA HILLS
Toland
Collinsville
Decker Island
STATE GAME MANAGEMENT AREA
Rio Vista
Oakley
Neroly
Lone Tree
Big Break
Franklin Ridge
Sulphur Springs Mountain
Sky Valley
Lake Herman
Hopkins Ravine
Lucol Hollow
Clank Hollow
Birds Landing
12
13
COMPOSITE ENVIRONME
SAN FRANCISCO REGION
POTENTIA



SOURCE: Dredge Disposal Study, Appendix K (in preparation)

PLATE VI-6



SOURCE: Poland, J.F. 1971. Land Subsidence in the Santa Clara Valley, Alameda, San Mateo, and Santa Clara Counties, California. U.S. Geological Survey, Misc. Field Studies, Map MF-336.

COMPOSITE ENVIRONMENTAL STATEMENT

SAN FRANCISCO BAY REGION CALIFORNIA

LAND SUBSIDENCE 1934–1967

U.S. ARMY ENGINEER DIST., SAN FRANCISCO, C OF E
FILE NO.

TO ACCOMPANY REPORT
DATED

the vast majority of these diked areas are now lower than before they were diked. Many of these diked, historic marshlands have subsided to an extent that even if opened to tidal circulation, they would not support marsh vegetation unless partially covered with a suitable substrate.

6.129 Thus it is clear that potential marsh development sites are available adjacent to San Francisco Bay.

6.130 (b) Dike construction. Considering the abundance of diked lowlands surrounding San Francisco Bay, the construction of new dikes to retain dredged slurries during disposal will seldom, if ever, be required. Dredging for the development of marsh substrates will generally be conducted by hydraulic dredge with a pipeline to the disposal area. The broad tideflats of the Bay prohibit the efficient use of any other type of dredging operation. Hydraulic slurries of Bay mud may contain as much as 90 percent water. To contain the slurry volume during dredging, existing dikes may have to be elevated. Depending upon the dredging rate and the dimension of the disposal area, several feet of elevation above final height may be required to contain the water-sediment mixture while the material consolidates and the resulting surface water drains.

6.131 Dikes may also require additional height to contain the tide waters after breaching. In general, the most bayward dikes in reclaimed areas are more substantial and higher than the more inland dikes. The bayward dikes are responsible for protecting the inland areas from the tides and must be strong enough to resist wave action. Once the exterior dikes are breached, the interior dikes inherit the responsibility for containing the tide waters. Dikes around the marsh development area must be surveyed before breaching so that low areas can be identified and corrected. All dikes surrounding the containment area must be of an elevation higher than the estimated highest tide. One must also consider the height of waves expected in the area to allow for wave over-wash. These considerations are of particular importance when adjacent areas are being actively used for salt production or agriculture. Though the construction of new dikes will seldom, if ever, be required in marsh development projects, existing dikes may require improvements.

6.132 (c) Dredging. It is essential that salt marsh substrates drain during ebbtides. Dredge discharge pipes should be located near interior dikes where the material can accumulate, frming the highest area of the pond and thereby creating a gentle slope toward the Bay.

6.133 There are several problems associated with creating designed elevations within the disposal area. One complicating factor is that during disposal operations the pond will be filled with water and the topography of the sediment fill will not be visible. This means that few, if any, corrections in the operation can be made during construction. Accurate survey of the volume of material to be dredged and the quantity of material required in the disposal area must be made before initiating the operation.

6.134 As a rule-of-thumb one can assume that the volume in place of the material to be dredged will be approximately equal to the final disposal volume.

6.135 After the dredged material has stablilized (less than six months) the breach of the dike can be made. If additional shaping or planting is planned for the area, a one-year consolidation period will greatly improve the bearing capacity of the material and further reduce its volume.

6.136 (3) Planting Considerations. In conjunction with the MDS, test plantings of cordgrass and pickleweed were made in May of 1974. Several methods of planting were used for both species, and these plots will be monitored through May of 1976.

6.137 No data was compiled on the geographical occurrence of cordgrass seed-producing stands, but areas were located in the mouths of the following tributaries: Petaluma River, Napa River, Sonoma Creek and the Faber Tract in East Palo Alto. It was determined that the seeds mature in October, and that germination is improved by 3-4 months' storage in cold saltwater. Results indicate a high survival rate and that this method should provide a commercially feasible method of establishing cordgrass on bare surfaces.

6.138 Several of the plots were planted with cordgrass cuttings which had been rooted in a nursery using a mixture of sand an vermiculite. After six months an average of 50 percent of the rooted cuttings had survived.

6.139 Seedlings established in the nursery were also transplanted to the test site. Survival ranged from 52 to 55 percent and growth from 8.4 to 19.6 cm after six months.

6.140 Cordgrass plugs (clumps of adult grass dug from marshes) were also transplanted and, as expected, showed high survival rates (96.8 to 83.2 percent) and better growth rates than any other method.

6.141 Fertilization of cordgrass had no significant effect on survival or growth.

6.142 The use of pickleweed seedlings rooted in the nursery was found to be the most successful of the procedures studied. Survival rates were high (64.0 to 73.3 percent) and 14.5 - 21.0 cm of growth was recorded on unfertilized and fertilized plots after six months.

6.143 Rooted cuttings of pickleweed did not survive as well as nursery seedlings. Unrooted cuttings showed lower survival rates but survival would have been higher had the cuttings been raked into the substrate.

6.144 One promising procedure not studied in the field test was direct seeding of pickleweed. Nursery studies, however, indicate that seeds germinate readily and may be found in great abundance.

6.145 Fertilization caused a statistically significant increase in survival and growth of pickleweed.

6.146 Table VI-5 outlines various recommended methods for establishing a marsh dependent on the salinity and elevation conditions at the site. At the lower elevations, artificial propagation by seeds is likely to be unsuccessful. Cordgrass seeds are recommended at lower salinities because they are a less expensive means of propagation and because fresh water exposure increases germination.

TABLE VI-5

RECOMMENDED METHOD OF PROPAGATION

	0-10	10-20	20-30	30-40	40-80
			SALINITY (PPT)		
MHHW	NPR	NPR	PS/C	PS/C	PS/C
MHW	CS	CS	CS	CP	PS/C
INTERMEDIATE	CS	CS	CS	CP	PS/C
MTL	CP	CP	CP	CP	NPR
INTERMEDIATE	NPR	NPR	NPR	NPR	NPR
MLW	NPR	NPR	NPR	NPR	NPR
MLLW	NPR	NPR	NPR	NPR	NPR

NPR - No Planting Required
PS/C - Seedlings, Unrooted Cuttings of Pickleweed, or Seeding
CS - Cordgrass Seeding
CP - Cordgrass "Plugs"

Source: Dredge Disposal Study, App. K (in preparation).

6.147 In general, natural invasion of pickleweed is very rapid and artificial planting is usually not needed, especially if a natural stand is nearby. Cordgrass, however, is less weedy and propagation can be justified in most cases.

6.148 In summary, it has been established that artificial propagation of cordgrass and pickleweed is feasible by several methods. The following table shows the approximate man hours required to plant 1,000 square meters by various methods.

TABLE VI-6
ESTIMATES OF PLANTING EFFORTS

METHOD	MAN-HOURS PER 1,000 Sq. M
Cordgrass	
seeds	30.5
rooted cuttings	121.0
seedlings	116.0
plugs	86.1
Pickleweed	
rooted cuttings	117
unrooted cuttings	22
seedlings	113

Source: Dredge Disposal Study, App. K (in preparation)

d. Potential Marsh Development Sites.

6.149 (1) Location of Available Sites. As previously noted, more than 120,000 acres of marshlands have been diked and/or filled along the margins of San Francisco Bay. In all, there are approximately 67,000 acres of diked lands which still remain at intertidal or subtidal elevations. Wind erosion, subsidence, consolidation, and drying have reduced the elevation of these diked areas since their reclamation 50 to 100 years ago. Historic intertidal elevations may be restored in these areas by the addition of dredged material. Plate VI-6 delineates the 67,000 acres of potential marshlands adjacent to San Francisco Bay.

6.150 (2) Estimate of Dredging Quantities. Final elevation of the disposal area is restricted in a marsh development project to the elevation of local tide waters. The depth of fill for marsh development will seldom exceed five feet and will typically be from two to three feet. Dredging quantities which could be accommodated in a 5,000-acre example site were computed. This site is located adjacent to and east of the mouth of the Petaluma River. The elevation of this area averages about 2.5 feet above mean lower low water (-0.5 sea level datum). Mean tide level in this reach of San Pablo Bay is approximately 3.5 feet above MLLW and mean higher high water is 6.0 feet above MLLW. For optimal development of vegetation the final fill elevation of the disposal area should average approximately 4.5 feet MLLW (range of elevation 3.5 to 6.0 MLLW). With an average fill depth of 2 feet, each acre could accommodate about 3,200 cubic yards of dredged material (assuming 1 to 1 ratio of shoal volume to disposal volume). This 5,000-acre site could accommodate a total of approximately 16 million cubic yards. Assuming that this example is somewhat typical, the 67,000 acres of potential marsh development lands represent a disposal alternative for about 214 million cubic yards of dredged material.

e. Problems.

6.151 (1) Water Quality During Disposal Operations. As previously noted, hydraulically dredged material slurries contain 80 to 90 percent water, which must be decanted during disposal operations. This is usually accomplished with the use of weirs. Because of the fine-grained nature of Bay sediments, the clarifying of supernate waters in disposal areas before release back into the Bay must be considered. It has been found that in fresh water the clay particles in dredged material may remain suspended for long periods of time. However, saline waters cause a flocculation of clay particles and the clarification of supernate waters occurs very rapidly (232). The threat of water degradation during the disposal operation can be alleviated for the most part if the salinities of return waters are high. When dredging operations are located near freshwater tributaries, dredging should be timed to correspond with periods of low freshwater inflow. It is important that residence times for water within a disposal area be kept to a minimum. Contrary to what one would expect, the quality of the supernate water in a confined disposal area is degraded when lengthy settline periods are allowed. Windom has observed that "Metal concentrations in the water column initially are depleted due to scavenging, presumably by the precipitation of hydrated iron oxides (261). After equilibration of the deposited dredged spoil, some of the accumulated metals are released to the water column again, reaching ambient levels or higher. This process takes on the order of a few days to occur". In general, waters decanted from disposal areas will be high in oxygen and during certain seasons may be more turbid than receiving waters.

6.152 (2) Marshes and Heavy Metal Cycling. Intertidal sediments trap many heavy metals (e.g. iron, lead, mercury, copper, cadmium, and manganese), which are selectively cycled by the flora and fauna of the intertidal zone. This selectivity is the reason why heavy metals in the tissues of cordgrass do not correlate with levels of heavy metals found on intertidal sediments (261). Iron, copper, and manganese do not seem to accumulate or concentrate in plant tissues; however, mercury and possible cadmium are taken up by marsh plants and concentrated to levels several times higher than backgrouns. As bits and pieces of marsh plants are disloged and exported, these metals can be made available to the marine environment.

6.153 (3) Mosquito Control. Two species of mosquitoes inhabit salt marsh areas. Both types (*Aedes squamiger* - Gray salt marsh mosquito and *Aedes dorsalis* - Salt marsh mosquito) are rated high in willingness to bite man and have been a problem to bay area residents in the past. Local mosquito control districts now keep populations well under control. The creation of additional salt marshes need not enhance the local mosquito populations, because intertidal salt marsh areas which are well drained to not provide breeding areas for these mosquitoes. Some maintenance of drainage patterns may be required to avoid ponding of water in marsh sites, though probably less than is now required to maintain diked areas which naturally accumulate rain waters.

E. ECONOMIC COMPARISON OF ALTERNATIVE DREDGING AND DISPOSAL SYSTEMS.

1. Introduction.

6.154 Comparing the cost efficiency of alternative dredging and disposal systems is an extremely complex undertaking, in lieu of the many options available. For any given dredging project in San Francisco Bay there are three basic types of dredging equipment (hopper dredge, clamshell dredge, and hydraulic), four alternative transport modes (hopper dredge, tug/scow, fixed pipeline, and temporary pipeline), and five disposal categories (Bay aquatic, ocean, land, marshland development, and Delta Island reclamation), which may be utilized. Considering only the basic options described above results in the development of 1200 potential dredging/disposal systems.

6.155 To assist in this economic analysis a computer model was developed. Given input data on dredging and disposal sites as well as dredging, transport, and transfer equipment, the model (San Francisco Bay Dredging Simulation Model) rapidly compares alternative systems on a relative unit cost basis. In one run the user can specify up to 200 dredging/transport equipment combinations, 18 dredge/disposal site schemes for any number of years from 1 to 20. (Details of the dredging simulation program may be found in Appendix J - Land Disposal, San Francisco Bay and Estuary Dredge Disposal Study.)

2. Model Input Data.

6.156 Considerable efforts have been expended in defining and quantifying geographical and economic variables in San Francisco Bay which have a bearing on determining the relative costs of alternative systems. The following is a summary of options considered in this analysis.

a. Dredging Sites.

6.157 All Federal, local, and private dredging projects (maintenance and new construction) were arbitrarily grouped according to geographical location into twelve dredging areas (Table VI-7) to simplify model calculations. The following geographical areas with their associated annual dredging volumes were used:

TABLE VI-7
ANNUAL DREDGED VOLUMES

Dredging Sites	Annual Volume (1000 cubic yards)
1. Suisun Bay	440
2. Mare Island	3,050
3. Napa River	84
4. Petaluma River	90
5. Pinole Shoal	1,800
6. Richmond Long Wharf	630
7. San Rafael	36
8. West Richmond Channel	450
9. Richmond and Pt. Molate	760
10. Oakland	1,910
11. San Francisco	650
12. Redwood City	670

6.158 The actual data input to the computer model contained yearly estimates for each of twenty years (1975-1994) to account for anticipated new construction and the fact that some projects are not dredged annually.

6.159 b. Disposal Sites

(1) Aquatic Disposal Sites (Bay)

Carquinez Strait Disposal Area
San Pablo Bay Disposal Area
Alcatraz Island Disposal Area
Hunters Point Disposal Area (no longer used)
San Francisco Bay South Disposal Area (no longer used)

(2) Aquatic Disposal Site (Ocean)

100-Fathom Disposal Area

(3) Land Disposal Area

Petaluma River Land Disposal Area (see Site No. 8, Plate VI-4)

(4) Delta Island Reclamation Area

Sherman Island Disposal Area (see Site No. 13, Plate VI-5)

(5) Marshland Development Area

Petaluma River Area (the portion below MHHW of Sub-area (1), Site No. 8, Plate VI-4)

c. Dredging/Disposal Schemes.

6.160 For purposes of this economic comparison six disposal schemes were considered.

(1) Scheme I - Closest Aquatic Site

It was assumed that there were no constraints on disposal and that material could be taken to the closest aquatic disposal site.

(2) Scheme II - Closest Aquatic Disposal Site Seaward.

This scheme is similar to Scheme I, but with the added restriction that material must be moved to the nearest site seaward of the dredging operation.

(3) Scheme III - Ocean Disposal

It was assumed that all dredged material generated in the Bay would be hauled to the ocean disposal site at the 100-fathom contour.

(4) Scheme IV - Land Disposal

It was assumed that all dredged material would be transported to the Petaluma River Land Disposal Area.

(5) Scheme V - Delta Island Reclamation

It was assumed that all dredged material would be moved to Sherman Island in the western Delta for disposal.

(6) Scheme VI - Marshland Development

It was assumed that all dredged material would be moved to a 5,000-acre portion of the Petaluma River Land Disposal Area for purposes of marshland development.

d. Dredging and Transport Equipment.

6.161 Of the hundreds of potential dredging/transport equipment combinations which could be considered, 29 representative combinations were selected for examination.

TABLE VI-8
SELECTED DREDGE/TRANSPORT COMBINATIONS

Dredging/Transport Equipment Code Letter	Dredging/Transport System Description
A	Hopper/Direct Pumpout, scow, dump basin, fixed pipeline
B	18 cy Clam, bottom dump scows, dump basin, fixed pipeline
C	Hopper/Direct Pumpout, bottom dump scow
D	Hopper, bottom dump
E	18 cy Clam, bottom dump scows
F	13 cy Clam, bottom dump scows
G	13 cy Clam, bottom dump scow, dump basin, fixed pipeline
H	18 cy Clam/Scows, transfer unit, fixed pipeline
I	Hopper, transfer unit, fixed pipeline
J	Hopper/Pumpout, scow, dump basin, fixed pipeline
K	36" Hydraulic, temporary pipeline
L	18 cy Clam/Scows, transfer unit, temporary pipeline
M	16" Hydraulic, booster unit, temporary pipeline
N	13 cy Clam, scows, transfer unit
O	9 cy Clam, scows, transfer unit
P	18 cy Clam, bottom dump scows
Q	13 cy Clam, bottom dump scows
R	9 cy Clam, bottom dump scows

TABLE VI-8 cont'd
SELECTED DREDGE/TRANSPORT COMBINATIONS

Dredging/Transport Equipment Code Letter	Dredging/Transport System Description
S	36" Hydraulic, booster unit, temporary pipeline
T	30" Hydraulic, booster unit, temporary pipeline
U	24" Hydraulic, booster unit, temporary pipeline
V	16" Hydraulic, booster unit, temporary pipeline
W	36" Hydraulic, booster unit, temporary pipeline
X	36" Hydraulic, temporary pipeline
Y	16" Hydraulic, booster unit, temporary pipeline
Z	36" Hydraulic, booster unit, temporary pipeline
A1	16" Hydraulic, booster unit, temporary pipeline
B1	16" Hydraulic, temporary pipeline
C1	16" Hydraulic, temporary pipeline

6.162 Though the model is an effective tool for estimating the relative costs of alternative dredging and disposal schemes, the altering of several parameters in the program may significantly change the ordering and costing of dredging equipment combinations. In order to provide a more objective summary of hourly equipment costs and productivity, two separate cost estimates were compiled. One estimate was prepared by the International Engineering Company, Inc. (hereafter referred to as Equipment Estimate 1) and a second was compiled by the West Coast Dredging Association (Equipment Estimate 2).

3. <u>Results of Cost Comparison Calculations</u>.

6.163 The following summary is based upon the results of the cost comparison calculations compiled with the assistance of the dredging simulation model. It must be emphasized that all costs described in this section do not include profit, overhead, supervision, or additional costs which might be incurred for the engineering and design of new equipment. Tables VI-11 through VI-16 present the costs per cubic yard involved in Schemes I through VI respectively. The costs are presented by project for four equipment categories:

6.164 1. Least Cost Only - This is an unrestricted category which includes all 29 dredging/transport equipment combinations. Some of these combinations are not currently available and may require extensive engineering, design, and testing.

6.165 2. Hopper Only - This category considers only available (presently operating on the west coast) hopper dredges. Because no hopper dredges on the west coast presently have direct pumpout capability, this category is limited to bottom dumping hopper dredges.

6.166 3. Clamshell Only - This category considers only dredging/transport combinations which include clamshell dredges. Though combinations in this category are in use in some areas, they are not necessarily presently located in the Bay area. Only the most economically efficient combinations for the particular dredging situation are included in the summary tables.

6.167 4. Hydraulic Only - This category considers only equipment combinations which include hydraulic dredges. Though the systems in this category are in use in some areas, they are not necessarily presently located in the Bay area. Only the most economically efficient combinations for the particular dredging situation are included in the tables.

a. Scheme I - Closest Aquatic (Table VI- 9).

6.168 The weighted least cost average per cubic yard for this disposal scheme was $0.41 to 0.44. The results indicate that relatively efficient equipment is presently in use or is readily available to perform this scheme. Equipment Estimate 1 indicated that bottom dump hopper dredges are generally the most efficient equipment for short aquatic hauls except for the inaccessible, shallow draft dredging areas (Napa River, Petaluma River, and San Rafael Creek). In the shallow draft areas a combination of clamshell/scow was preferred by both Equipment Estimates. Estimate 2 indicated that for short hauls to aquatic disposal sites (three miles or less) hydraulic dredges are comparable cost-wise to hopper dredges.

b. Scheme II - Closest Aquatic Seaward (Table VI-10).

6.169 The results reflected costs and equipment options similar to Scheme I.

c. Scheme III - Ocean Disposal (Table VI-11).

6.170 Moving all dredged material generated in San Francisco Bay to the 100-fathom contour (designated ocean disposal site) would increase dredging costs by 75% over Scheme I ($0.78 to 0.71 per cubic yard). Fixed pipeline systems appear to be the most efficient transport mode for this alternative. However, the cost calculations do not include costs for pipeline right-of-way, engineering and design, and possible construction problems involved in locating a fixed line in high energy areas such as the Golden Gate. The most efficient transport mode in lieu of the fixed pipeline is tug and scow. The use of tug and scow for ocean disposal would increase costs 100% over Scheme I.

d. Scheme IV - Land Disposal (Table VI-12).

6.171 The Petaluma River Land Disposal Site encompasses approximately 7400 acres of diked lands. It was assumed that the dredged material would be placed to a thickness of 10 feet and that the air dried disposal volume would be 60% of the dredged material shoal volume. The total capacity of the site was calculated to be approximately

TABLE VI-9

SCHEME I - CLOSEST AQUATIC DISPOSAL

Dredge Site	Suisun Bay	Mare Island	Napa River 1/	Petaluma River 1/	Pinole Shoal	Richmond L. W.	San Rafael Cr. 1/	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Disposal Site	Carquinez	Carquinez	Carquinez	San Pablo	Carquinez	San Pablo	San Pablo	San Pablo	San Pablo	Alcatraz	San Bruno	South Bay
Distance Miles	9	3	11	12	4	5	5	7	7	7	3	3
Run 1												
Least cost only 3/	(C) 2/ 0.40	(D) 0.31	0.76	(E) 1.09	(D) 0.25	(D) 0.45	0.66	(D) 0.37	(D) 0.52	(C) 0.54	(D) 0.27	(D) 0.31
Hopper only 4/	(D) 0.45	(D) 0.31			(D) 0.25	(D) 0.45		(D) 0.37	(D) 0.52	(D) 0.70	(D) 0.27	(D) 0.31
Clamshell only 4/	(E) 0.76	(E) 0.79		(E) 1.09	(E) 0.69	(E) 0.62		(E) 0.70	(E) 0.65	(E) 0.85	(E) 0.70	(E) 0.69
Hydraulic only 4/	(W) 1.08	(X) 0.38			(Z) 0.63	(M) 0.89		(M) 1.22	(Z) 1.01	(Z) 1.06	(C) 0.63	(C) 0.48
Run 2												
Least cost only 3/	(C) 0.47	(K) 0.27	(E) 0.59	(E) 0.87	(D) 0.35	(E) 0.49	(E) 0.52	(C) 0.47	(E) 0.50	(C) 0.63	(D) 0.38	(K) 0.41
Hopper only 4/	(D) 0.63	(D) 0.43			(D) 0.35	(D) 0.64		(D) 0.52	(D) 0.73	(D) 0.99	(D) 0.38	(D) 0.43
Clamshell only 4/	(E) 0.60	(E) 0.62	(E) 0.59	(E) 0.87	(E) 0.55	(E) 0.49	(E) 0.52	(E) 0.55	(E) 0.50	(E) 0.66	(E) 0.55	(E) 0.54
Hydraulic only 4/	(W) 0.87	(X) 0.27	(Y) 1.63	(Y) 2.10	(Z) 0.48	(Z) 0.77	(A) 1.56	(Z) 1.11	(Z) 0.84	(Z) 0.83	(B) 0.58	(X) 0.41

1/ Large hydraulics and hoppers not practical at dredge site due to narrow or shallow dimension of waterway.

2/ Equipment combinations - see Page VI-46 for equipment letter codes.

3/ Least cost utilizing any system, whether currently available, would require extensive engineering and testing prior to use.

4/ Cost for currently available systems only equipment available although not necessarily presently located in the Bay area.

Source: Dredge Disposal Study, Appendix J (1974).

TABLE VI-10

SCHEME II - CLOSEST AQUATIC SEAWARD DISPOSAL

Dredge Site	Suisun Bay	Mare Island	Napa River 1/	Petaluma River 1/	Pinole Shoal	Richmond L. W.	San Rafael Cr 1/	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Disposal Site	Carquinez	Carquinez	Carquinez	San Pablo	San Pablo	Alcatraz	Alcatraz	Alcatraz	Alcatraz	Alcatraz	Alcatraz	South Bay
Distance Miles	9	3	11	12	5	9	11	7	8	7	7	3
Run 1												
Least cost only 3/	(C) 2/ 0.40	(D) 0.31	0.76	(E) 1.09	(D) 0.29	(C) 0.50	0.86	(D) 0.37	(C) 0.55	(C) 0.54	(D) 0.46	(D) 0.31
Hopper only 4/	(D) 0.45	(D) 0.31			(D) 0.29	(D) 0.63		(D) 0.37	(D) 0.57	(D) 0.70	(D) 0.46	(D) 0.31
Clamshell only 4/	(E) 0.76	(E) 0.79		(E) 1.09	(E) 0.69	(E) 0.65		(E) 0.70	(E) 0.65	(E) 0.85	(E) 0.70	(E) 0.69
Hydraulic only 4/	(W) 1.08	(X) 0.38			(Z) 0.66	(Y) 1.12		(M) 1.22	(Z) 1.07	(Z) 1.07	(M) 1.34	(C) 0.48
Run 2												
Least cost only 3/	(C) 0.47	(K) 0.27	(E) 0.59	(E) 0.87	(D) 0.41	(E) 0.50	(E) 0.68	(C) 0.47	(E) 0.50	(C) 0.63	(E) 0.55	(K) 0.41
Hopper only 4/	(D) 0.63	(D) 0.43			(D) 0.41	(D) 0.89		(D) 0.52	(D) 0.80	(D) 0.99	(D) 0.65	(D) 0.43
Clamshell only 4/	(E) 0.60	(E) 0.62	(E) 0.59	(E) 0.87	(E) 0.55	(E) 0.50	(E) 0.68	(E) 0.55	(E) 0.50	(E) 0.66	(E) 0.55	(E) 0.54
Hydraulic only 4/	(W) 0.87	(X) 0.27	(Y) 1.63	(Y) 2.10	(Z) 0.51	(W) 0.94	(Y) 2.63	(Z) 1.11	(Z) 0.90	(Z) 0.83	(Z) 1.24	(X) 0.41

1/ Large hydraulics and hoppers not practical at redge site due to narrow or shallow dimension of waterway.

2/ Equipment combinations - see Page VI-46 for equipment letter codes.

3/ Least cost utilizing any system, whether currently available, would require extensive engineering and testing prior to use.

4/ Cost for currently available systems only equipment available although not necessarily presently located in the Bay area.

Source: Dredge Disposal Study, Appendix J (1974).

TABLE VI-11

SCHEME III - OCEAN DISPOSAL

Dredge Site	Suisun Bay	Mare Island	Napa River[1/]	Petaluma River[1/]	Pinole Shoal	Richmond L. W.	San Rafael Cr[1/]	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Disposal Site	100 Fathom Line											
Distance Miles	62	56	64	35	48	38	40	36	37	38	39	56
Run 1												
Least cost only[3/]	(A)[2/] 0.74	(A) 0.66	(B) 1.17	(B) 1.28	(A) 0.62	(A) 0.76	(B) 1.05	(A) 0.65	(A) 0.80	(C) 0.86	(C) 0.80	(C) 0.91
Hopper only[4/]	(D) 2.47	(D) 2.33			(D) 1.93	(D) 1.95		(D) 1.48	(D) 2.01	(D) 2.15	(D) 1.98	(D) 2.46
Clamshell only[4/]	(E) 1.21	(E) 1.19	(E) 1.18	(E) 2.36	(E) 1.05	(E) 0.89	(B) 1.05	(E) 0.91	(E) 0.84	(F) 0.99	(E) 0.94	(E) 1.10
Hydraulic only[4/]	(W) 3.78	(W) 1.91			(W) 1.87	(W) 2.64		(W) 3.31	(W) 2.89	(W) 2.48	(W) 3.93	(W) 3.59
Run 2												
Least cost only[3/]	(A) 0.79	(A) 0.71	(B) 0.98	(B) 1.07	(C) 0.69	(E) 0.64	(B) 0.88	(E) 0.67	(E) 0.61	(E) 0.74	(E) 0.68	(E) 0.81
Hopper only[4/]	(D) 3.47	(D) 3.28			(D) 2.72	(D) 2.74		(D) 2.08	(D) 2.82	(D) 3.02	(D) 2.78	(D) 3.45
Clamshell only[4/]	(E) 0.88	(E) 0.90	(E) 1.18	(Q) 1.81	(E) 0.79	(E) 0.69	(E) 1.50	(E) 0.67	(E) 0.61	(E) 0.74	(E) 0.68	(E) 0.81
Hydraulic only[4/]	(W) 3.46	(W) 1.70	(Y) 5.23	(Y) 6.01	(W) 1.64	(W) 2.40	(Y) 7.90	(W) 3.05	(W) 2.67	(W) 2.16	(W) 3.64	(W) 3.29

1/ Large hydraulics and hoppers not practical at dredge site due to narrow or shallow dimensions of waterway.

2/ Equipment combinations - see Page VI-46 for equipment letter codes.

3/ Least cost utilizing any system whether currently available, would require extensive engineering and testing prior to use.

4/ Cost for currently available systems only equipment available although not necessarily presently located in the Bay area.

Source: Dredge Disposal Study, Appendix J (1974).