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The WRDA of 1986: Background and Beneficial Use of Dredged Material with Particular Reference to the Great Lakes

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ABSTRACT

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In 1986, the United States Congress passed the Water Resources Development Act (WRDA, 1986) with the objective of better managing some of this country's most valuable marine and terrestrial resources. Among the Act's provisions was the authorization to initiate several new dredging projects, and to deepen and widen existing ones across the United States and the Great Lakes region. Hundreds of millions of dollars have been allocated for Great Lakes dredging projects. The execution of these schemes means that tens of millions of tons of dredged material, both clean and polluted, will have to be disposed of annually in an environmentally safe and economically sound manner. Much of the clean and lightly contaminated portion of this material may be beneficially used. A large portion of the polluted part may be disposed of cheaply and safely by employing innovative disposal techniques which have been successfully utilized in some parts of the United States, but have yet to be employed in the Great Lakes. The purpose of this paper is to review some of the ways in which dredged materials have been utilized, and to suggest some innovative disposal methods which can be successfully practised in the Great Lakes. These methods have implications for possible future research on dredging and disposal, particularly in the Great Lakes region.

ADDITIONAL INDEX WORDS: *Water Resources Development Act, wildlife habitat creation, capping, beach nourishment, underwater berms, biotechnical stabilisation of shorelines, aquaculture, agriculture*

INTRODUCTION

The Water Resources Development Act of 1986 (PUBLIC LAW 99-662, November 16, 1986, referred to hereafter simply as WRDA 1986) was passed by the United States Congress with the general objective of properly managing some of this nation's vital marine and terrestrial resources. The Act itself is a very comprehensive piece of legislation comprising almost two hundred statutes and encompassing a wide range of social, recreational, economic, environmental, hydrologic, engineering, and biological issues across the United States.

Several statutes in the WRDA 1986 addressed specific issues in the Great Lakes, the Great Lakes basin, and the Great Lakes economic region. Many of the issues are intricately interwoven including (a) the initiation of new dredging projects and the widening and deepening of existing waterways, ports and harbors on the Great Lakes, (b) the disposal of dredged material and possible beneficial use of such material, (c) shoreline erosion and compensation to riparian property owners who suffer from such damage, (d) ice control along waterways, (e) possible diversions of Great Lakes water, and the regular and precise measurements of diversion from Lake Michigan, (f) consumptive studies of Great Lakes water, (g) tolls, user fees, harbor maintenance taxes, and cost-sharing for maintaining these waterways, ports and harbors and (h) the creation of a commodities board which will enable farmers in the Great Lakes economic region to advertise and market their products more efficiently, quickly and economically, thereby making them more competitive on national and international levels.

Congress, by virtue of passing the WRDA 1986, has mandated that several dredging projects be undertaken. Since the money has already been allocated, the issue then becomes one of where and how best to dispose of the spoil. Answers should be found quickly to several pertinent questions, such as: Where is the dredged material to be disposed of?; how much of the dredged material can be beneficially used?; what research should be undertaken on new and alternative beneficial uses, the long term behavior of dredged material, particularly the contaminated portion?;

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and, how best can the idea of 'beneficial use' be sold to the taxpaying public?

The objective of this paper is to examine several dredge disposal methods which have been employed in the United States, and to suggest alternative methods not yet practised in the Great Lakes region, particularly those pertaining to beneficial use.

GREAT LAKES DREDGING

In order to facilitate the continuance of commercial, military, and leisure maritime traffic in the U.S., most waterways, harbors, ports and channels must be dredged periodically. Although the primary purpose of dredging in the U.S. is to improve navigation, dredging is also performed in this country for a variety of other purposes including flood control, construction and reclamation, mining, and general purposes such as placement of pipelines, drainage of swampy or lowland areas, and for the removal of pollutants (INTERNATIONAL ASSOCIATION OF PORTS AND HARBORS, 1989).

Both new and maintenance dredging operations in federal harbors and waterways are regulated in the U.S. by the Army Corps of Engineers, and in Canada by the Department of Public Works. The Army Corps no longer owns or operates a dredge of any type on the Great Lakes, and all dredging is now done by contract work (ZANDE, 1990).

In the U.S., more than 306 million cubic meters of material are dredged annually to maintain and develop our national waterway system (HATCH, 1988). About 39 million cubic meters are dumped in ocean waters at 40 or 50 sites, while the remainder is disposed of by means other than ocean disposal. Most of the dredged material is clean and can be beneficially used (HATCH, 1987, 1988). About 153 million cubic meters of sediment are dredged annually from the Mississippi and its tributaries, and the Great Lakes (HATCH, 1987).

Although dredging volumes from the Great Lakes vary temporally, it has been estimated that about 12 million cubic meters are dredged annually from the U.S. and Canadian Great Lakes (RAPHAEL *et al.*, 1974). During the period 1966–1972, Great Lakes annual dredging volumes reached 8.7 million cubic meters (GUIDELINES TO GREAT LAKES DREDGING, 1987) but declined to 5 million cubic meters during 1975–1979 (GUIDELINES AND REGISTER, 1982). This decline is attributed to a rise in environmental awareness in the U.S. (REPORT TO CONGRESS, 1977), and to the fact that economic expansion of and migration into the Great Lakes economic region had already peaked. It is not surprising, therefore, that the percentage of new dredging has declined in the U.S. and in the Great Lakes (RAPHAEL *et al.*, 1974) while there has been a concomitant increase in maintenance dredging percentages.

Table 1. *Pollutant loadings in the five Great Lakes basins during 1975–1979. Source:* GUIDELINES AND REGISTER, *1982.*

Pollutant	Total Loadings (tons)	# of Locations	% of Locations	Highest Concen.
Volatile solids	2,124,052.00	86	94	33%
Phosphorus	30,297.00	71	84	3.7 μg/g
PCB's	13.97	21	25	7.0 μg/g
Mercury	10.72	69	80	1.2 μg/g
Lead	2,293.60	70	88	399.0 μg/g
Arsenic	313.03	51	76	33.0 μg/g
Cadmium	165.92	49	77	59.0 μg/g
Copper	1,729.83	53	78	1,118.00 μg/g
Zinc	8,395.64	68	88	1,664.00 μg/g
Nickel	1,670.33	50	77	204.00 μg/g
Chromium	2,111.02	52	76	281.00 μg/g

Sediments from the Great Lakes are generally considered by the Environmental Protection Agency (EPA) to be polluted, and as such, dredged sediments have to be disposed of in confined disposal facilities (CDF's) in compliance with the Rivers and Harbors Flood Act of 1970 (JAWORSKI and RAPHAEL, 1976). An analysis of Table 1 reveals that: (a) the most prevalent pollutants by volume in the five Great Lake basins during 1975–1979 include volatile solids, phosphorus, PCB's, lead, arsenic, cadmium, copper, zinc, nickel, and chromium (There is no reason to believe that this list of rankings changes significantly over time.); (b) a great majority of the sites tested contained these pollutants, except for PCB's which were found at only 25 percent of sites; and (c) concentrations of lead, copper and zinc were the highest among all pollutants (GUIDELINES TO GREAT LAKES DREDGING, 1987).

The origin of these pollutants include tributary loadings from soil erosion (GREAT LAKES SOIL EROSION AND SEDIMENTATION SURVEY, 1984), municipal and industrial wastes, and atmospheric inputs. The latter contributes significantly to Great Lakes pollution (ELDER, 1983) and contains significant quantities of HCH's, dieldrin, and PCB's (CHAN and PERKINS, 1989; GLASS *et al.*, 1986). Atmospheric and tributary loadings from erosion greatly outweigh those from dredge spoil inputs (GUIDELINES TO GREAT LAKES DREDGING, 1987).

As a consequence of the execution of these projects, tens of millions of tons of dredged material will have to be disposed of in an environmentally safe manner, and much of this material can be beneficially used. Congress, in discussing the passage of the WRDA 1986, was aware of the critical disposal issue and included several statutes in the WRDA to address it. For example, Section 1154 states that "In planning and implementing any navigation project (including maintenance thereof) on the Great Lakes and adjacent waters, the Secretary shall consult and cooperate with concerned states in selecting disposal areas for dredged material which is suitable for beach nourishment" (WRDA, 1986). Sections 933, 934 and 935 also pertain to beach nourishment.

THE BENEFICIAL USES OF DREDGED MATERIAL

Dredged material has been beneficially used at numerous locations across the United States. Increasing environmental awareness among the public, particularly during the 1960's and the early 1970's, led to concern over the Army Corps' dredging and disposal activities on the Upper Mississippi River (REPORT TO CONGRESS, 1977). Several Great Lakes state governments, state agencies, and the public opposed dredging methods, disposal sites and disposal practices. Consequently, the Great River Environmental Action Team (GREAT, 1980) was established as a working partnership of federal and state agencies, state governments and the public. Often, federal agencies such as the Environmental Protection Agency delegate authority to state agencies. For example, the EPA permits the Wisconsin Department of Natural Resources to grant licenses for dredging projects undertaken in that state.

An important component of GREAT's schemes was a Dredged Material Disposal Plan whose purpose was to make recommendations to the Army Corps regarding site selection, with the most important criterion being the site of beneficial use that would have little or no adverse impact on terrestrial or aquatic ecosystems (GREAT, 1980). GREAT and its successor GREAT II were very successful, particularly in coordinating several bodies, agencies, and the public in garnering support for and executing beneficial reuse programs. It is recommended that organizations similar to GREAT be formed with the objective of exploring, emphasizing, advertising, researching and implementing beneficial reuse schemes.

Dredged material has been beneficially used in several ways:

(1) Agriculture

It has been demonstrated by GUPTA *et al.* (1978) and GORINI (1987) that dredged material, if dewatered and chemically treated, can be successfully utilized to cultivate certain crops. GUPTA *et al.*'s (1978) investigation, involving dredged material in Minnesota, revealed that fine-grained material treated chemically or mixed with coarse-grained material improved agronomic qualities such as higher hydraulic conductivity, increased water-holding capacity, and soil fertility. Millions of hectares in the U.S. could be brought under cultivation if maximum use were made of dredged material.

(2) Aquaculture

Edible aquatic organisms including shrimp, crayfish, catfish, trout, redfish, hybrid striped bass, shellfish, and bait shrimp have been successfully raised in Confined Disposal Facilities (CDF's) which were constructed to contain dredged material. Aquaculture was first demonstrated by the Army Corps in 1976 in Texas where white shrimp could be grown to a marketable size and quantity. Aquaculture in active CDF's are a feasible, cost effective, and compatible use of containment areas (LUNZ and KONIKOFF, 1987), and some types of vegetation in marshes created from dredge spoil supply nutrients which are suitable for young fish and shellfish (CAMMEN *et al.*, 1976). The Army Corps aggressively promotes the dissemination of knowledge pertaining to CDF's to be used as aquaculture areas, and in November, 1991, conducted a national workshop on the subject (U.S. ARMY CORPS OF ENGINEERS, 1991).

(3) Beach Nourishment

Dredged sediment that is clean and texturally compatible with native beach material can be used to artificially nourish eroding beaches in order to minimize erosion. The use of dredged material for beach nourishment was probably the first beneficial use undertaken in the U.S. in 1970 (MASON *et al.*, 1985).

Many beach nourishment projects have been attempted along the the U.S. Atlantic, Pacific, and Great Lakes shorelines. Some of these projects involved the use of dredged sediment, while others utilized sand. It is very difficult to predict the success of nourished beaches (PILKEY, 1990), and beach nourishment with non-dredged and dredged material has often failed. LEONARD *et al.* (1990) observed that nourished beaches on the Pacific coast are more durable than their counterparts along the Gulf and Atlantic coasts. The high frequency of storms and texturally incompatible nourishment material are the major reasons accounting for this phenomenon.

Beach nourishment, utilizing dredged material, has experienced some measure of success including beaches at Hampton Roads, Virginia (MCGEE, 1988), Sandy Hook, New Jersey (SLEZAK, 1988), Southern California (DOMURAT, 1987), and the Gulf of Mexico (THACKERAY, 1987). There have been some instances where dredged material used for beach nourishment was carried away from its intended destination (JARRETT and HEMSLEY, 1988).

Beach Nourishment in the Great Lakes

Between 1977 and 1981, the U.S. Army Corps of Engineers used 25 percent of the material dredged from the Great Lakes for beach nourishment (MASON *et al.*, 1985). Generally, beach nourishment in the Great Lakes region has only met with partial success. Empirical studies (KEILLOR and RAGOTZKIE, 1976; ALBERS *et al.*, 1983; RAPHAEL and KURETH, 1988; RAMRAJ, 1990) and laboratory experiments (KAMPHIUS and BRIDGEMAN, 1975) have indicated that, generally, textural incompatibility is the main cause of beach nourishment failure.

Textural incompatibility occurs when the material used for nourishment is poorly sorted or is either too coarse or too fine compared to the native material. The latter is more stable because it has adjusted to environmental conditions such as wave energy, and water and wind velocity. Sediment used as nourishment that is finer or coarser than the native material may be quickly removed from its intended destination. KEILLOR and RAGOTZKIE (1976), for example, reported that 270,000 cubic yards of dredged material dumped on a beach with the intention of nourishing it at Minnesota Point in Minnesota in 1963 was washed away. The nourishment material which ranged from fine sand (0.35 mm) to silt and fine clays (0.06 mm) and which was also poorly sorted was transported lakewards creating shoals which absorbed wave energy. RAPHAEL and KURETH (1988) monitored the success of a beach nourishment project at St. Joseph's Harbor on the eastern shore of Lake Michigan and concluded that the fine material used was washed away by storm wave action. In their investigation of beach nourishment at Superior, Wisconsin, ALBERS *et al.* (1983) found that the textural characteristics of the sand and gravel portion of the dredged material used for nourishment (67 percent) dumped in water four to eight feet deep had remained unchanged several months after disposal. The remaining portion of the material consisting of clay and silt, however, was suspended immediately after disposal operations and eventually transported lakewards.

One area of potentially useful research is the long-term movement of dredged material. It is possible that such material contributes to the alleviation of shoreline erosion in localities some distance away from the originally nourished site. It is not known whether any studies have been done as yet on the benefits of beach nourishment at distal locations from the nourished sites. One instance of an unintentional benefit was reported by KEILLOR and RAGOTZKIE (1976) who found that the disposal of dredged material as beach nourishment sometimes causes shoaling offshore which absorbs wave action, thereby alleviating shoreline erosion.

In some instances, the construction of seawalls, groins and other protective structures have been used in conjunction with nourishment material. RAPHAEL and KURETH (1988) found that while such structures may trap fine dredge material on the updrift side, erosion is accelerated on the downdrift side.

Since the morphogenic environment (winds, current, waves, storms, *etc.*) and hydrodynamics (thermal stratification and lake bottom currents, for example) along Great Lakes shorelines differ in several respects from areas that were successfully nourished, it is realized that there is need to do more research on beach nourishment in the Great Lakes.

(4) The Creation and Restoration of Wildlife Habitat

About 95 percent of material dredged in the U.S. is clean (LANDIN, 1988) and some of it has been beneficially used for the creation and enhancement of wildlife habitat (HATCH, 1987). Dredged material was used successfully to create barrier islands off the Texas coast (BOETTCHER, 1987).

The largest and most ambitious wildlife habitat restoration project on the Great Lakes was undertaken by the Army Corps at Point Mouillee, located in Lake Erie. Almost 14 million cubic meters of polluted dredged material removed from the Detroit and Rouge Rivers over a ten-year period were used to restore 770 hectares of marshes (U.S. ARMY CORPS OF ENGINEERS, undated). The project completed in 1983 generated a tourist industry and, consequently, visitor centers and marinas were constructed.

Seed banks (nurseries for seedlings which are subsequently used for vegetating wildlife habitat) were successfully developed on dredged material obtained from Sandusky Bay, Ohio (SIEGLEY *et al.*, 1988).

Although there is great potential for using dredged material for creating and enhancing wildlife habitat, some problems still remain. These include (a) the lack of consensus on what "beneficial use" is (BIGFORD, 1988); (b) the unavailability of the right type of vegetation required to be planted on dredged material in order to stabilize it. (Often, the compatible vegetation has to be imported from localities far away (CARROLL, 1987)); (c) long fetch distances which are not conducive for marsh development. KNUTSON and STEELE (1988) reported that long fetch distances permit the development of large waves which have the ability to erode newly-deposited dredged material in marshes placed there with the intention of creating islands; (d) outdated and ecologically unsound dredging and disposal methods which are not only inefficient but which also may be ecologically harmful (TERRELL, 1988); (e) the difficulty of quantitatively assessing the value of man-made habitat (THAYER, 1987); (f) defining how "clean" is clean. The following pertinent questions are often asked about dredged material: What is polluted; what is toxic; what is a contaminant; what is toxic to what and to whom; what is "clean"; how are contaminant levels defined; and are there consistent standards for determining levels of contamination? MUDROCK *et al.* (1988) realized that there are too many different sampling techniques and analytical methods used to evaluate Great Lakes sediments, and they suggested that a standard protocol be developed for determining levels of pollution. HARTIG *et al.* (1990) recognized the need for an approach to defining what is clean. They suggested that in deciding "how clean is clean," scientific criteria should not be the sole determinant. A whole series of other factors including socio-economic conditions, public perceptions and human values are required input. They also observed that the scientist should provide the public and the policy maker with the best scientific information for determining the more important issue of "how clean is safe." The policy maker and the public should weigh this information carefully against all factors in determining "how clean is clean" and "how clean is safe" and (g) the obstacles which are created by legal and institutional constraints to the beneficial use of even clean dredged material (RAMRAJ, 1990). There are too many bodies, laws, guidelines and agencies involved in the decision-making process for dredging and disposal. Consequently, the present permit process has become a complex and time-consuming procedure. This process is long, expensive, tedious, cumbersome, and has been described by HUTCHINS (1984) as a "maze and labyrinth." While some states such as Wisconsin are implementing more rules and establishing more guidelines for dredging, other states, particularly Maryland (where a new handbook has been produced to assist concerned parties in understanding and undertaking the permit process) and Florida, have taken the initiative to accelerate the permit process.

INNOVATIVE METHODS OF DREDGED MATERIAL DISPOSAL

Three innovative disposal methods—biotechnical stabilization, the creation of underwater berms, and underwater capping—have not as yet been utilized on the Great Lakes, but have been successfully undertaken elsewhere in the U.S., particularly in the New York Bight. It is realized that the Great Lakes may differ hydrologically from ocean dumping sites, but this should not preclude the testing of investigative methods in the Great Lakes.

Biotechnical Stabilisation of Shorelines

Dredged material has been successfully used by combining chemicals with it to stabilize low energy shorelines (ALLEN, 1988; MARQUAND, 1988). Fine-grained dredged material (a type that is commonly dredged from the Great Lakes) can be stabilized with Firmex and Paratex which are biodegradable substances, and the latter is particularly effective in icy areas (ALLEN, 1988; MARQUAND, 1988). Additionally, erosion control mats, plant rolls (soil and transplanted clumps on a strip of burlap), sandbags, and breakwaters made of tires have been effectively used in conjunction with dredged material at Galveston Bay, Texas (ALLEN, 1988).

The Creation of Underwater Berms

Another dredged disposal technique which is economical, technologically feasible, and environmentally sound is to use dredged material as underwater mounds or berms in deep water where such man-made structures are less subject to wave and current action than if they were placed in very shallow water. This disposal method, successfully demonstrated off the California and New Jersey coasts, and at Neck Dam, Virginia (LANGAN, 1987) is also cost effective since haul distances for the dredged material are greatly reduced.

Underwater berms reduce wave energy in the nearshore region, thereby minimizing potentially destructive wave forces. On-going long-term investigations by DELOACH (1986) are being undertaken to determine whether sands, silts, or clays create the most effective underwater berms.

Capping

Polluted material disposed of in marine environments may be capped by a layer of clean dredged material or sand to prevent contamination of the surrounding water (SHIELDS and MONTGOMERY, 1984). Capping is technically feasible, environmentally safe, and economically sound (TRUITT, 1987a,b). Capping was carried out from 1980 to 1985 on a large scale (over 4 million tons of clean material alone) at the Mud Dump site in New York Harbor and after several years of capping at that site, PARKER and VALENTE (1988) reported no sign of cap erosion and suggested that the potential for bioturbation was very small.

GUNNISON *et al.* (1987) recommended that empirical investigations should be conducted to predict the required thickness of a given cap, although TRUITT's (1986) study of capping in the Dumawish Waterway in Seattle revealed that caps one meter thick are sufficiently effective in insulating water from dredged material contamination. TRUITT (1986) recommended that dredged material/cap ratio should be 4 to 1.

O'CONNOR and O'CONNOR (1983) predicted that cap life under average conditions in New York is 20 years but warned that caps could be removed by major storms. This fear, however, has not materialized. FREDETTE *et al.* (1989) investigated the effects of storms associated with Hurricane Gloria in 1985 on capped disposal mounds in Long Island Sound, and they concluded that there was very little disturbance of the disposed material (only sediment in the top 1 to 5 cm of the cap experienced any resuspension), and that capping effectiveness was not decreased after the storm. A laboratory experiment by BRANNON *et al.* (1985) revealed that caps with high proportions of clays and silts are more effective than those consisting primarily of sand, and that caps thicker than 50 cm were most effective in isolating the contaminated sediment from surrounding water and non-burrowing biota.

Only one experiment of capping polluted dredged material with clean material has been done in the Great Lakes (KHAN and GROSSI, 1984) at Port Credit Marina, 40 miles west of Toronto. The experiment was conducted in water 40 meters deep, and was partially successful (some of the cap and some dredged material was eroded). This is an excellent beginning in the investigation of the behavior of capped dredged material in the Great Lakes, and future studies of this type will certainly provide invaluable information towards a better understanding of the behavior of natural, dredged and capped sediments in lacustrine environments.

CONCLUSION

The implementation of dredging projects in the Great Lakes region authorized by the Water Resources Development Act of 1986, for which hundreds of millions of dollars have been allocated, means that millions of metric tons of clean and polluted dredged material must be disposed of economically and in an environmentally safe manner. More research should be done on how best (economically and environmentally) to dispose of both clean and polluted portions of the dredged material. Research has shown that some of the material could be beneficially used in several ways including the creation and enhancement of wildlife habitat, beach nourishment (if the material used for nourishment is texturally compatible with the native beach material), agriculture, and aquaculture. Three innovative disposal methods which have been successfully utilized in some locations in the United States, but still not practiced nor even experimented with in the Great Lakes, are the biotechnical stabilisation of shorelines, the creation of underwater berms, and underwater capping.

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