PRELIMINARY

LAND DISPOSAL

OF DREDGE SPOILS

FOR SAN FRANCISCO BAY

This is a Special Report providing important information about San Francisco Bay that is not covered in the Commission's basic series of 23 planning reports. The information contained in the report has not been reviewed or approved by the Commission, thus is preliminary and subject to revision.

Prepared for

SAN FRANCISCO BAY CONSERVATION
AND
DEVELOPMENT COMMISSION

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SUMMARY AND CONCLUSIONS

1. Dredge spoils generated in the study area will average 11,200,000 cubic yards annually during the construction period of the John F. Baldwin Ship Channel.
2. If land disposal is used exclusively, approximately 7,500 acres of land will be required.
3. Nearly 19,000 acres of land have been identified in the study area that meet preliminary criteria for disposal sites and have a combined total shoal volume capacity of 600 million cubic yards.
4. Each site should be separately analyzed to determine its acceptability as a disposal site.
5. The spoil disposal site should be designed to accommodate a variety of dredging operations.
6. The greatest efficiencies can be attained by using a single organization to develop the sites and equipment for disposal.
7. Preliminary cost estimates indicate that, in some locations, the disposal site cost can be substantially offset by the increased value of the filled land.
8. The maximum benefit to the disposal of dredge spoil would probably be obtained by use of a public agency to implement the program.
9. Additional studies should be undertaken as soon as possible to develop more precise data and accurate estimates.
10. Because land disposal does not appear to be suitable to meet all needs, the areas where it appears feasible should be identified early.

INTRODUCTION

San Francisco Bay Conservation and Development Commission's Bay Plan policies on dredging includes the disposal of dredging spoils on dry land. Present methods of disposing of spoils from dredging new projects and for maintaining existing projects include ocean disposal, bay water disposal, and land disposal. This report will review some of the possibilities for increased land disposal by use of low lying lands adjacent to the Bay and operational methods presently in use in other parts of the United States. Because of the large amount of dredging in Northern San Francisco Bay and the lower reaches of the San Joaquin River, near-by areas were reveiwed to determine if sufficient low land sites were available for spoils.

This report will discuss the quantities of spoils from dredging, availability of land, factors used to determine site suitability, site preparation, disposal techniques, and steps for implementation. It is intended as a guide for a later more detailed study and thus makes recommendations for additional studies.

When applied to the appropriate situation with suitable equipment and taking advantage of scale, efficient operation and amortization of equipment, land disposal is feasible. Although only rough estimates were made, the cost of disposal on land is similar to the cost of disposal in the deep ocean.

SPOIL GENERATION

Before determining if sufficient land is available for spoils disposal, it is necessary to estimate the quantity of spoil generated each year in general areas of the Bay. Once spoil quantities are known, land availability can be evaluated.

In the area from Richmond in San Francisco Bay to Chipps Island in the San Joaquin River, there are four deep draft and three shallow draft projects maintained by the Corps of Engineers, and three naval installations that generate most of the spoils in the Bay. The locations of these projects are shown on Figure 1 and the approximate quantities of spoil generated at each location is summarized in Table 1. Table 1 also lists the quantities of spoil retained within the Bay system, much of which must be redredged later. The dredged quantities indicated in Table 1 (5,000,000 cubic yards) must be increased by 10 per cent to account for overdredging. The approximate annual maintenance dredge quantity is thus 5,500,000 cubic yards.

In addition to the tabulated quantities being dredged by governmental agencies, there are substantial amounts being dredged by private contractors in and about the pier facilities and marinas that are served by the maintained channels. To establish an estimate of the quantity of this private dredging, the Point Molate Navy Fuel Depot has been used as a guide. Based upon the assumption that ten such pier areas are privately maintained, the annual maintenance dredging from such operations will amount to 1,500,000 cubic yards. Therefore, existing maintenance dredging in the North Bay generates approximately 7,000,000 cubic yards annually.

FIGURE 1 MAP

TABLE 1

ESTIMATE OF DREDGE VOLUME AND AMOUNT
RETAINED IN BAY SYSTEM FOR
NORTH SAN FRANCISCO BAY SYSTEM FROM OVERBOARD DISPOSAL

	Maintenance Agency	Estimated Quantities Dredged (1,000 c.y. per year)	Quantities Retained in Bay (1,000 c.y. per year)
Pinole Shoal	Corps	500	470
Mare Island Strait	Corps	1,920	1,860
Mare Island Strait	Navy (by the COE)	600	580
Suisun Bay Channel	Corps	390	0*
Richmond Harbor	Corps	590	315+
San Rafael Creek	Corps	30	0*
Petaluma River	Corps	70 30	0* 28
Napa River	Corps	70	0*
Mare Island Naval Shipyard	Navy	1,180	0*
Navy Fuel Depot, Point Molate	Navy	120	95
Naval Ammunition Depot, Port Chicago	Navy	35	35
TOTAL		4,935	3,383

* Present spoil on land
\+ Present spoil at Alcatraz

In addition to maintenance spoils, additional dredge spoils will be generated by new construction. Several proposed new construction projects are within the limits of this study. The major new project in the Bay Area, the proposed John F. Baldwin Ship Channel, would extend through the entire study area and for the purpose of this study, the dredge spoil quantities from this project indicate the maximum annual new construction dredge spoil volume that may be generated in the near future.

New construction increases the annual disposal requirements both by the amount of excavation and by increased quantity of annual maintenance caused by the accelerated rate of accumulation of bottom silts in the new and deeper cuts. The portion of the John F. Baldwin Ship Channel to be constructed within the study area will require an initial excavation of 29,000,000 cubic yards and an estimated annual maintenance dredging of 1,100,000 cubic yards. Both of these figures include a 10 per cent allowance for overdredge.

Assuming that the John F. Baldwin Ship Channel will be constructed over a six-year period, the new construction excavation will average 4,830,000 cubic yards per year while the maintenance dredging will increase at a rate of 220,000 cubic yards per year. Table 2 indicates the estimated total dredge spoil generated in the study area in an eight-year period assuming construction of the John F. Baldwin Ship Channel begins in the second year. The peak generation of dredge spoils from all sources in the study area is estimated to be 13,000,000 cubic yards in the seventh year and the average annual dredging would be 11,200,000 cubic yards during the eight-year period. As indicated in Table 2, the annual dredging should be about 8,100,000 cubic yards after completion of the John Baldwin Ship Channel.

TABLE 2

ESTIMATE OF ANNUAL DREDGE SPOIL GENERATED
BY BOTH MAINTENANCE AND NEW CONSTRUCTION FROM
POINT SAN PABLO TO PITTSBURG
(UNITS IN 1,000 CUBIC YARDS)

Year	Present Annual Maintenance	New Construction Excavation	Additional Maintenance	Year Total
1	7,000	None	None	7,000
2	7,000	4,830	None	11,830
3	7,000	4,830	220	12,050
4	7,000	4,830	440	12,270
5	7,000	4,830	660	12,490
6	7,000	4,830	880	12,710
7	7,000	4,830	1,100	12,930
8	7,000	None	1,100	8,100

As indicated in Table 1, about two-thirds of the dredged material is spoiled within the Bay, much of which eventually returns to the navigation channels and is re-dredged. If dredged material is transported to land disposal sites and thus prevented from returning to the Bay, the annual quantity of materials to be dredged should decline. The extent of this reduction was not determined as a part of this study and should be evaluated as a part of a subsequent, more comprehensive analysis.

Table 2 indicates that the maximum quantity of dredge spoil generated in the study area is estimated to be nearly 13,000,000 cubic yards in one year, and conceivably the same amount may be disposed of on land. Realistically, the land disposal amount would be much less since some spoil will be dumped in water areas.

In any case, quantities of dredge spoil indicated are large and thus a program of land disposal must also be large. As noted in subsequent portions of the report, large capital expenditures for specialized equipment, and efficient operating methods will be required to implement an economically feasible land disposal program. The exception to this situation is where polluted spoils must be disposed of and land disposal may be the only acceptable solution, regardless of economics.

AVAILABILITY OF LAND

A cursory review of lands lying below 15' MSL and adjacent to San Pablo Bay, Suisun Bay, and the lower reaches of the San Joaquin River has revealed that there are substantial land areas that may be available for use as disposal sites for dredged spoils. Among the criteria used in tentatively identifying these lands as acceptable for spoil disposal were land elevation, land use designation as shown on the San Francisco Bay Plan, and accessibility to the area where spoil is generated.

Based on these criteria, nearly 19,000 acres of land were identified. The volume of spoil these lands can contain depends on the depth of fill and several other factors discussed in the following section on site selection. Each site must be separately analyzed, but based on the assumption that all of these lands could be filled to an elevation of 15 feet above mean sea level, their combined capacity is estimated to be 400 million cubic yards.

Assuming that the spoils will consolidate when dried to two-thirds of the shoal volume (volume of sediments in the channel), the volume of material that could be dredged from the channels and spoiled on these lands would be 600 million cubic yards. This amount exceeds all the estimated dredging from the study area for more than 50 years.

Based on experience in other areas, it is assumed that spoils can be deposited, dried and compacted at a rate of 1.5 feet per year and that after drying and compaction the 1.5 feet of spoil will be one foot of fill. For every 1,000,000 cubic yards of shoal volume dredging, 413 acres of land disposal area plus 275 acres of ponding area will be required. The pond area is necessary to process the effluent from the hydraulically dredged spoil before it can be discharged back into the Bay.

If the average annual dredging rate during the construction of the John Baldwin Ship Channel is 11,000,000 cubic yards (See Table 2), approximately 4,500 acres for drying and compacting and 3,000 acres for ponding will be required.

Even if 19,000 acres of land are not available for use as spoil areas, and if the areas cannot be filled to an elevation of 15 feet MSL, it is concluded that enough land does exist to consider land disposal a viable method of disposing of dredge spoils and thus worthy of further study.

SITE SELECTION

Several factors must be considered in evaluating the suitability of a site for land disposal of dredge spoils; each factor alone may be cause enough to eliminate the site from further consideration. Before specific suitability analysis the area of search must be defined. Because the cost of disposal increases as the distance of transportation increases, disposal sites should be located in the proximity of the point of dredging. The acceptable distance is influenced by the economics of various sites, and is also a function of the method of transportation. The cost of transporting the dredge spoil is dependent upon the length of haul and many other variable factors including the relatively fixed cost of loading and unloading the barges, the time of the trip with relation to the tidal cycles, the type of equipment used (value, crew size, speed, capacity) and the physical characteristics of the dredge spoil (easy or difficult to handle and pump). Sites within a few miles of the shoreline and within a 25-mile range of the point of dredging warrant first consideration.

The specific factors to be considered are as follows:

1. Topography

The size and elevation, or topography, of a potential site are major factors affecting the selection. Lands lying below 15 feet MSL would be most desirable. However, spoil can be pumped to higher elevations, but at higher costs. A large site, capable of receiving large volumes of spoil over many years may be necessary in order to provide a broad base over which to amortize expenses of securing the land, site preparation, setting up equipment, and solving access problems. Land disposal of polluted sediments is particularly appropriate; however, control of the return water will create added expense and will influence the size of disposal site. In all cases return water will require some control to reduce the settleable solids; in extreme cases, however, it is possible that no return water will be allowed. In general, the necessary size of site will increase as the requirements for effluent quality increase. A very large site to store and evaporate all the water will be required if the spoils are polluted and effluent discharge is not permitted. The size of a disposal site will also vary with the kind of sediments to be placed. A sandy material will settle much more quickly and require less ponding area than colloidal clay and silt sediments which may remain in suspension for longer periods. Even after settling, these sediments must dry longer to become workable, thus the rate at which silts and clays can be placed is less than the rate at which sand sediments can be placed.

Disposal sites may be divided into several sub-areas to allow continuous disposal at the site while sub-areas are alternated so sediments can dry and be compacted in one area while wet spoils are received in an adjacent area. Sub-areas also would allow the separation of materials so that sandy sediments can be placed in areas either needed for development sooner, or in locations where better foundation materials are needed. The clayey or silty sediments can then be placed in other sub-areas which are not intended for immediate near term use. In some areas the natural topography may aid in development of sub-areas because of existing features such as hills, roads or railroads.

2. Accessibility

One of the major costs in disposing dredge spoils is the cost of transporting the spoil to the disposal site. Even if the site is near the area where the dredging occurs, accessibility still may be a problem. A site that is accessible to deep water may be more economical than one adjacent to shallow water which would require multiple handling of the spoil material or dredging an access channel. It is possible to install deep water receiving stations capable of pumping spoil material through pipes traversing the shallows to land disposal sites. Such stations may be necessary in San Pablo Bay where the access channels through the shallows must be deep enough to allow barges and/or dredges to approach the disposal site. In some locations of the Bay, access is a major problem and it may be necessary to develop permanent facilities to transport the dredge spoils to the site. Land access for equipment to be used in conditioning the spoil areas should also be considered in computing the cost of access.

3. Land Use

In addition to physical and economical criteria, current and future land use must be considered. Land use is regulated by the planning of government units, the plans of property owners, and the desires of the public.

Current land use may preclude filling because of aesthetic, economic, or ecological reasons, or because of statutory restrictions. In addition to the more obvious physical restrictions of already developed-lands (e.g., urban or industrial land), lands used for agriculture, grazing, open space or lands with historical significance or other value may not be available for filling because of public interest.

Sites planned for development may be ideal for filling if sufficient time is available for the sediment to dry and for the fill to be completed. On the other hand, filling may be incompatible with the eventual use of the site, or the interim use as a disposal site, and may be incompatible with existing surrounding uses. Low land sites proposed for development could be reserved for spoil disposal instead of allowing the use of upland material for filling, thus accomplishing multiple use of the low lands.

4. Governmental Regulations

Land subject to tidal action, diked salt ponds, and managed wetlands are within the jurisdiction of the San Francisco Bay Conservation and Development Commission, the U. S. Army Corps of Engineers, the State Lands Commission, the counties, cities and special purpose districts. Current use, planned use, and zoning restrictions are usually designated on the general plans and ordinances by these agencies. Therefore, proposed filling must be in conformance with these plans and ordinances. Only those areas compatible with the plans of governmental agencies should be further evaluated.

BCDC = Bay Conservation and Development Commission

State controls include many agencies. BCDC's jurisdiction covers all submerged lands, tidelands, and marshlands situated below the line of highest tidal action (a line demarked by the highest tide at any time on or subsequent to September 17, 1965). The Bay is defined for this purpose as extending from a line between Point Lobos and Point Bonita (west of the Golden Gate) to the entire central and south Bays, northeasterly to a line drawn between Simmons Point and Stake Point in Suisun Bay, and around the southern edge of Chipps Island to Marshall Cut in Solano County.

The law specifically includes, as part of the Bay, marshlands (salt marsh habitat either at an elevation lower than 5 feet above mean sea level or subject to tidal action, whichever area is greater) and all sloughs.

BCDC has jurisdiction over certain construction on the dry land bordering the Bay within a 100-foot wide shoreline band, which is measured inland from the line of highest tidal action. Jurisdiction over other areas covers (a) salt ponds and managed wetlands (areas diked off from the Bay and used three years previously for duck hunting, game preserve, or agriculture) and (b) portions of some tributaries to the Bay, including parts of Plummer Creek, Coyote Creek, Redwood Creek, Tolay Creek, San Antonio Creek, Sonoma Creek, Napa River and Petaluma River and tributary marshlands.

BCDC may allow filling within these areas only when public benefits from fill clearly exceed public detriment from the loss of the water areas and should be limited to water-oriented uses (such as ports, water-related industry, airports, bridges, wildlife refuges, water-oriented recreation and public assembly, water intake and discharge lines for desalinization plants and power generating plants requiring large amounts of water for cooling purposes) or minor fill for improving shoreline appearance or public access to the Bay and only when no alternative upland location is available. In processing permits BCDC will request comments from the State Lands Commission, the State Department of Fish and Game, the Regional Water Quality Control Board, and the U. S. Army Corps of Enginners on all projects involving new fill.

Vehicle water used to transport spoils hydraulically to the spoil site will, in most cases, be returned to the Bay. Although the mechanics are discussed later, the Regional Water Quality Control Board will impose waste discharge requirements similar to the typical requirements given in the Appendix.

If the lands to be filled are within the jurisdiction of the U. S. Army Corps of Engineers (all areas below the plane of the mean of the higher high water, including unfilled portions of the interior of diked lands below former mean higher high water), a permit from the District Engineer will be required. If the area to be filled is beyond the Corps of Engineers' jurisdiction, a Corps dredging permit is required. Before the spoil from federal projects can be placed on land a "local sponsor" is needed to provide the land and necessary permits.

For the time being federal environmental impact statements are not required except when federal funds are involved. State Environmental Impact Statements will be required.

Many of the low lying lands surrounding the Bay are presently in public ownership. The sale, lease, or development of these lands will be determined by the government unit owning the land. The disposition of State lands is determined by the State Lands Commission.

5. Foundation Conditions

Each potential spoil site should be analyzed to determine the nature of the underlying soil and its ability to sustain the loads placed on it during filling operations and later during its planned use. The type and extent of geologic hazards associated with the site (proximity to fault, potential for liquefaction or slope instability) and the fill materials should be identified and an assessment made of the suitability of the site for the intended use in view of the associated risks. These analyses should be made by a qualified soils engineer and should include a review of the type of material to be placed on the site and the methods and schedule of placement.

The character of the foundation material and the dredge spoil will vary greatly from site to site; therefore, individual site analysis is essential to assure that the site can be used for its intended purpose. Subsurface conditions will control the rate of foundation consolidation and influence the extent and pattern of settlement. Foundation strength determines the amount and rate of fill material that can be placed.

The time required for a site to be readied for development depends in part on the foundation and the materials being placed. Estimates should also be made of the rate of filling without creating foundation failure. Because fill causes clayey foundation soils to gradually gain strength with time, fill materials should be placed as the strength increases so greater amounts can be placed without the failure that would be caused if the fill was placed too rapidly. This factor, fortunately, is compatible with the need to allow spoils to settle out and dry.

The kind of spoil to be placed will affect the eventual site use. In general, dense sand above the water table is a firmer, more stable foundation material than silt or clay. Silt and clay characteristics can be improved on the addition of chemicals and proper compaction.

6. Profit Potential

In many cases the placing of fill on a parcel of land will increase the number of potential uses and thereby increase its value. This increase in value can help offset the cost of land disposal, but the amount of increase will depend on many factors, including the initial property value, the tax rate, the time required for the site to be prepared for development, the ultimate use, and the market value for improved land. These factors will vary substantially throughout the Bay Area and during the period of spoils disposal. Properly planned development and coordination with spoiling can result in substantial profits. Sites with high profit potential will probably be filled sooner than ones not marketable for many years.

SITE PREPARATION

Most dredge disposal sites will require extensive site preparation. Levees must be constructed to encompass the site and to divide it into sub-areas. Experience has shown that levees constructed on many of the low lying lands around San Francisco Bay must be raised slowly and maintained regularly if the levee elevation is to be preserved. In some cases the underlying soil material has such poor foundation characteristics that it takes many years to construct a stable levee. It may be possible to develop the levees while spoil is being placed since the clayey or silty soils must be placed in relatively shallow layers to allow sufficient exposure for drying.

Drainage facilities consisting of settling basins, weirs and channels will be required to collect the water running off from the settled solids and to conduct it back to the Bay. Controls regulating the depth and velocities of the water will determine the volume of the ponded water and affect the rate of settlement. In areas where sandy material is being deposited, the length of time of settling and the size and number of the settling ponds will be considerably less than where the spoil consists of silty or clayey soils. Some ponds may need to be sealed off from the Bay to prevent the return of water polluted by undesirable chemicals in the dredge spoil. Laboratory facilities must be provided for testing the effluent before allowing its return to the Bay. As a rule of thumb about twice the shoal volume should be provided between levees to provide sufficient ponding area so the effluent will be clean.

If a large site is proposed to be used for the deposition of varying types of dredge spoil over a long period of years, it may be economical to develop a permanent spoil transfer and control system to allow the switching of material from one sub-area to another depending on the type of material and the future land use. Such a system would be more complicated and expensive than a simple system not capable of segregating materials in an area that has limited capacity.

When desirable to reduce the settling and drying time or to improve the engineering properties of the sediments, chemicals can be introduced and/or the soil can be mechanically worked to increase air exposure. If such methods are to be used, the site should be planned to allow access by the necessary equipment to the critical areas. Consolidation of the underlying soils and the new fill can be accelerated by installing subdrains before commencement of filling to expedite the drainage of subsurface waters.

Some of the materials received at the disposal site may be capable of reclamation and re-use in other parts of the Bay Area. Future uses of these materials may require reclamation facilities which should be considered in site selection and preparation.

The cost of site preparation will vary with each site depending upon local conditions, the need for drains and runback facilities, and natural vegetation to be stripped. The height and length of levees and the length of time to construct them will vary based on the strength and stability of the foundation soils and the material being used for levee construction. The transfer, drainage and reclamation facilities will depend on the individual characteristics of each site.

In July 1966, the Corps of Engineers, Charleston District, published a survey report on Cooper River, South Carolina, containing an appendix on spoil disposal. The costs of site preparation, excluding land costs, used in that report were approximately 5 cents per cubic yard.

Preliminary comparisons indicate that the methods of site preparation outlined in this report would be more complicated and may require greater lengths of levees and pipelines. Using current cost figures it is estimated that site preparation costs would be as follows:

DREDGE SPOIL DISPOSAL SITE

ESTIMATE OF COST OF SITE ACQUISITION AND PREPARATION

This estimate is based on a typical potential disposal site located adjacent to deep water in the San Joaquin River. The site has an area of 1,830 acres and has been divided by interior levees into seventeen sub-areas. Based on filling the site to an elevation of 15 feet, mean sea level datum, the total site capacity is estimated to be 37,500,000 cubic yards, or using a consolidation ratio of 3:2, 56,300,000 cubic yards of shoal volume. Cost estimates are based on current values and prices.

ITEM	QUANTITY	UNIT	UNIT COST	COST
Land purchase	1,830	Acres	$ 1,000	$ 1,830,000
Levees, channels, gates, etc.	33	Miles	100,000	3,300,000
Pipelines, valves, controls	5	Miles	130,000	650,000
	TOTAL			$ 5,780,000

The annual capacity of this site is calculated as follows:

Fill area = 1,100 acres

Pond area = 730 acres

Total Area = 1,830 acres

Shoal volume depth of 1.5 ft. per acre would contain

1.5 x 1,100 x 43,560/27 = 2,662,000 cu. yds.

Life of site = 56,300,000 cu. yds./2,662,000 cu. yds./yr.

= 21 years

Average annual capital cost at interest rate of 6 percent

= $5,780,000 x .08500445 = $491,000

Average annual maintenance & operation cost = 40,000

TOTAL ANNUAL COST $531,000

METHOD OF OPERATION

Dredging in the San Francisco Bay Area is being accomplished by three principal methods: (1) hydraulic dredges; (2) clamshell or dragline dredges; and (3) hopper dredges. Each of these types of dredge operates in a unique manner and is best suited for particular kinds of dredging.

The hydraulic dredge uses a suction head with or without a cutter, to excavate the material in the channel and suck it together with large quantities of water into a pipeline which transports the fluid mixture to the disposal site. In many cases, the on-shore disposal site may be close enough (approximately two miles) to the project site that the pumping capacity of the hydraulic dredge is sufficient to transport the spoil to the disposal area. In other cases, a booster pump may be required to transport the spoil to the disposal site. Hydraulic dredging creates large quantities of return water that must be accommodated with settling basins, channels and weirs.

The clamshell or dragline dredge mechanically digs up the material and deposits in an adjacent area or in a barge for transportation. If the disposal site is beyond the limited range of the boom of the dredge, barges must be used. At a land disposal site, the material must be rehandled to remove it from the barge. The material transported is in a solid or semi-solid state and must be converted to a fluid slurry to be moved on land by pipeline. The movement of barges is affected by the tidal currents and tug capacity. In the Bay, barges usually are moved with the tide.

The major portion of the maintenance dredging of the Corps of Engineers is accomplished by use of a hopper dredge. These dredges.

are ocean-going ships which are specially equipped with large suction sweeps which pump a mixture of solids and water into the hopper for transport to the disposal site. Presently the dredged material is dumped back into Bay waters at designated disposal sites. Hopper dredges have been modified for overboard dumping into a sump rehandler and also for direct pump-out to a transfer pipeline which carries the spoil to the disposal areas. Hopper dredges with land disposal capability have been used since December 1954, in maintenance of the Delaware River from Philadelphia to the sea, a length of 96 miles. Prior to beginning this operation, dredging in the Delaware River was accomplished by hopper dredges with disposal by bottom dumping into the sea or in deep water of the river or into previously excavated rehandling bases where a pipeline dredge pumped the material to a land disposal area.

Hopper Dredges used in Philadelphia

In December 1954, the Sump Rehandling Dredging System was initiated. To operate the system, two hopper dredges, the Goethals and the Comber, were modified to provide overboard dumping into the sump rehandler. The former hopper dredge, New Orleans, was converted to a rehandler by removing all original machinery and installing two large 3,000 HP centrifugal pumps and the necessary piping to pump material from her hopper to land disposal areas. These three pieces of equipment operated for 8-1/4 years and handled 101,398,700 cubic yards in the Delaware River, Norfolk Harbor and other smaller areas. Prior to sump rehandling, 22 hopper dredge months per year and the full time use of several pipeline dredges were necessary to handle nearly 25,000,000 cubic yards annually. Because of the retention of the spoils in land disposal areas, the annual dredging was reduced to 7,500,000 cubic yards and only 10 hopper dredge months were required annually. The success of this system is evident in the reduction of the workload to one-half the former amount.

Studies by the Philadelphia District led to a decision to convert the Comber to direct pump-out in 1963. Following conversion she was able to unload spoil from her hoppers directly to the on-shore disposal site through a pipeline up to 20,000 feet in length. A Wellons Pier Barge was modified to act as a shore connection for the hopper dredges. The cost of converting the Comber was $1,109,200 and the cost of the shore connection was $450,000. During the first seven months of operation, the costs of dredging were reduced by approximately 20 per cent from costs using the sump rehandler method. Because of the great capital value of hopper dredges, unloading must be fast and efficient to minimize the cost caused by the dredge being idle. Thus unloading can not be slowed by the capacity of the rehandling station.

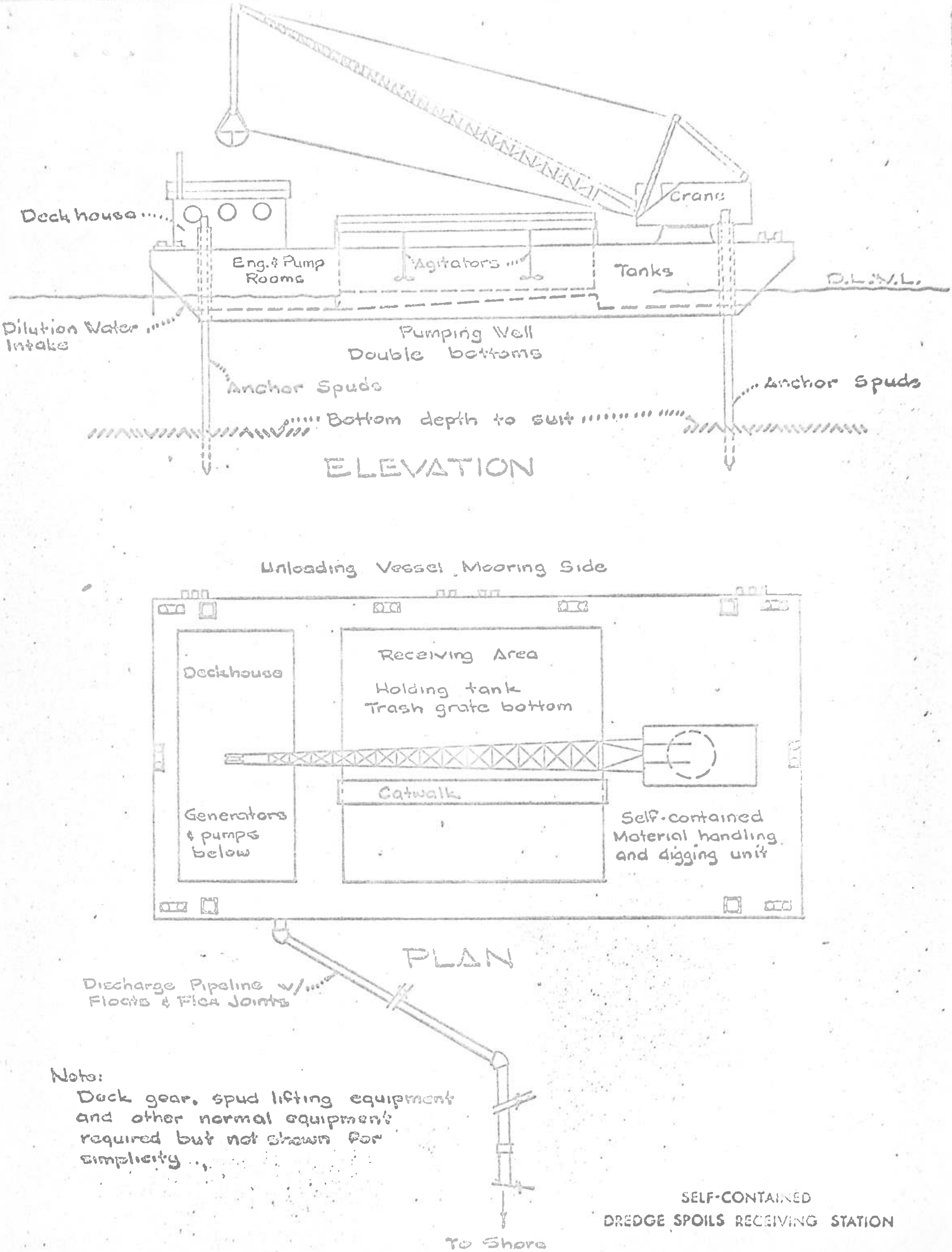
Rehandling stations will be the key link to economical land disposal. The operation of rehandling stations will vary with the type of dredge and the consistency of spoil materials. Hopper dredges, for example, capable of direct pump-out could pump through the station's land pipes using the station pumps as boosters. Hopper dredges capable of overboard discharge could be emptied at the receiving station to hopper barges, or the barges could be filled at the dredge site and towed to the rehandling station.

Clamshell, dragline and bucket dredges generally load hopper barges. These barges would be towed to the receiving station for unloading either by clamshell, or hydraulically. Hydraulic dredges also could discharge through the rehandling station using the pumps as boosters.

In order to have the flexibility of handling any type of dredge spoil (solid, semi-solid, or fluid), the receiving station should be capable of converting spoil into a fluid state as well as act as a shore connection for possible hopper dredge direct pump-out. The size of the station must be sufficient to handle the maximum hourly output of any of the dredges that may discharge to it.

To be useful as a shore connection for direct pump-out from a hopper dredge, the receiving station must be located in water having a depth of 30 feet to permit maneuvering and mooring of the hopper dredge. The disposal sites should be located within three miles of the receiving station, although rehandling or booster pumps may be employed to permit transporting the spoils greater distances, but at greater costs. Experience of the Corps of Engineers in the Cooper River Project in 1966 indicated that the cost of pumping spoils by booster pumps was about 4 cents per yard per mile. If spoils are delivered by barge, or hydraulic pipeline, water depth at the station can be about 5 to 10 feet. In order to lower costs, rehandling stations could be built to receive spoils from a variety of sources. Even though existing equipment used for dredging may not be best suited for land disposal, rehandling stations should be designed to accommodate this equipment.

Figure 2 shows receiving station with the ability to handle most types of dredge spoil while being capable of moving with relative ease from one disposal site to another. The receiving station could receive spoils from hopper dredges, hydraulic dredges, and has its own crane for unloading barges. It also can agitate the spoil material to a fluid state then pump it to the land disposal site. The crane can be used to remove timbers, iron and other debris from the spoil before pumping.



SELF-CONTAINED
DREDGE SPOILS RECEIVING STATION

FIGURE 2

Because of its portable nature, it could be used as a booster station on a hydraulic pipeline.

The receiving station could act as a monitoring station for determining the quality of the spoil material. Samples could be taken, as required, from spoil being transferred through the station and control could be established to assure that contaminated spoils are placed in areas that will not pollute the Bay waters.

The estimated cost of the receiving station shown in Figure 2 is $3,000,000. Its capacity is estimated to be 10,000,000 cubic yards of dredge spoil annually. Based on a crew of 30 men for 24 hour operation all year, a life of 30 years and interest rates of 6 percent, the following costs are derived:

Estimated capital cost	=	$ 3,000,000
Annual capital cost	=	$ 218,000
Annual maintenance and operating cost	=	400,000
TOTAL ESTIMATED ANNUAL COST	=	$ 618,000

The cost of developing and operating a dredge spoil disposal project would be a major factor affecting its successful implementation. If the lands selected to become fill areas were physically feasible of being filled to support future structures and were located in an area that had potential use for industrial or other purposes, the increased value of the land resulting from its filling could offset at least a portion of the disposal costs.

In the typical site described in preceding sections of this report, the average annual cost of acquiring, preparing and operating the site was estimated to be $531,000. This site provided an annual disposal capacity of 2,662,000 cubic yards. The average annual cost of constructing and operating a receiving station was estimated to be $618,000 for an annual capacity of 10,000,000 cubic yards. Assuming that this station would operate for one-third of its time at this site, the average annual cost of the station chargeable to this site would be $306,000. The total annual cost would be $837,000 for 2,662,000 cubic yards, or $.314 per cubic yard.

The above costs do not consider the value of the site upon completion of the disposal operation. The value should increase because the land should be able to be developed and used for industrial purposes in accordance with the Bay Plan. Assuming an interest rate of 6 percent, the cost of the project at the end of 21 years would be approximately $30,000,000, or $16,400 per acre. Filled and graded industrial land adjacent to the river in Contra Costa County is now selling for $ per acre. Therefore, if the reclaim value of the land is written off against the project cost, it substantially reduces the disposal costs.

ADDITIONAL STUDIES

This report has been necessarily brief and limited in scope when compared to the enormity of the problem. Additional studies should be undertaken as soon as possible to develop more precise data and accurate estimates. These studies should include:

1. Define the role land disposal should play in conjunction with other disposal methods. Determine reasons why land disposal would be required or circumstances under which it would be more desirable than open water disposal. Estimate the volume and points of origin of spoil for land disposal and the general areas where spoil sites will be needed during the next several years.

2. Review in detail the capabilities and costs of equipment necessary to implement land disposal on a scale consistent with the quantities involved. Existing programs and equipment throughout the world should be reviewed and new methods and equipment suitable for efficient operation in San Francisco Bay should be explored. Accurate cost estimates, and detailed procedures should be prepared.

3. Locate low land sites planned for filling in the immediate future and determine the feasibility of filling with dredge spoils.

4. Develop comprehensive guidelines for securing governmental approval of projects, and for evaluating social and ecological impact.

5. Develop detailed alternative organizations (private companies, or governmental agencies) for implementing land disposal operations.

6. Form an ad hoc task force of involved government agencies, dredging contractors and port interests to prepare a report covering these recommendations and other germane points by July 1, 1973.

7. Locate specific parcels of land for disposal.

8. Initiate a pilot disposal project.