CHAPTER 2

DREDGED MATERIAL AS A RESOURCE

2-1. General.

a. The Dredged Material Research Program (1973-1978), the Dredging Operations Technical Support Program (1978-present), and the Environmental Effects of Dredging Program (1982-present) have determined the environmental impacts of dredged material disposal, alternatives to increase the beneficial use of dredged material, and means to reduce the adverse effects of both land and water dredged material disposal. Increased interest in dredged material as a manageable, beneficial resource as an alternative to conventional disposal practices is due to the fact that, while the amount of material dredged each year continues to rise, increasing urbanization around waterways and ports has made it difficult to locate new sites for containment areas. New environmental regulations have further restricted both land and water disposal options. Costs of dredged material disposal have increased rapidly as disposal sites are located at greater distances from the dredging site and environmental controls are added. By considering dredged material as a resource, a dual objective can be achieved. The dredged material from needed navigation projects can be disposed of with minimal environmental damage, and benefits can accrue from its use.

b. Physical, engineering, and chemical characteristics of dredged material proposed for beneficial use and land enhancement projects must be identified. This includes examination of contaminants. Such information is essential for evaluating the suitability of the material for numerous alternative uses. These characteristics must be determined during the initial stages of planning since proposed uses may prove infeasible due to unsuitable material. Chapter 2 presents discussions of the physical, engineering, and chemical characteristics of dredged material, contaminant and water quality considerations, and some of the limitations which may be encountered with dredged material substrates that may preclude alternatives. Most dredged material is below contaminant levels that would preclude a beneficial use.

2-2. Physical and Engineering Characteristics.

a. Physical Characteristics. A number of standard soil properties are used to determine the physical and engineering characteristics of dredged material (item 3). Soil tests include grain-size, plasticity, and organic content determinations. Engineering tests include compaction, consolidation, and shear strength. Item 4 indicates that dredged material is made up of various types of soil that can be classified under the Unified Soil Classification System (USCS) (item 60).

(1) Grain size. Grain size is the principal physical characteristic to be determined when considering dredged material for beneficial uses, and grain size is also the basis for most soil classification systems. Land enhancement

guidelines presented in this EM for the beneficial uses of dredged material include engineering, environmental, and agricultural projects. For this reason, both the USCS (item 60) and U.S. Department of Agriculture (USDA) (items 6 and 38) classifications are used. The USCS method emphasizes characteristics of a construction material, whereas the USDA method emphasizes soil agricultural properties. The USCS method is the method most often used for classifying dredged material, but for certain beneficial uses it may be necessary to use the USDA method.

(2) Bulk density. Bulk density is a weight measurement by which the entire soil volume is taken into consideration. The bulk density of dredged material is usually low for fine-grained material, but a highly productive agricultural loam soil can range from 70 to 86 pounds per cubic foot (item 38). These low bulk densities in fine-grained dredged material can be attributed to the sedimentation process and the amorphous nature of the clay. Bulk density data are needed for converting water percentage by weight to water content by volume for estimating the weight of a large volume of material. Examples are the weight of dredged material in a disposal site or estimating the volume of dredged material in a dump truck, barge, or railroad car.

(3) Plasticity. For USCS classification, the Atterburg liquid limit (LL) and plastic limit (PL) must be determined to evaluate the plasticity of fine-grained sediment samples. The LL is that water content above which the material is said to be in a semiliquid state and below which the material is in a plastic state. Water content (item 68) which defines the lower limit of the plastic state and the upper limit of the semisolid state is termed the PL. The plasticity index (PI), defined as the numerical difference between the LL and the PL, is used to express the plasticity of the sediment. Plasticity analyses should be performed on the separated fine-grained fraction of dredged material samples.

(4) Specific gravity. Values for the specific gravity of solids for fine-grained sediments and dredged material are required for determining void ratios, conducting hydrometer analyses, and consolidation testing.

(5) Water retention and permeability. Water retention characteristics of soil describe the energy relation of soil to water, can be used to determine the availability of water to plants, describe the moisture-storing capacity of a soil (dredged material), and are strongly influenced by the arrangement of the solid components and the quantity of fine particles and organic matter (Table 2-1). The potential available water capacity of a field soil is defined as the amount of water a crop can remove from the soil before its yield is seriously affected by drought (Table 2-2). The permeability and sorptive properties of a material express the ease with which water will move or pass through (Figure 2-1). Permeability is determined by a number of factors; however, size of soil pores and magnitude of soil water retention are most important.

Table 2-1

Available Water Capacity of Soils of Different Grain Size Range*

Grain Size Range	Available Water Capacity at Saturation, Inch of Water per Inch of Soil Depth
Sand	0.015
Loamy sand	0.074
Sandy loam	0.121
Fine sandy loam	0.171
Very fine sandy loam	0.257
Loam	0.191
Silt loam	0.234
Silt	0.256
Sandy clay loam	0.209
Silty clay loam	0.204
Sandy clay	0.185
Silty clay	0.180
Clay	0.156

* Source: item 25.

Table 2-2

Available Water Capacity Suitable for Agricultural Crops*

Available Water Capacity, Inch Water/Inch of Soil	Total Available Water Capacity, Inches per Yard of Soil Depth	Recommended Plants
0.05	1.8	Not suitable for most agricultural crops unless irrigated
>0.05-0.075	>1.8-2.7	Best suited for grasses
>0.075	>2.7	Suitable for most agri-cultural crops

Source: item 25.

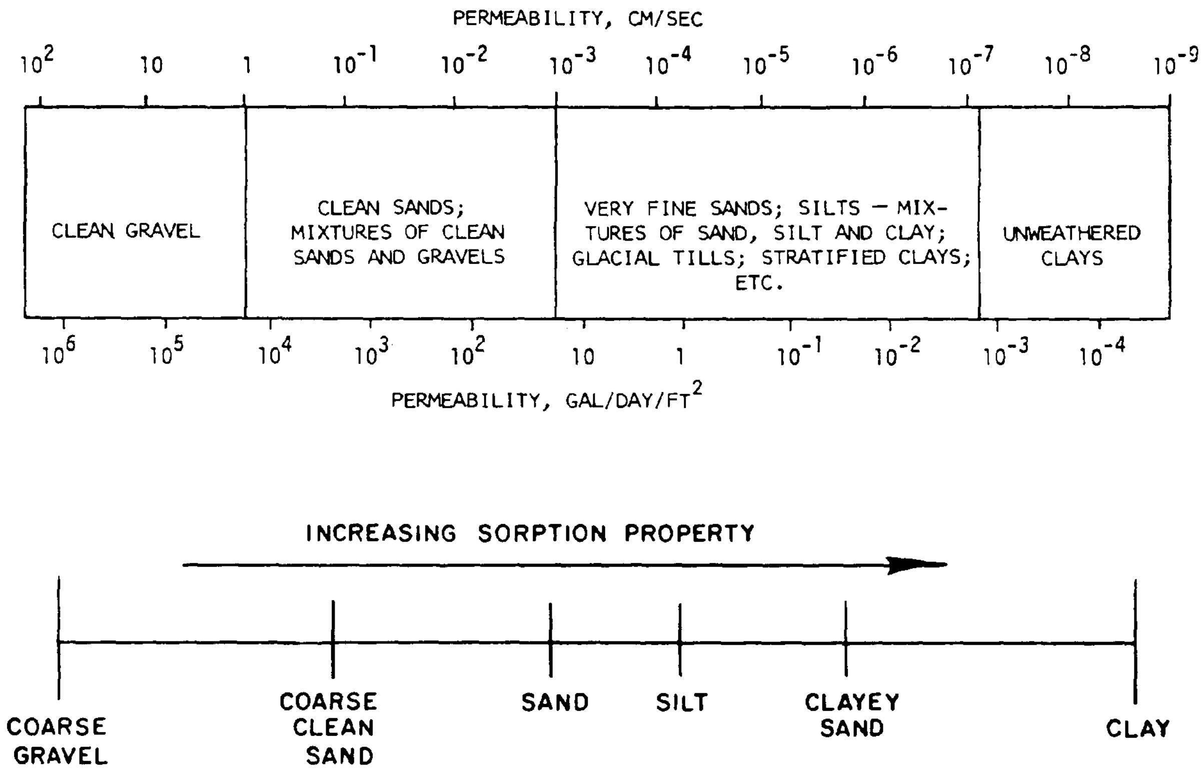

Figure 2-1. Range in permeability and sorptive properties of different soil classes (item 68)

(6) Volatile solids. Volatile solids are important in determining contaminant retention within a soil or dredged material, and for the material's capacity for plant growth and beneficial use.

b. Physical properties of dredged material. When hydraulically placed into a disposal area, dredged slurry can have a dry solids content ranging from near 0 to approximately 20 percent by weight (item 33). Generally, this value is about 13 percent. As the slurry flows across the disposal area, the solid particles settle from suspension: coarse particles near the inlet (dredge pipe), fine particles farther into the area, and finest materials in the immediate vicinity of the outlet weir. As a disposal operation progresses, coarse-grained dredged material may accumulate in a mound and displace the soft fine-grained dredged material.

(1) During and after the disposal operation, surface water is drained from the disposal area. A surface crust begins to form on fine-grained dredged material as it desiccates. Over time, surface and base drainage cause some lowering of the ground-water table, the surface crust continues to increase in thickness, secondary compression effects develop, and

consolidation occurs as the effective material weight above the ground-water level is increased from a submerged weight to a saturated weight. The dredged material below the surface crust remains very soft and weak.

(2) The water content of fine-grained dredged material in disposal areas is generally less than 1.5 times the LL of the material, and it is possible that in freshwater areas the water content is about equal to the LL. The LL of dredged material is generally less than 200, with most values being between 50 and 100.

c. Engineering Properties of Dredged Material.

(1) Engineering properties are critical to determining the types of beneficial uses possible. Soft, fine-grained dredged material has little load-bearing capacity, and can generally be used only on sites not involving heavy structures or intensive activities (urban, recreational, other). EM 1110-2-5025 contains more detailed information concerning physical and engineering properties.

(2) The surface crust associated with fine-grained material usually has a very low water content (often near the shrinkage limit) that increases slightly with increasing depth of the crust. The crust is usually overconsolidated due to the increase in effective stress caused by high negative pore pressure resulting from evaporation. Below the surface crust, however, the fine-grained material is extremely soft, with water content usually showing little change from the time of deposition. Density and shear strength increase very slightly, if at all, with increasing depth. Data show that engineering properties are generally better near the inlet than the outlet because the coarse-grained material settles near the dredge discharge. The engineering properties of the fine-grained material in the containment area near the outlet are poorer and improve very slowly with time. In general, dredged material is soil with a high water content, that upon dewatering exhibits soil properties with a high beneficial use potential.

2-3. Chemical Characteristics.

a. General. Dredged material characteristics reflect the population, industry, and land uses of an area (item 81). The chemical constituents of dredged material help determine the suitability of that material for a particular land use (item 11). Chemical analysis of the dredged material must be made to indicate potential detrimental effects on the environment in the disposal area. Four potential problem areas exist depending on the presence of available chemical constituents in the dredged material: plant toxicity, animal toxicity, surface water contamination and ground-water contamination (items 44 and 53). Plant uptake of chemicals may also present problems if growth or reproduction potential of the plant is altered or if harmful chemicals are passed via the food web into higher organisms.

b. Cation Exchange Capacity. The capacity of soil particulates to adsorb nutrients which become available for plant growth is called the cation exchange capacity (CEC). Adsorbed or sorbed nutrients are readily available to higher plants and easily find their way into the soil solution. The grain size and organic content of sediments determine to a large extent the capacity of that material to sorb and desorb cations, anions, oil and grease, and pesticides. Silts and clays with relatively high organic contents can sorb and fix large amounts of plant nutrients as well as many other constituents (Figure 2-1). The CEC of dredged material governs the sorption of nitrogen and potassium, heavy metals, and some pesticides. The nutrient content of dredged material varies widely, as does that of different soils. Generally, fine-grained dredged material contains considerably more nutrients than coarse-grained material and is also more likely to contain one or more contaminants.

c. Nitrogen. The total nitrogen content of dredged material varies widely with geographic location. The most predominant form of nitrogen in inorganic sediments is ammonium nitrogen. In organically enriched sediments, organic nitrogen predominates, even though ammonium concentrations can be very high.

d. Sulfur. Item 44 indicates that sediments in a South Carolina tidal marsh developed high acidity when drained and dried. These sediments contained up to 5.5 percent total sulfur. When drained, sulfides were oxidized to sulfate with a resultant decrease in sediment pH from 6.4 to as low as 2.0. This effect may be a serious problem in dredged material containing high levels (usually greater than 0.1 percent) of nonvolatile sulfide, predominantly iron and manganese sulfide. This is especially true if the dredged material is not limed or its acidity is not otherwise counteracted by application to an alkaline upland soil.

e. Heavy Metals.

(1) A wide range of heavy metal concentrations has been reported in a number of sediments from rivers, harbors, and bays throughout the United States and Canada, primarily in intensely urban and highly industrialized regions. Some of the major sources of heavy metals include industrial and sewage discharges, urban and highway runoff waters, and snow removal. Wastes from metal plating industries that have found their way into some sediments contain significant amounts of copper, chromium, zinc, nickel, and cadmium. Chemical partitioning studies of sediments have shown that these metals occupy the least stable of the sediment fractions and that the sediment chemistry dominates the mobility and availability of the contaminant as well as the indigenous metals.

(2) An important heavy metal consideration is the solubility of specific constituents whose concentrations are high, since soluble forms are readily available to the biological food web. The potential of a heavy metal to become a contaminant depends greatly on its form and availability rather

than on its total concentration within a dredged sediment (item 44). Heavy metals may be fixed in a slightly soluble form in dredged material containing excessive sulfide. The land application of dry oxidized dredged material may increase the solubility of heavy metal sulfides. However, under oxidizing conditions, the levels of pH and heavy metal hydroxyl and oxide formation become the important factors, and sulfur no longer governs the solubility and availability of heavy metals (item 25).

(3) Until Federal standards are set for sediments, guidelines for dredged material disposal must be taken from other research areas such as sludge disposal. The USDA has been investigating the application of sewage sludge to agricultural lands. Recommended maximum limits on the metal content of sludge are shown in Table 2-3.

Table 2-3

Recommended Maximum Limits for

Metal Content in Digested Sewage Sludges*

Element	Domestic Sludge Concentration, ppm
Zinc	2,000
Copper	1,000
Nickel	200
Cadmium	15 or 1.0% of zinc
Boron	100
Lead	1,000
Mercury	10
Chromium	1,000

Source: item 9.

* Typical sludge from communities without excessive industrial waste inputs or with adequate abatement.

In most cases, the heavy metal contents of dredged material fall below the maximum allowable limits recommended in domestic sewage applied to land. If higher concentrations of chemical constituents are found in dredged material, it should not be used in a land improvement project without prior treatment to remove or reduce contaminants.

2-4. Water Quality Considerations.

a. Ecological impacts of the discharge of dredged or fill material can be divided into two main categories: physical effects and chemical-biological interactive effects. Physical effects are often straightforward, and evaluation may often be made without laboratory tests by examining both the character of the dredged or fill material proposed for discharge and the sediments of the disposal area. On the other hand, chemical-biological interactive effects resulting from the discharge of dredged or fill material are usually difficult to predict.

b. Natural processes in aquatic ecosystems tend to concentrate heavy metals, chlorinated hydrocarbons, pesticides, nutrients, and oil and grease compounds in bottom sediments. These contaminants are not very soluble in water under the conditions that normally occur in oxygenated uncontaminated surface waters. Therefore, introducing high concentrations of these contaminants into aquatic ecosystems will generally result in an equilibrium condition where most of the contaminant will be sorbed (adsorbed and absorbed) by suspended particulate material and then deposited on the bottom when the suspended material settles. The time necessary to achieve the equilibrium condition depends upon the physicochemical conditions in the aquatic system and the quantity and duration of the contaminant introduction. There has been concern that dredging and open-water disposal operations may release these trapped contaminants again, and thus have the potential to damage wetland, upland, and aquatic environments. WES reports (items 7 and 23) and other literature indicate that dredging operations have the potential to temporarily mobilize or release some contaminants from the sediments. During disposal operations, the anaerobic sediments are mixed with aerated surface water, and a complex chemical interaction occurs. Heavy metals such as cadmium, copper, chromium, lead, and zinc, which had been stabilized in oxygen-free sediments, form precipitates and coagulate in the presence of oxygen. Phosphorus and nitrogen can be temporarily released into the water column, while pesticides and oils and grease are usually not very water soluble. However, all of these contaminants have the potential to affect a proposed beneficial use project.

c. The Environmental Protection Agency (EPA), in conjunction with the CE, has published a comprehensive procedure manual (items 23 and 66) that contains summaries and descriptions of tests, definitions, sample collection and preservation procedures, analytical procedures, calculations, and references required for detailed water quality evaluations. The purpose of this is to provide state-of-the-art guidance on the subjects of sampling, preservation, and analysis of water and dredged and fill material. The interim guidance for implementing Section 404(b) of the Clean Water Act was published in 1976 (item 18). It has also been published jointly by the EPA and the CE pursuant to the Marine Protection, Research, and Sanctuaries Act of 1972, which addresses the primary intent of Section 103 of regulating and limiting adverse ecological effects of ocean dumping.

2-5. Contaminated Dredged Material. Over 90 percent of the total volume of dredged material is considered acceptable for disposal at a wide range of disposal alternatives. However, the presence of contamination in some locations has generated concern that dredged material disposal may adversely affect water quality and aquatic or terrestrial organisms. Since many of the waterways are located in industrial and urban areas, some sediments may be highly contaminated with wastes from these sources. In addition, sediments may be contaminated with chemicals from agricultural practices. The EPA guidance in Section 230.60 (Federal Register, Vol. 45, No. 249) should be used to determine whether there is sufficient cause for concern to warrant testing for contaminants and to identify the contaminants of concern.

2-6. Biological Limitations. Although dredged material has been generally found to be a soil resource of great value and use, it has some limitations as a beneficial product.

a. Texture and Physical Characteristics. Dredged material is composed predominantly of mineral particles ranging in size from coarse sand to fine/ clay and can have an extremely mixed mineralogy (item 44). Dredged material deposits within one disposal site can vary from well-ordered sand to organic clay. In addition to soil, dredged material may contain other solids such as rock, wood, pieces of metal, glass, and other debris. Contamination of these sediments in the form of organic material, elevated concentration of heavy metals, a vast array of chlorinated hydrocarbons, oil and grease, and other organics reflects the influences of population and industry in the area. The actual physical texture of the material on a site may limit its use; i.e., pure sand dredged material would not be suitable for agricultural land applications. However, as fill material and for some dike construction, it may be excellent. Predominantly uncontaminated silt would not be well suited for waterbird island construction, but would make an excellent soil addition for agriculture and forestry, and for some habitat development sites.

b. Contamination.

(1) In certain areas of the United States, such as near certain industries or extensive agriculture, contamination is an important factor to be considered. If the dredged material contains contaminants, it may have to be placed in a confined disposal site, which will probably limit its beneficial use. Planning for beneficial use of contaminated dredged material should consider the following factors:

(a) Amounts and type of contaminants in the material, possibly to include heavy metals, fertilizers, sewer wastes, pesticides, or petroleum products.

(b) Maximum acceptable levels for pollutants in water, soils, plants, and animals as set by the EPA.

(c) Kinds of plants and animals that will be on the site, their abilities to regulate uptake of these pollutants, and their tolerance levels before life efficiency is reduced, reproduction ceases, or death occurs.

(d) Chances of biomagnification via the food chain from plants, invertebrates, and microbes to animals on the site or to humans.

(e) Impact of contaminants on the site and surrounding areas.

(2) Item 46 and other studies have shown that plants grown in dredged material wetlands absorb heavy metals in varying degrees depending upon the plant species. These contaminants in most cases are not generally translocated into the top shoots but are retained primarily in the root systems. Most potential danger is limited to users of the root systems, such as waterfowl that feed on plant tubers. However, research on plants grown in dredged material upland areas indicates a tendency to accumulate heavy metals in all plant parts, including stems and seeds.

(3) Many pesticides, chemical by-products, and petroleum products in dredged material have unknown biomagnification abilities. It is known that some pesticides have affected reproductive abilities of birds by causing eggshell thinning and behavior modification. Petroleum products can smother small organisms (potential food items). Fertilizers and sewer wastes in dredged material alter the habitats where they accumulate by changing plant growth habits and species composition and by reducing dissolved oxygen levels in water. This affects the food supply of fish-eating animals. Highly acidic dredged material can severely limit beneficial use options unless corrected with lime. The contaminant problem can be minimized on most beneficial use sites through these management procedures:

(a) Stabilizing the areas with plant species that do not transport contaminants into their top shoots.

(b) Avoiding management for wildlife grazing, fish nursery use, or intense human use to reduce danger of a biomagnification problem.

(c) Managing for animals that will not feed on the site, such as fish-eating birds that use the site for nesting and roosting purposes only. A good example of this is the Toledo Harbor, Ohio, disposal site in Lake Erie that is being filled over a 20- to 30-year period with contaminated dredged material. Common terns, ring-billed gulls, and herring gulls are nesting inside the dikes but do not feed there since they are all fish-eating species.

(4) Contaminated sites can be capped with about 2 feet of clean soil or dredged material. This will allow use of the site for a number of beneficial uses involving shallow-rooted plants, i.e., nesting meadows, recreational sites, etc.

c. Site Habitat Changes. Beneficial uses can frequently mean the replacement of one desirable habitat with another. This will likely be a source of some opposition. There are few reliable methods for comparing the various losses and gains associated with this habitat conversion; consequently, the determination of relative impact may best be made on the basis of relative scarcity or abundance of the new habitat, environmental regulations, or of professional opinions. An example would be changing aquatic or marine habitat to an emergent wetland or an upland site.

d. Impacts on Surrounding Land and Animals. When dredged material is placed on a site for a beneficial use, there may be a number of associated impacts. Examples are increased runoff of nutrient-charged or contaminant-charged effluent, increased human or other animal use, interference on surrounding land such as from increased bird activity at disposal sites near airport runways, increased recreational use in disposal sites subject to heavy industrial and shipping use, and changes in hydrology from additions of water-charged dredged material to new or existing sites.