Department of the Army – US Army Corps of Engineers
United States Environmental Protection Agency

Great Lakes Confined Disposal Facilities

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Table of Contents

List of Figures

Acknowledgments

This report is a collaborative effort of the following offices of the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency:

USACE

Great Lakes & Ohio River Division
Buffalo District
Chicago District
Detroit District
Environmental Laboratory,
Engineering Research & Development Center

USEPA

Great Lakes National Program Office
Region 5

The opinions and conclusions expressed in this report reflect the combined knowledge and understanding of staff from these offices who have worked together on individual projects, coordinated through numerous committees and working groups, and conducted collaborative studies and research on dredging and management of contaminated sediments from Great Lakes harbors and channels.

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Executive Summary

Contaminated bottom sediments are present in many of the Federal navigation projects in the Great Lakes and every one of the Areas of Concern designated under the Great Lakes Water Quality Agreement. "Restrictions on dredging activities" is one of the fourteen beneficial use impairments identified in the Agreement. The U.S. Army Corps of Engineers (Corps) dredges about 4 million cubic yards of sediments annually from Great Lakes projects. About half of these dredged materials are contaminated to a degree that restricts their disposal.

Through Section 123 of the Rivers and Harbors Act of 1970, as well as project-specific authorities, the Corps has constructed and/or operated 45 confined disposal facilities, or CDFs to manage over 90 million cubic yards of contaminated sediments dredged from Great Lakes harbors and channels in the past forty years at a Federal cost of $300 million (construction costs unadjusted for inflation). In this report, the Corps and the Environmental Protection Agency (EPA) present a summary of information about the existing CDFs and an assessment of their cumulative impacts on the Great Lakes ecosystem.

Individual CDFs have been planned, sited, and designed in partnership with non-Federal sponsors, including states, local governments and port authorities. The size, shape, and design of individual CDFs have been selected to fit dredging needs of the harbor(s) and channel(s) served, the physical and chemical characteristics of the dredged material, local conditions and resources, and the interests of the non-Federal sponsor. CDFs have been planned and sited with full opportunity for public and agency review and input.

The impacts of CDFs on the Great Lakes ecosystem have been considered from physical, chemical, biological, and socio-economic perspectives. Environmental assessments and impact statements were prepared for facilities in accordance with the National Environmental Policy Act. In addition, the monitoring and performance of operating CDFs has been conducted in cooperation with state and Federal resource agencies. Great Lakes CDFs have routinely complied with all applicable Federal and state environmental requirements.

The construction and operation of CDFs have produced both negative and positive physical effects. Over half of the CDFs were constructed at in-water sites, resulting in the loss of lake and river bottom habitat. However, the CDF dikes have created reef-like habitat for fisheries and the interior areas have supported dense vegetation and a temporary habitat for fish and wildlife. CDFs have also created new lands along the shoreline that have been used to support community waterfront and recreational development plans.

From a chemical perspective, CDFs retain a high percentage of the contaminants they receive, and discharge effluents that consistently meet state water quality requirements. Studies have indicated that the long-term release of contaminants from CDFs may be calculated using computer models, but cannot be detected with conventional or advanced monitoring techniques, and are not considered ecologically significant. Cumulatively, CDFs have facilitated the removal of 90 million cubic yards of contaminated sediments from the Great Lakes and tributaries, of which over 70 million were from Areas of Concern. The removal of sediment contaminants provided by the CDF program represents a substantial contribution to the goals of Remedial Action Plans and Lakewide Management Plans.

Biologically, the CDFs have produced losses and gains in habitat that appear to be of comparable value. Wildlife that inhabit or visit CDFs may uptake increased levels of some contaminants, and management practices are being used to reduce this effect. In the lakes and rivers outside the CDFs, biological communities are exposed to lower levels of contamination as a result of the removal and confinement of contaminated sediments from navigation channels.

CDFs have enabled the continued, safe transport of goods and materials at Great Lakes harbors and channels. Commercial and recreational use of these waterways is a major contributor to the national and regional economies as well as the history and social identity of many communities along the Great Lakes shoreline.

Significant reductions to the loading of contaminants to the Great Lakes have been achieved in the past 40 years through pollution prevention and control measures. However, many navigation channels continue to receive contaminated sediments from adjacent or upstream deposits and loadings from non-point pollution sources. CDFs continue to be needed to manage contaminated sediments dredged from Great Lakes navigation channels. Measures to prolong the use of existing CDFs and beneficially use dredged material are being evaluated and implemented by the Corps, EPA and several CDF sponsors. The long-term solution to contaminated sediments is a combination of preventative and remedial measures, including soil conservation, non-point pollution prevention, and implementation of Remedial Action Plans and Lakewide Management Plans. Only through these measures will the need for additional CDFs on the Great Lakes be minimized.

Purpose

The U.S. Army Corps of Engineers (Corps) has designed, constructed and/or operated 45 confined disposal facilities (CDFs) around the Great Lakes for the disposal of contaminated dredged materials from Federal navigation projects. The Corps and the United States Environmental Protection Agency (EPA) jointly regulate the discharge of dredged or fill materials to the Great Lakes and tributaries through Section 404 of the Clean Water Act (CWA). These two agencies have worked closely to ensure that dredged materials from the Great Lakes are managed in an environmentally protective manner. The Corps and EPA have collaborated in the development of regional testing guidance for dredged material, evaluations of sediment treatment technologies, and investigations on the environmental performance of Great Lakes CDFs.

Contaminated sediments are a significant environmental problem at a number of Great Lakes sites, including every one of the Areas of Concern identified in the Great Lakes Water Quality Agreement. A variety of concerns about the environmental effects of dredging and management of contaminated sediments has been expressed by resource agencies and the public since the 1960's. These concerns have included the potential environmental risks posed by contaminant releases from the CDFs and the potential impacts on wildlife that may visit or inhabit the CDFs.

In response to these concerns, Congress directed the Corps and EPA to evaluate and document the status and impacts of CDFs on the Great Lakes through the following authorities (full text of these authorities are provided in Appendix A): Section 24 (b) of the Water Resources Development Act (WRDA) of 1988 authorized a study and monitoring program to determine the presence and concentration of toxic pollutants in dredged material disposed in Great Lakes CDFs, and to determine if these pollutants were leaking from these facilities; Section 104 of the Great Lakes Critical Programs Act of 1990 amended Section 118 of the Clean Water Act by directing the EPA, in consultation with the Corps, to develop and implement management plans for every Great Lakes CDF in order to provide monitoring, anticipated use and management of each site for 20 years, and; Section 513 of the WRDA 1996 directed the Corps to conduct an assessment of the general condition of Great Lakes CDFs and to submit a report to Congress.

This report provides a summary of monitoring conducted at Great Lakes CDFs, management practices applied to enhance performance and minimize adverse impacts, existing and future uses of filled facilities, and studies conducted to estimate the loss of contaminants. The report provides an assessment of the condition of CDFs and their overall impacts on the Great Lakes from physical, chemical, biological, and socio-economic perspectives. The contents of this report reflect the combined experience of the Corps and EPA through separate and collaborative investigations of Great Lakes CDFs.

Overview

Great Lakes Dredging Requirements

The Great Lakes serve as the Nation's fourth seacoast by transporting commodities to and from the Nation's heartland. Waterborne commerce is critical to the regional and national economy. Commercial navigation on the Great Lakes is dominated by the transport of raw materials for steel making, coal-fired power production, and construction (limestone, cement, stone, and gravel). Total annual commerce on the Great Lakes averages 175 million tons, with 86 million tons passing through the locks of Sault Saint Marie, Michigan (USACE 2000), which connects Lake Superior with Lake Huron. This equates to $3.5 billion of annual economic trade. Over 75 percent of the iron ore produced in the United States transits through these locks. Large vessels, which must use the Poe Lock (one of four locks at the Sault Saint Marie), account for over 70 percent of the total United States cargo capacity.

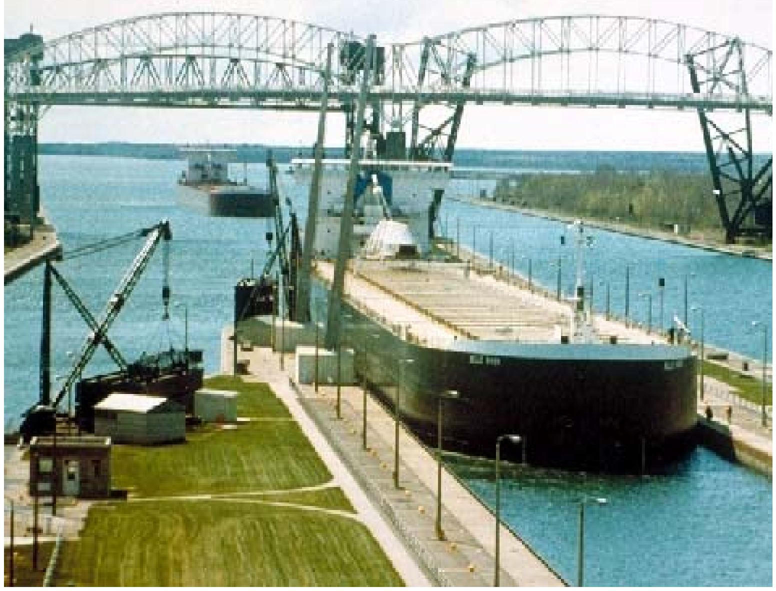


Figure 1: Lock at Sault Ste Marie, MI

The Corps is authorized to maintain navigation projects around the Great Lakes and connecting channels that serve commercial and recreational users. This system includes the following project features:

- 68 deep draft harbors;
- 71 shallow, recreational harbors;
- 745 miles of navigation channel;
- 138 miles of breakwater;
- 25 locks, and;
- 2 visitor centers.

Great Lakes harbors and channels are maintained by Corps districts in:

- Buffalo (harbors in New York, Pennsylvania, and Ohio);
- Chicago (harbors in Indiana and Illinois), and;
- Detroit (harbors and connecting channels in Michigan, Wisconsin, and Minnesota).

Dredging of harbors on the Great Lakes dates back to the early 19th century. At that time, improvements to harbors consisted of measures to combat the formation of sand bars at river mouths. In general, the projects provided for removal of bars by dredging or the construction of parallel piers extending into the lake. The need for, and frequency of dredging increased gradually with growth in vessel dimensions. At the beginning of the 20th century, large harbors were formed along lakefronts by the construction of breakwaters out into the Lakes. These large areas served as excellent settling basins for sediments brought down from upstream (Buffalo District 1969).

Figure 2: Hydraulic Dredge at Indiana Harbor Canal, IN (Circa 1905)

The Federal harbors and channels within the Great Lakes Basin were authorized individually, and have distinct channel dimensions. These authorities enable the Corps to maintain channels to maximum depths, typically referenced to Low Water Datum (LWD). Authorized channel depths are keyed to a specific elevation, and do not fluctuate with short or long-term lake level trends. At a harbor project, authorized channel depths are not necessarily the same throughout. The channel depths are typically greatest in the outer harbor and approach channels, where ship draft may be subject to wave action. As one moves upstream and away from the influence of lake waves, authorized channel depths may become progressively shallower.

Figure 3. Lorain Harbor, OH

The Corps determines the need for dredging at Federal channels by periodic surveys and coordination with navigation users. Channels are dredged to maintain safe navigation depths. Portions of channels that no longer have deep draft navigation users may be maintained at shallower depths. More information on the Federal harbors in the Great Lakes Basin is available on the Internet at web site **www.lrd.usace.army.mil/gl/nav.htm**.

Figure 4: Hydraulic Dredge at Waukegan Harbor, IL

Dredging is the largest continuing maintenance activity of the Great Lakes navigation system. Typically, about 4 million cubic yards of sediments are dredged by the Corps each year from Federal harbors and channels on the Great Lakes. On average, the Corps spends about $20 million annually for dredging and dredged material management in the Great Lakes Basin.

Figure 5: Clamshell Bucket Dredge

Aside from maintenance of Federal navigation projects, sediments are also removed to maintain navigation channels at public and private harbors and marinas throughout the Great Lakes. In addition, sediments are also dredged to maintain flood protection projects, for waterfront construction, maintenance and repair of utilities and water intakes, and for environmental remediation purposes. Between one and two million cubic yards of sediments are dredged annually by state, local and private interests in the Great Lakes Basin.

Sources of Sediments and Sediment Contamination

Maintenance dredging of navigation channels does not create sediments. Sediments are the product of the natural processes of soil erosion, transport and sedimentation. Within any watershed, human activities may alter these processes in several ways. Agricultural and forestry practices can increase soil erosion. These land uses, along with urbanization can alter the overall hydrology of the watershed, changing the flow patterns in streams and rivers. Changes to flows along with modifications to stream and river channel morphology can alter the patterns of erosion ad deposition in these channels.

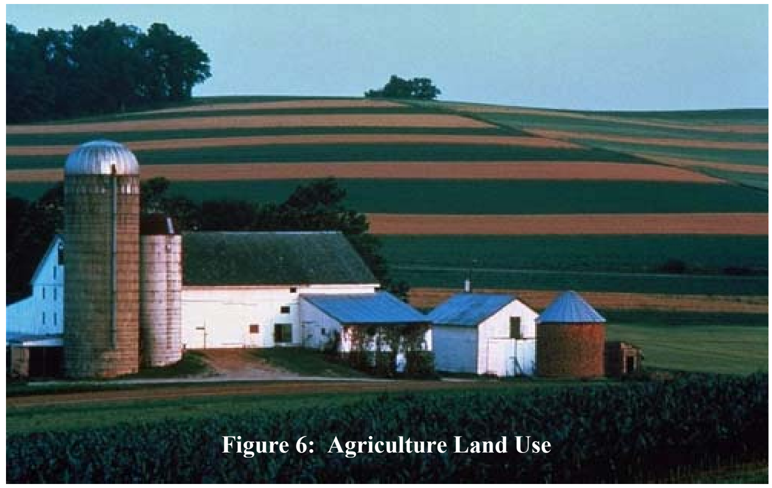


Figure 6: Agriculture Land Use

Fluvial sediments are those that are carried by rivers and streams. Deepened navigation channels and maintenance dredging interrupt the natural flow of fluvial sediments into the Great Lakes. Much of the human development around the Great Lakes was centered at ports and harbors located at the mouths of rivers. In many cases, the natural river channel was deepened as much as twenty feet. Sediments carried by the river are more prone to settle to the bottom in this deepened channel where river currents are slower.

Another type of sediment found in the Great Lakes is fine-grained sand, which is common to the near shore areas of the Great Lakes. The natural movement of these sands along the shoreline is called littoral drift. These sandy sediments deposit in deepened channels and harbors that extend into the lake.

Dredging does not create sediment contamination. The physical characteristics of sediments vary depending on the source of the sediments, properties of soil in the watershed, and the hydraulics of the waterway. The chemical characteristics of sediments will also vary, depending on the characteristics of the watershed, the presence, type and number of contaminant sources, including:

- urban and agricultural runoff;
- sewer overflows/bypassing;
- industrial and municipal wastewater discharges;
- landfill leachate/groundwater discharges;
- spills of oil or chemicals;
- illegal discharges;
- air deposition;
- biological production, and;
- naturally occurring mineral deposits.

The rate of deposition of sediments in deepened navigation channels can be mitigated by controlling sediments at the source through soil conservation practices, protection and restoration of wetlands, and measures to alleviate streambank and shoreline erosion. The levels of contamination in sediments can also be reduced through point- and non-point source pollution prevention and remediation of in-place contaminated sediment deposits.

Over the past 30 years, a massive investment has been made to reduce the discharge of sediments and pollutants to the Great Lakes and its tributaries, including wastewater treatment upgrades, separation of combined sewer systems, air pollution controls, soil conservation and non-point pollution prevention. This effort has resulted in reductions of contaminant levels found in the sediments at many of the Federal navigation projects throughout the Great Lakes. At most harbors, sediments dredged today are significantly cleaner than those dredged twenty or thirty years ago. However, there exists a substantial lag in time between the implementation of source controls and the appearance of cleaner sediments. This is caused by the reservoir of contaminants in sediments already in the waterway that are slowly migrating downstream. Consequently, the need to dredge and manage contaminated sediments from Great Lakes harbors and channels will continue.

Dredged Material Management

The alternatives available for managing dredged materials include:

- open water placement that involves the discharge of dredged material directly to the lake or river;
- beach/littoral nourishment, which is the placement of dredged material directly onto a beach or into shallow water;
- capping, which is the placement of a contaminated dredged material on the level bottom or in a subaqueous pit and covering the material with a layer of clean material;
- beneficial use at upland sites, including construction fill, landscaping, landfill cover, agricultural soil amendment, etc;
- confined disposal at a CDF or disposal at a licensed landfill, and;
- treatment of sediments to enable unrestricted disposal or beneficial use of some or all of the treated soils.

Figure 7: Beach Nourishment at St. Joseph, MI

The selection of the most appropriate alternative for managing dredged material should consider the materials physical properties, levels of contamination, the quantity of material to be dredged, availability and suitability of disposal sites, as well as economic, social, and other factors.

The Corps and EPA have jointly developed guidance for decision making on dredged material management, including

"Evaluating Environmental Effects of Dredged Material Management Alternatives - A Technical Framework," (USACE/EPA 1992). The "Technical Framework" document presents broad guidance on management of dredged material, covering most of the alternatives listed above. This guidance discusses testing and evaluation methods appropriate to each of these management options in general terms, and directs the user to other reports, manuals, computer software, and other guidance documents for more detail. The philosophy behind this and other dredged material management guidance is for site-specific determinations, rather than "one size fits all."


Figure 8: Sediment Sampling with Gravity Core

The Corps and EPA share the responsibility of regulating dredged material management activities within waters of the U.S. under Section 404 of the Federal Water Pollution Control Act Amendments of 1972, also called the Clean Water Act (CWA). Discharge of dredged material to lakes, rivers and wetlands is regulated under this authority. As directed by Section 404, the Corps and EPA have developed national and regional guidance specifically for dredged material testing and evaluation. These are the "Inland Testing Manual," (USEPA/USACE 1998a) and the "Great Lakes Dredged Material Testing and Evaluation Manual," (USEPA/USACE 1998b). This later manual provides protocols specifically tailored to evaluations of dredged material disposal in the Great Lakes and their tributaries. The methods outlined in these manuals are only a part of the Section 404 evaluation procedure used to determine the suitability of open water disposal and beach/littoral nourishment alternatives. Dredged material that is unsuitable for open water disposal may still be suitable for capping or a variety of upland beneficial uses without presenting an unacceptable environmental risk. The Corps and EPA have developed guidance documents on capping (Palermo et al 1998), beneficial use (USACE 1987c), and upland disposal of dredged material (USACE 2003).

If a dredged material is not suitable for open water disposal, beneficial use, or capping, the only remaining alternatives are confined disposal and treatment. The EPA Great Lakes National Program Office developed extensive guidance on the feasibility of treatment technologies for contaminated sediments under the Assessment and Remediation of Contaminated Sediments (ARCS) Program (Averett et al 1990; USEPA 1994). The Corps and EPA continue to evaluate and demonstrate promising technologies for sediment decontamination at sites in the Great Lakes and elsewhere.

The Corps developed a number of technical manuals on the design, construction, and operation of confined disposal facilities under the Dredged Material Research Program (USACE 1978). This guidance has been updated periodically, including the most recent Engineer Manual "Confined Disposal of Dredged Material" (USACE 1987a). EPA Region 5 developed a guidance document on confined disposal of contaminated sediments for cleanup projects that was largely based on Corps guidance and experience from Great Lakes CDFs (Richardson et al 1995).

All Corps and EPA guidance manuals emphasize the coordination effort required between the dredged material management evaluation process and applicable Federal, state, and local regulations. Federal regulations that have been applied to the management of dredged material from Great Lakes harbors and channels include:

- Clean Water Act, Section 401 (Water Quality Certificate);
- Clean Water Act Amendment of 1972, Section 404 (Section 404 Permit);
- Rivers & Harbors Act of 1899, Section 10;
- Coastal Zone Management Act of 1972;
- National Environmental Policy Act (NEPA) of 1969;
- Fish & Wildlife Coordination Act of 1934, and;
- Endangered Species Act of 1973

For more information about these refer to "Decision Making Process for Dredged Material Management," by the Great Lakes Dredging Team (GLDT 1998).

History of Great Lakes Confined Disposal Facilities

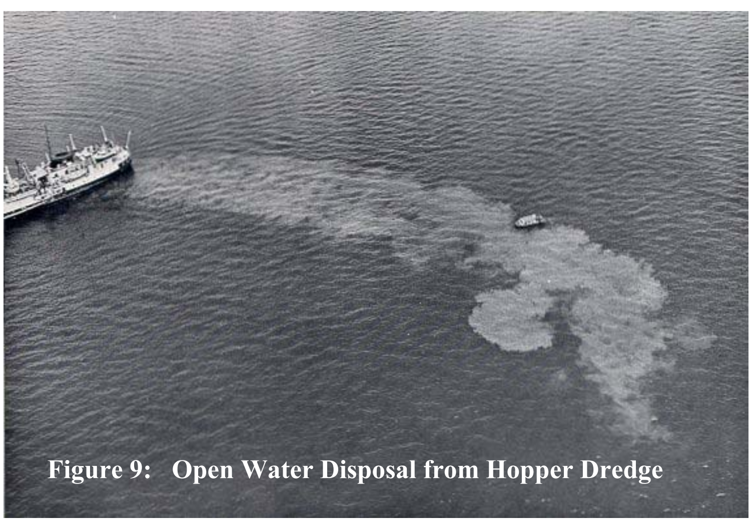


Figure 9: Open Water Disposal from Hopper Dredge

Up until 1960, dredged material from Great Lakes channels and harbors was disposed based solely on cost efficiencies. This meant unconfined, open-water disposal in most cases. The first concerns about the impacts of dredging activities on water quality were raised in response to pollution in the lower Detroit River (U.S. Public Health Service 1950; U.S. Health, Education, and Welfare 1965). Environmental concerns for the Great Lakes increased with algae blooms and other visible symptoms of water quality degradation in Lake Erie. These concerns primarily focused on eutrophication, meaning a depletion of available oxygen in the water body, and nutrient loadings such as phosphorus and nitrogen. It was in this context that the practice of open-water disposal of dredged material from polluted harbors and waterways was called into question.

Prior to 1960, dredged material from Great Lakes harbors had been placed at upland sites on a limited basis when it was more cost effective. Fine-grained sediments were rarely used for fill because their hydroscopic properties provided a poor material for construction. Diked disposal areas were first used for containment of dredged material for environmental reasons at the Detroit River (Grassy Island) and Toledo Harbor (Island 18) in 1960 and 1961, respectively (Buffalo District 1969).

Figure 10: Grassy Island CDF, Detroit, MI

In 1967, the Corps, in cooperation with the Federal Water Pollution Control Administration (the predecessor of EPA) initiated a pilot investigation on alternatives for disposal of polluted dredged material from Great Lakes harbors and channels. A variety of disposal alternatives were investigated and pilot projects were undertaken, including the construction of CDFs at: Cleveland Harbor, OH; Buffalo Harbor, NY; Calumet River, IL, and; Green Bay, WI. A number of technologies for treating sediment contaminants were evaluated at a laboratory scale, and discharge of dredged material to a municipal wastewater facility was evaluated at a pilot-scale.

In 1969, the Corps completed a report on the two-year study entitled "Dredging and Water Quality Problems in the Great Lakes" (Buffalo District 1969). This 12-volume report examined the status of pollution in the Great Lakes, provided a detailed look at existing dredging and disposal practices, described the effects of these operations on water quality, and examined potential modifications and control measures to abate environmental impacts. This study did not document substantial impacts on water quality or benthic communities. Impacts were of a transient nature. The report concluded, though, that open-water disposal of polluted dredged material is "presumptively undesirable." Recommendations of this report included additional research on the environmental effects of dredging and disposal and the development of a program for the confinement of polluted dredged material around the Great

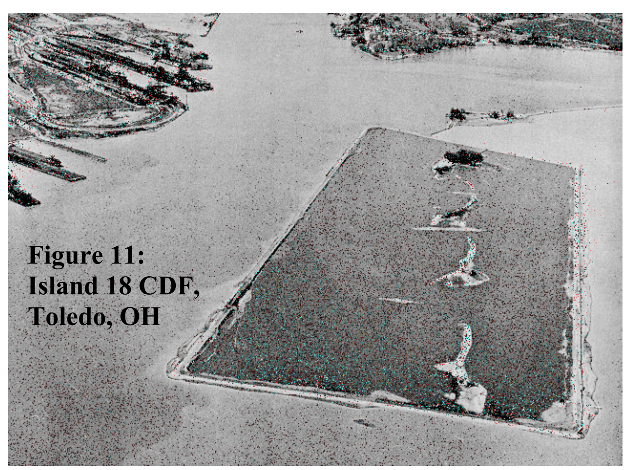


Figure 11: Island 18 CDF, Toledo, OH

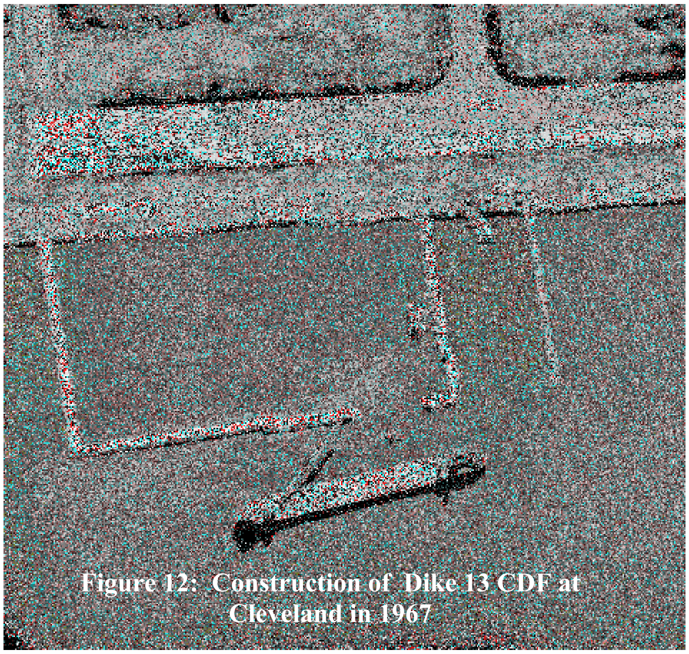


Figure 12: Construction of Dike 13 CDF at Cleveland in 1967

Lakes.

In 1970, Congress authorized two programs that were to have a major impact on the dredging and disposal practices of the Corps through the passage of the River and Harbor Act of 1970, Public Law 91-611, Title I. Section 123 of this Act established the Diked Disposal Program to provide funding for construction of CDFs to contain polluted dredged materials from Great Lakes navigation projects. The same law also authorized the Dredged Material Research Program (DMRP), a five-year research program to examine the environmental effects of dredging and disposal. The Corps' Waterways Experiment Station (WES) in Vicksburg, Mississippi was tasked to manage this research program.

Section 123 authorized the Corps to construct CDFs that could accommodate a 10-year duration of maintenance dredging. This authority required that there be a local sponsor for each CDF who must provide all lands, easements, and rights-of-way to the Corps for the CDF site. Local sponsors for existing CDFs include states, port authorities, city and county governments. The local sponsor was also required to provide 25 percent of the funds for construction of the CDF. This local cost share could, however, be waived if EPA certified that the area was in compliance with an approved water quality program. The local sponsor would be responsible for the long-term maintenance of the CDF after it was filled.

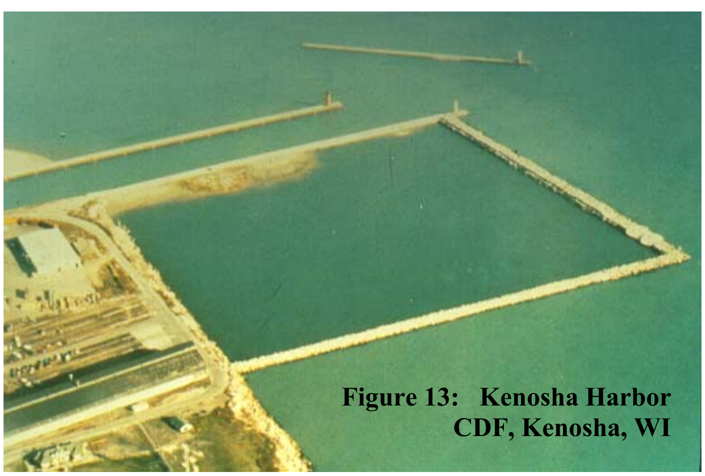


Figure 13: Kenosha Harbor CDF, Kenosha, WI

In the early to mid-1980's, there was some question about the duration of the Section 123 (PL 91-611) authority. The authority enabled the Corps to construct CDFs with a capacity for a period not to exceed 10 years. However, by this time it was clear that the need for CDFs would go beyond 10 years at most Great Lakes harbors. An exception was the CDF in Kenosha, Wisconsin, where the need for existing CDF capacity had been almost completely eliminated as a result of the loss of commercial navigation at the channels served (Kenosha and Racine Harbors). A report prepared in 1986 by the General

Accounting Office (GAO) at the request of Senator Aspin (WI) recommended that the Corps temporarily discontinue using some existing CDFs (GAO 1986). The Corps disagreed with the GAO opinion, and the issue was sent to the Comptroller General who determined that the Corps authority to use the CDFs was limited to 10 years. Congress amended this CDF authority through Section 24(a) of the Water Resources Development Act of 1988. This amendment authorized the Corps to use CDFs constructed under Section 123 until the Corps determines that the facility is no longer needed for that purpose or the facility is completely filled.


Figure 14: Windmill Island CDF, Holland, MI

Twenty-nine (29) CDFs were constructed by the Corps under the Section 123 authority. Another 12 facilities were constructed under the authorities for the Corps to operate and maintain individual navigation projects. At four other sites, diked disposal areas were provided by a non-Federal interest. Fact sheets on each existing CDF in the Great Lakes Basin are contained in Appendix B, along with a table with summary information.

All of the CDFs developed under Section 123 were in areas with water quality plans approved by the EPA, and therefore constructed without a non-Federal cost share (other than lands, easements and rights-of-way). All of the CDFs constructed by the Corps were planned in cooperation with state and local governments, with opportunities for public review and comment.

Because of the limited availability and cost of vacant upland sites near harbors, many local sponsors preferred that CDFs be constructed at in-water sites, typically inside the protected harbor. Over half of the CDFs were constructed as fills in the rivers or lakes. In many cases, local sponsors have planned or implemented productive and beneficial uses for CDFs. These uses have included port and waterfront expansion, development of recreational areas, new or expanded marinas, and wildlife refuges. The Ohio Department of Natural Resources conducted an extensive evaluation to survey the preferences of local stakeholders for the post-disposal uses of the Dike 14 CDF in Cleveland (ODNR 2002). Any post-closure uses for a CDF must be compatible with the environmental integrity and function of the facility. Further, these lands cannot be transferred from ownership of the local sponsor without the approval of the Corps.

In 1996, Congress created a national program for the construction of CDFs through Section 201 of the Water Resources Development Act of 1996. This authority created uniform cost-sharing requirements for all future CDFs. The non-Federal cost share is based on the depth of the navigation channel. For deep draft channels in the Great Lakes (greater than 18 feet and less than 45 feet), the non-Federal sponsor must provide 25 percent of CDF construction costs, plus an additional 10 percent against which all lands, easements, rights-of-way and relocations may be credited.

Confined disposal has been, and remains the most commonly used management alternative for contaminated sediments. Of the approximately four million cubic yards of sediments dredged annually from Federal navigation projects in the Great Lakes, about half are placed into existing CDFs. Since the 1960's, approximately 90 million cubic yards of contaminated sediments dredged from Great Lakes ports and harbors have been placed in CDFs. In addition, 36 out of 40 sediment remedial actions conducted in the Great Lakes used confined disposal to commercial landfills or on-site facilities for the management of dredged materials (USEPA 1998; USEPA 2000). One Corps-operated CDF (Saginaw, MI) has been used for disposal of contaminated sediments dredged as part of a remedial action. Confined disposal facilities under design and construction at Ashtabula, OH and East Chicago, IN will manage contaminated sediments dredged for navigation and cleanup purposes.

The following sections will provide general summaries about CDF designs, how they are operated, types of monitoring, interagency coordination and public outreach activities, and a synopsis of the environmental performance of Great Lakes CDFs. Fact sheets with more detailed information about individual CDFs are provided in Appendix B.

CDF Designs

Great Lakes CDFs have been designed to perform three basic functions:

- physical containment of dredged material;
- management of water within the site, and;
- environmental protection.

The design features for these functions are discussed below. CDF designs were developed in cooperation with local sponsors in order to meet local objectives for future use, aesthetics and waterfront development, where practical.

Material Containment

All confined disposal facilities are designed to permanently contain a volume of dredged material determined from estimates of future dredging needs. Dikes, or berms are constructed to contain the dredged material laterally. The nature of these dikes is quite different for in-water and upland CDFs.

Most in-water facilities provide containment using rubble mound dikes constructed with stone gravel and occasionally using sheet piling. In most cases, these dikes look very much like a breakwater, having outer layers of large stones, weighing up to a ton or more, to protect the facility from wave energy. The center, or core of the dike is typically composed of smaller stone, gravel or sand. Four basic types of dike designs are utilized at most of the Great Lakes in-water CDFs:

- circular sheet pile cells: interlocking circular steel sheet pile cells with random, granular fill and armor stone at dike toe (figure 15);

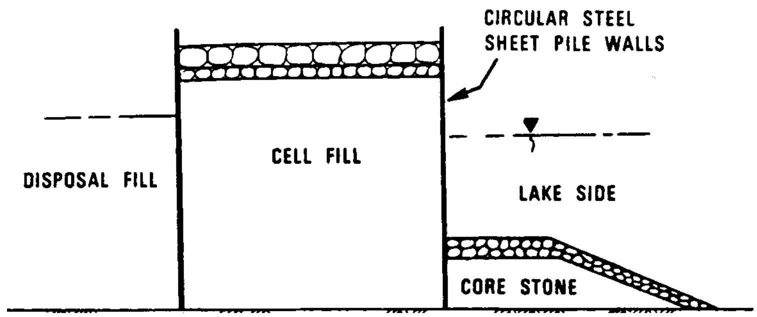


Figure 15: Dike Cross Section, Huron Harbor CDF, Huron, OH

- soldier-pile stone dike: a trapezoidal stone dike with steel sheet pile in the center of the dike to provide vertical stability and allow steeper side slopes, armor stone on both sides of dike, and a small core with variable stone or gravel sizes (figure 16);

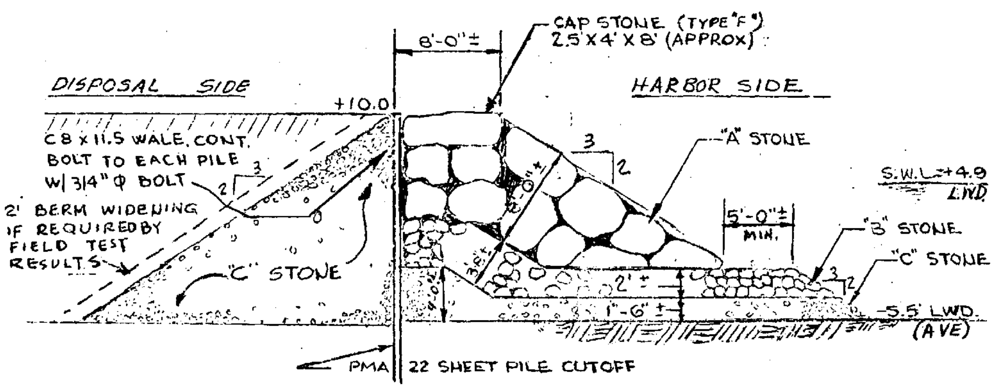


Figure 16: Dike Cross Section, Kewaunee CDF, Kewaunee, WI

- layered core dike: a trapezoidal stone dike with armor stone on outside of dike, not always on inside and a core consisting of two or more layers of stone, gravel, sand (Figure 17), and;

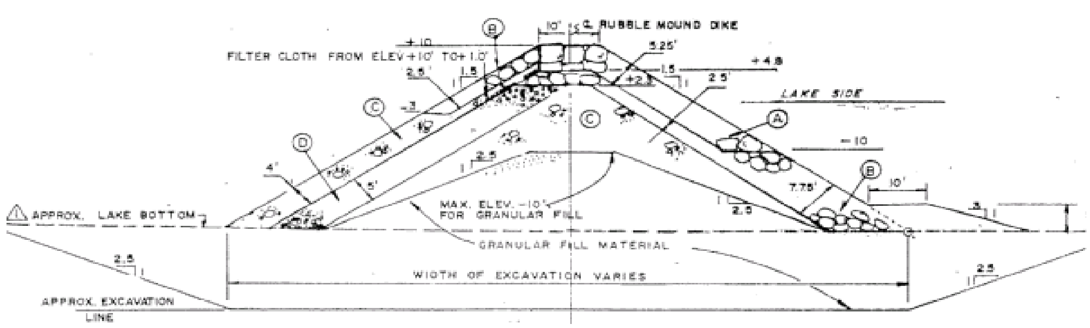


Figure 17: Dike Cross Section, Milwaukee Harbor CDF, Milwaukee, WI
Note: The letters A, B, C, and D represent different stone sizes

- mono-layer core dike: a trapezoidal stone dike with armor stone on outside of dike, not always on inside, and a core consisting of single grade of stone, commonly 4-inch minus limestone (Figure 18).

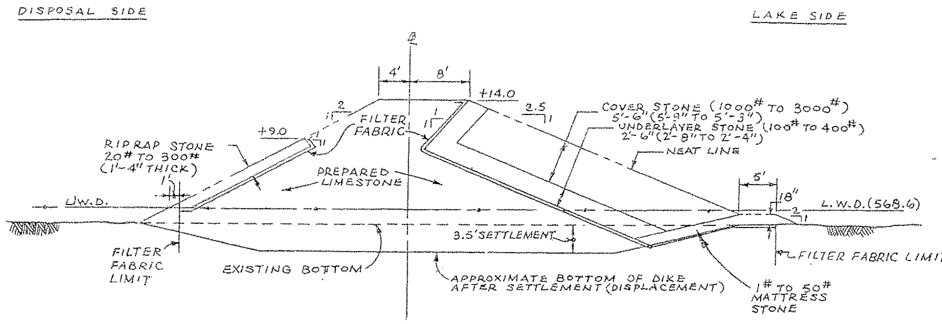


Figure 18: Dike Cross Section, Point Mouillee CDF, Monroe, MI

A clay core was used at a few in-water CDF dikes. However, there were construction problems with clay (placement and underwater compaction) at in-water CDFs that were eliminated with use of gravel cores.

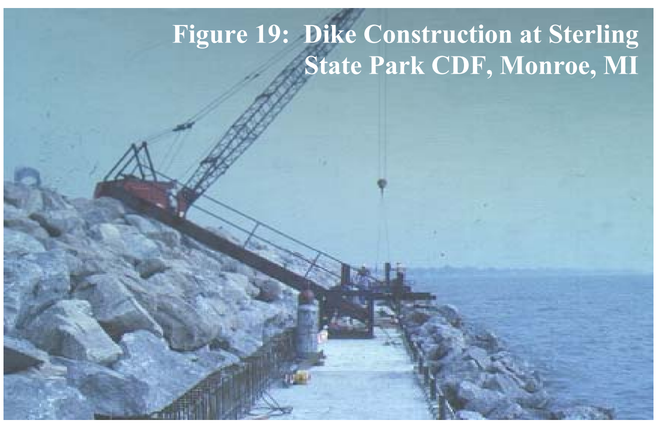


Figure 19: Dike Construction at Sterling State Park CDF, Monroe, MI

Designs for in-water CDF dikes were based on Corps design criteria for shore protection structures, like breakwaters. The dike heights, slopes, and armor stone sizes were designed to withstand a sustained wave attack based on a lake level and wind direction/speed of some recurrence in accordance with the Corps' "Shore Protection Manual" (USACE, 1984). Stone sizes on in-lake CDFs were typically designed to withstand a 20-year storm. Dike height was typically designed to limit overtopping by waves with a 20-year lake level and a 20-year storm. The gradation of the material in the core of the dike was based on availability and construct-ability concerns in most cases. The sizing of granular material in CDFs with layered cores included some consideration of their ability to retain sediment particles inside the CDF .

In most cases, upland CDFs were constructed with earthen dikes, which are like berms used for landscaping, levees or landfills. The side slopes of earthen dikes are generally more shallow (flatter)

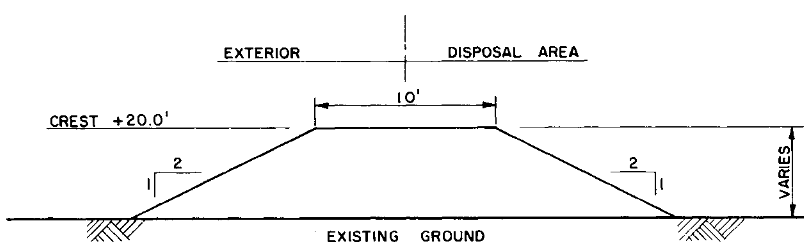


Figure 20: Dike Cross Section, River View CDF, Holland, MI

than those of in-water stone dikes, and made using soil from the immediate area or previously dredged materials. The character of the soil used is site dependent, although sites were commonly selected because of their soil characteristics. Some upland CDFs were built on property that had previously been used by local interests for disposal of sludge, debris or waste. Upland CDF dike designs were largely based on geotechnical and structural stability using the same procedures as for levees and earthen dams.

Water Management

The management of water is a primary design purpose of most CDFs. Dredged sediment contains a high percentage of water, and a CDF must be designed to retain as high a percentage of the sediment particles as practical while allowing for the removal of most of the water. The removal of water from a CDF is needed to provide capacity for additional dredged material and to facilitate drying and consolidation of the solids. In most cases, the bulk of water is released from a CDF at times when dredging operations are ongoing. This generally represents a period of a few weeks a year, and in many cases dredging does not take place every year. During non-dredging periods, limited amounts of water from rainfall runoff may accumulate inside a CDF that may be drained, treated if necessary, and discharged (Miller 1997; USACE 1987a).

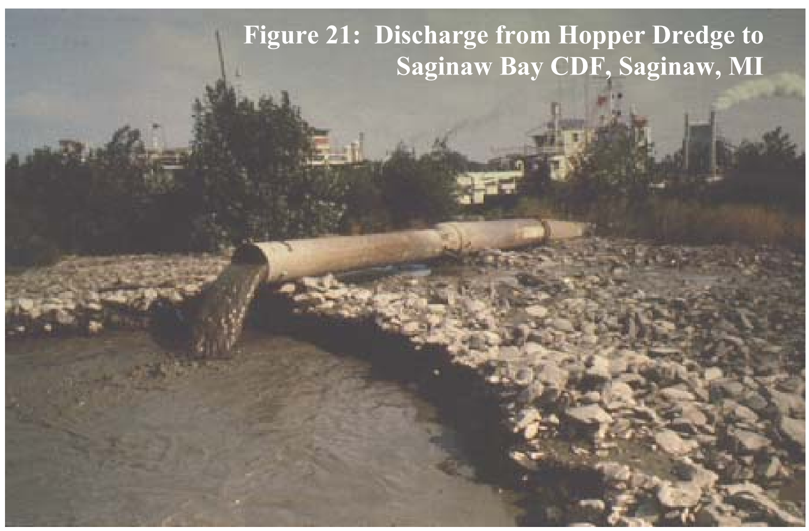


Figure 21: Discharge from Hopper Dredge to Saginaw Bay CDF, Saginaw, MI

Water enters a CDF with the dredged material, as precipitation, and through seepage. The amount entering a CDF during dredged material disposal operations varies depending on how the sediments are dredged and rehandled. Fine grained sediments, undisturbed, are typically about 50 percent water by weight. Hydraulically dredged sediments, placed into the CDF by pipeline, typically carry four volumes of water for every one volume of sediment. In contrast, mechanically dredged sediments might be placed into the CDF by a clamshell and crane or by truck with virtually no additional water (beyond that in the undisturbed sediments).

Water inside a CDF may be collected at the surface and discharged, released to the atmosphere by evaporation and transpiration, or seep out through the dikes or floor of the CDF. Lateral seepage of excess water through the permeable dikes was an intended part of the overall design of most in-water CDFs throughout the Great Lakes. The dikes of most in-water CDFs are permeable upon construction. The in-water CDF has a ponded area inside with a water surface in hydrostatic equilibrium with the adjacent harbor or lake. As dredged material is placed inside, water is displaced and moves passively through the dike. The dike becomes clogged as the sediments are mounded against it and the dike walls become progressively less permeable, limiting lateral seepage out of the CDF. Eventually, the ponded water inside the CDF begins to rise and must be released by another pathway (USEPA 1994; USACE 1987). Surface water inside CDFs has been released by overflow weirs, through filter cells, or by pumping.

Figure 22: Pond at River View CDF, Holland, MI

CDFs designed for mechanically dredged sediments typically have very little water to be discharged, other than rainfall runoff. Evaporation and seepage are generally sufficient for water management.

Environmental Protection

Environmental protection is a fundamental function of Great Lakes CDFs. The construction of these facilities was authorized by Congress as a means for controlling dredged material contaminants and preventing them from reentering the Great Lakes. Research on dredged material has identified the following pathways by which contaminants may migrate from a CDF (USACE/USEPA 1992; Myers et al. 1996).

- effluent: contaminants associated with water discharged from CDFs into the adjacent harbor, lake or stream through overflow weirs, effluent pipes, and permeable dikes;
- leachate/seepage: contaminants entering the groundwater through the bottom of the CDF;
- bioaccumulation: contaminants accumulated by plants and animals inhabiting the CDF, and;
- volatilization: volatile contaminants can evaporate directly into the air.

These contaminant release pathways, pictured on figure 23 are affected by a number of factors including the dredged material physical and chemical properties, and the CDF location, design and operating procedures. Not all of these pathways are available for all CDFs. The majority of existing, Great Lakes CDFs were designed with emphasis on the first pathway (effluent), which has the greatest potential for contaminant loss (Myers et al 1996).

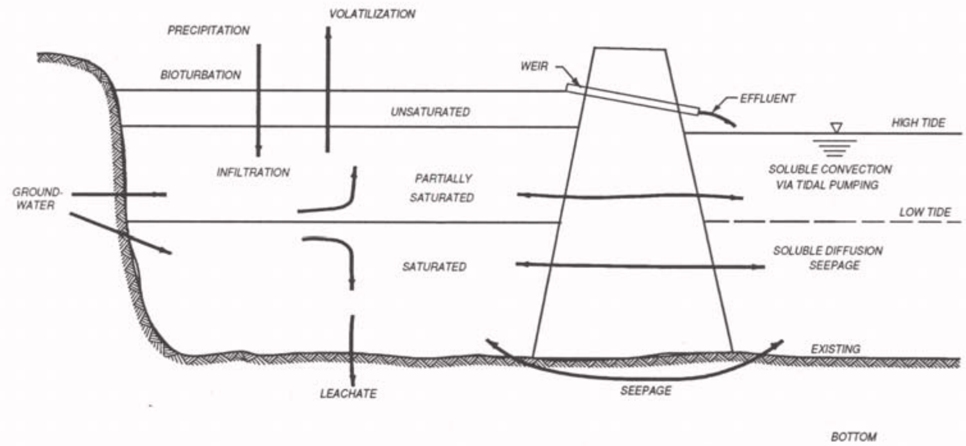


Figure 23: Contaminant Loss Pathways; In-Water CDFs

Water released from a CDF to a stream, river or lake is considered a dredged material discharge and is regulated under Sections 404 and 401 of the Clean Water Act. The discharge must comply with state water quality standards after allowing for mixing. Research has shown that most contaminants are tightly bound to the sediment particles and not readily released in a soluble form. A CDF that retains a high percentage of the sediment particles will therefore be effective in containing the associated contaminants (USACE 1978).

A number of conventional wastewater treatment technologies have been applied at Great Lakes CDFs. Facilities that accommodate hydraulically dredged material have been designed to receive a large volume of water and allow for settling of sediment particles before the water is released. These designs are based on the same procedures as a primary settling basin for wastewater treatment facilities (USACE 1987a; Palermo 1988). Most of the coarse sediments, including sands and gravel, settle rapidly near the point of disposal. Fine-grained sediments, including silts and clays, require more time to settle out.

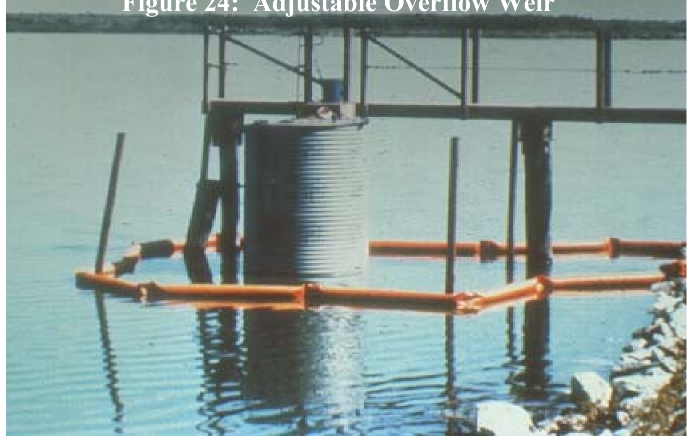


Figure 24: Adjustable Overflow Weir

Some Great Lakes CDFs utilize design features to enhance the efficiency of primary settling, such as multiple settling basins or cells and adjustable overflow weirs (figure 24). CDF dikes may have to be constructed several feet higher to accommodate the additional capacity required for treatment of water from hydraulically dredged material. Where primary settling alone was not adequate to treat the water discharged from the CDF, secondary treatment including filtration and polymer flocculation have been used. Several CDFs in the Great Lakes have filter cells built into the dikes (figure 25).

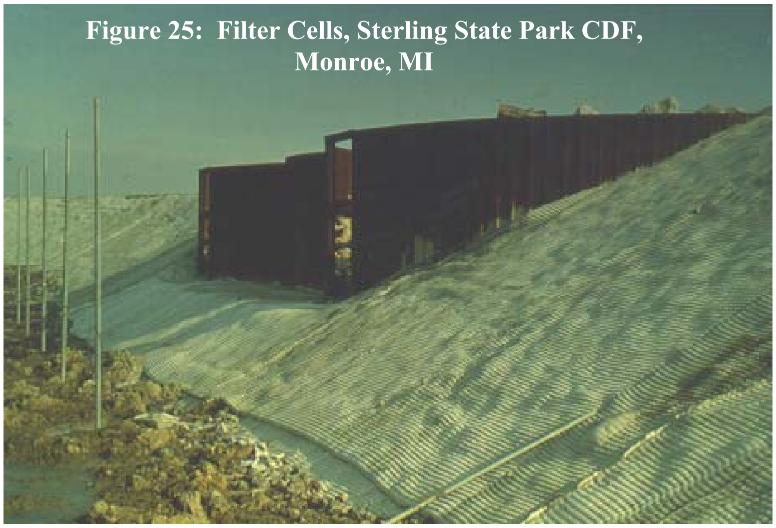


Figure 25: Filter Cells, Sterling State Park CDF, Monroe, MI

Most Great Lakes CDF dikes were permeable upon construction, and water was intended to move laterally through the dikes. In most in-water CDFs, this movement may be either inward (from the lake) or outward (from the CDF), depending on the water surface elevations of the CDF pond and adjacent harbor. Seepage in upland CDFs is generally outward unless the local groundwater table temporarily rises above the elevation of the CDF floor. The movement of contaminants through seepage has been a concern at a few CDFs, either because of highly elevated levels of contamination in the dredged material or the proximity of a specific resource. Research has indicated that sediment contaminants do not readily move through this pathway, especially those contaminants that are most persistent and bioaccumulative (Environmental Laboratory 1987; Myers & Brannon 1991).

Figure 26: Keweenaw Waterway CDF, MI

Only a few in-water CDFs have features designed to reduce dike permeability such as compacted clay, plastic liners, and grouted mattresses (as shown on figure 25). Some dikes have steel sheet pile in portions of the design, although these were not intended to control seepage.

Since most upland CDFs were constructed with earthen dikes using soil excavated on-site, the seepage potential of these facilities reflects the properties of the local soils. As with in-water CDFs, the primary design criteria was to keep the sediment particles inside the CDF and allow for release of water through one or more routes.

The long-term seepage of water from CDFs is generally limited by the soil properties of the dredged material. Most contaminated sediments are fine-grained soils (silts and clays) that have relatively low permeabilities after settling and compaction. CDFs that have been filled to capacity and closed to further disposal have typically been used without any cap or cover. Most have used the last layer of dredged material as the cover with the intent that this layer be of the cleanest material available at the harbor or channel. In some cases, the CDF has been capped with gravel and paved to facilitate parking (as done at the CDF shown on figure 27) or landscaped to facilitate drainage. In all cases, the ultimate use of the filled CDF is determined by the local sponsor, with concurrence of the Corps that the use will not jeopardize the environmental integrity of the facility.

Figure 27: Small Boat Harbor CDF, Buffalo NY

Bioaccumulation of contaminants by plants and animals inhabiting CDFs was not a pathway considered in the pre-construction design of most of the existing Great Lakes CDFs. Efforts to control contaminant losses and impacts from this pathway are being addressed almost entirely through operational modifications discussed on the next pages.

Volatilization is a contaminant loss pathway that has been considered at only a few CDFs with elevated levels of volatile and semi-volatile organic contaminants. The Corps and EPA have collaborated on studies and risk analysis of this pathway for the Indiana Harbor CDF, which may serve as the template for evaluating the significance of this pathway at future CDFs. More details on results and references are provided in later sections of this document.

CDF Operations and Management

The operation of a CDF is planned while the facility is under design, but must be adaptable to changing conditions and needs. The major operational considerations at Great Lakes CDFs include:

- dredged material placement;
- dewatering and consolidation;
- plant and wildlife management, and;
- site security and safety.

Dredged Material Placement

Virtually all dredging at Federal harbors in the Great Lakes is conducted by private contractors. The Corps does not typically prescribe what type of dredge or placement method must be used, so long as the contractor meets the environmental performance requirements of the contract plans and specifications. Contractors have shown innovation in delivering dredged material to CDFs while minimizing spillage.

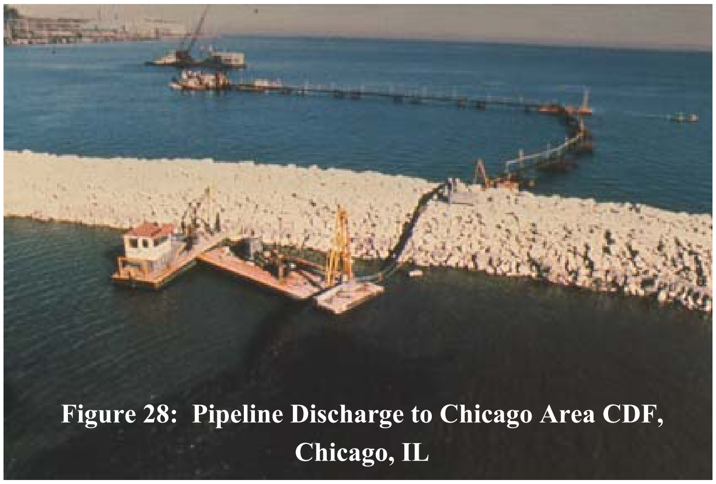


Figure 28: Pipeline Discharge to Chicago Area CDF, Chicago, IL

Dredged material has been placed into CDFs a number of ways, depending on how the sediments were dredged (Miller 1998). Hydraulically dredged sediments are always placed by pipeline (figure 27). Mechanically dredged material are often removed from a barge and placed into in-water CDFs using a crane and bucket with a slide or sluice (figure 29). Mechanically dredged material may be transferred to trucks and offloaded to CDFs (figure 30). Specially designed pumps and small hydraulic dredges have also been used to slurry mechanically dredged sediments inside the barge for transport by pipeline.

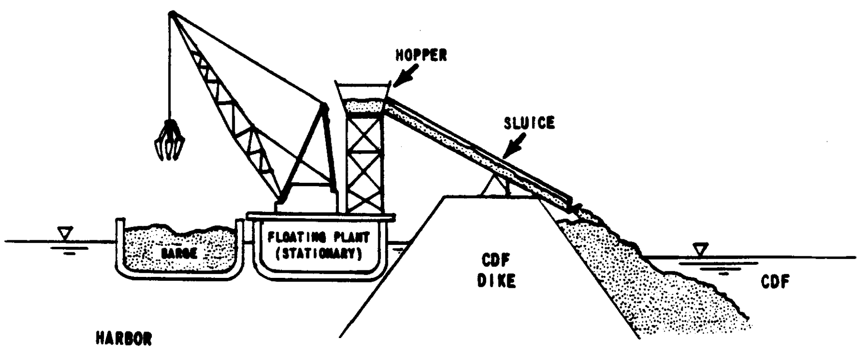


Figure 29: Discharge to In-water CDF by Hopper and Sluice

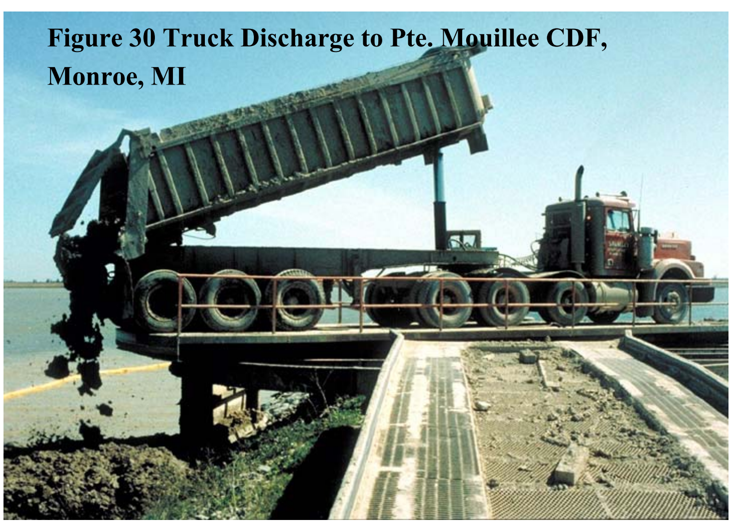


Figure 30 Truck Discharge to Pte. Mouillee CDF, Monroe, MI

Dewatering and Consolidation

The water inside the CDF is managed in order to facilitate dewatering and consolidation of the dredged material and to treat the water released from the CDF, as previously discussed. Consolidation is important because it provides for additional capacity in the CDF, and is necessary to allow safe access onto the dewatered dredged material. Active water management has been accomplished by adjusting overflow weirs, drainage and pumpage. This has been generally limited to the periods when the dredge is operating, which may be less than ten percent of the time. The rest of the year, dewatering and consolidation are passive activities resulting from evaporation from ponded areas and exposed sediments, transpiration from vegetation, gravity drainage, seepage and self-weight consolidation.

A more active attempt to dewater dredged material is being conducted at the Bayport CDF in Green Bay, where the Port Authority has modified the facility into a number of cells (figure 30). The plan is to dewater the dredged material more quickly, remove it for beneficial uses at remote sites, and re-use the CDF cells for future dredgings (Robert E. Lee & Assoc 1998).

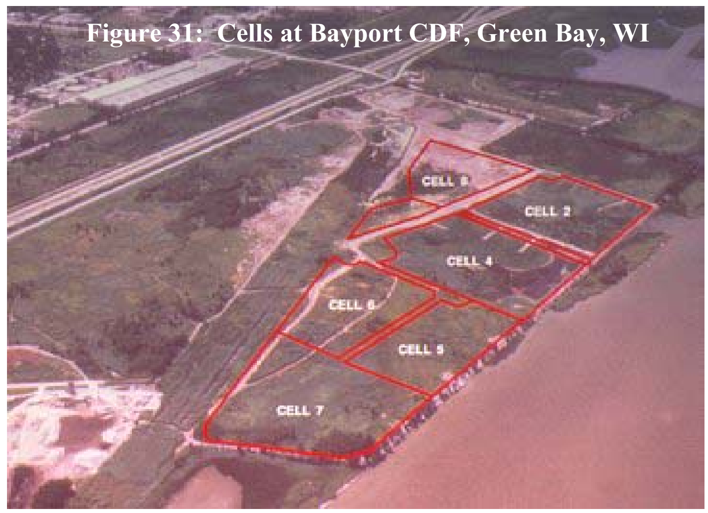


Figure 31: Cells at Bayport CDF, Green Bay, WI

Plant and Wildlife Management

Much of the dredged material placed in Great Lakes CDFs is enriched with plant nutrients (nitrogen and phosphorous). As CDFs are filled, dense vegetation has rapidly covered exposed dredged material (figure 32). The combination of this vegetation plus the quiescent ponded areas in the CDF creates a very attractive habitat for a variety of wildlife. In some areas along the Great Lakes, a CDF may appear as a green oasis in the midst of an urban-industrial shoreline. A few CDFs have become intensely used by migratory waterfowl for nesting, and several


Figure 32: Vegetation at Renard Island CDF, Green Bay, WI

are known by local residents as prime areas for bird watching**.**

The proliferation of plants and animals at CDFs is a concern to the Corps, EPA and other Federal and state resource agencies. On the one hand, there is a concern that the wildlife may be exposed to contaminants present in dredged material, some of which may be bioaccumulative. On the other hand, the CDF may be providing habitat in an area where most of the natural habitat has been eliminated and where much of the surrounding waters have sediments with the same types of contaminants as those found inside the CDF.

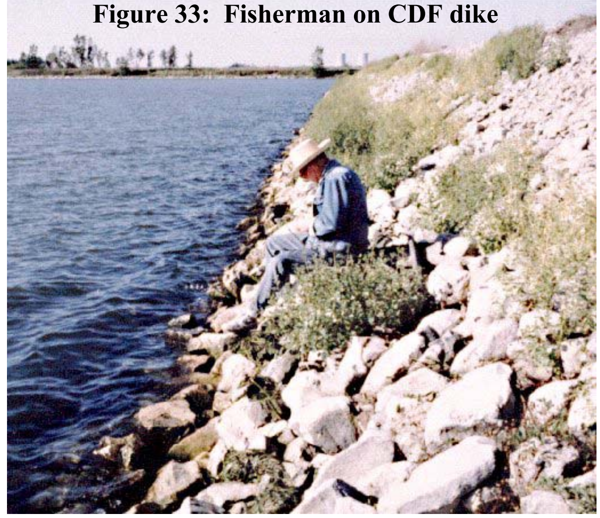
The Corps has worked with the U.S. Fish & Wildlife Service and state resource agencies to develop wildlife management plans for some Great Lakes CDFs. These plans are site specific, and have included provisions such as:

- prevent disturbances to nesting areas during critical periods;
- eliminate fish from ponds inside CDFs to prevent bioaccumulation of contaminants;
- remove or cover animal carcasses that may pose a botulism threat, and;
- control vegetation to make site less attractive to certain animals.

Site Security and Safety

Some CDFs have been constructed in urban areas where access and security are a concern. These issues are especially important to the local sponsors for CDFs, since they carry the liability for accidents not directly resulting from the negligence of the Corps or its contractors. In some urban waterfronts, the CDF may appear to be the only "public" access to the harbor, river or lake. Dikes of in-water CDFs are attractive to fisherman and the heavy vegetation growing on dredged material inside the CDF may provide the "greenest" spot in an otherwise barren waterfront. The concerns with public access include:

Figure 33: Fisherman on CDF dike



- fishing boats being damaged by dikes;
- drownings outside the CDF dikes or in the CDF pond;
- climbing and falling on the dikes;
- walking on unconsolidated dredged material inside the CDF;
- consuming contaminated fish or wildlife from inside the CDF, and;
- unauthorized hunting.

Security at CDFs is site specific. Most CDFs have signs posted to warn people to stay off the dikes and dredged material. Fencing is commonly used at upland CDFs and in-water facilities that have a land connection. These measures are not completely effective, since CDFs are inactive for many months or years between dredging operations and typically located in non-residential areas.

CDF Research, Monitoring & Evaluation

The Corps, EPA and other agencies have performed a variety of investigations on the performance and environmental impacts of CDFs, including basic and applied research, routine monitoring of operating facilities, modeling and theoretical evaluations, and special field studies. The bulk of research conducted on confined disposal of contaminated dredged material has been conducted by the Corps of Engineers through the following research and technical support programs:

- Dredged Material Research Program (DMRP);
- Long-Term Effects of Dredging Operations (LEDO);
- Field Verification Program (FVP);
- Dredging Operations and Technical Support (DOTS), and;
- Dredging Operations and Environmental Research Program (DOER).

Numerous technical reports have been prepared and distributed from the individual studies conducted under these programs. The results have also been distilled into engineering manuals and technical guidance used by the Corps, other agencies and private consultants for CDF planning, design and operation (USACE 1978; Francingues et al 1985; USACE 1987a; Schroeder and Palermo 1990; Brannon et al 1990; USACE/USEPA 1992; USEPA 1994a; Richardson et al 1995; USACE 2003).

Routine monitoring of individual CDFs is conducted for a number of purposes, including:

- ensure that dikes are constructed in accordance with Corps designs;
- ensure continued structural integrity of CDF dikes;
- ensure that dredged material placement by contractors is in accordance with plans and environmental requirements;
- ensure that effluent water quality meets conditions of state water quality certification;
- track dewatering & consolidation of dredged material inside the CDF, and;
- track vegetation and wildlife use of the site.

Monitoring procedures at CDFs are as individual as the designs. There is no single, systematic monitoring program applicable to all facilities. The monitoring program for a CDF is typically the result of review and coordination with the public, state, and Federal regulatory agencies (Miller 1998).

Special studies on the environmental performance of Great Lakes CDFs have been conducted at existing facilities and as part of evaluations for proposed CDFs. These studies have focused on one or more of the pathways by which contaminants may migrate from a CDF or cause environmental harm. In some cases, these special studies were done as part of, or in combination with research studies and/or routine CDF monitoring.

Dike Construction and Structural Integrity

CDF dikes and other features have been inspected periodically to assure that they are constructed properly, remain intact and function as designed. Visual inspections are typically conducted before and after disposal operations and following events like storms with high waves, massive ice flows or heavy rains. These inspections are used to determine when maintenance or repairs are necessary.

Figure 34: Dike Repairs

Storm waves or ice have caused erosion of stone from a few in-water CDF dikes, and two CDFs have experienced damages (Saginaw Bay CDF, Saginaw, MI, 1985 and Times Beach CDF, Buffalo, NY, 1986). However, these damages did not produce any loss of contaminated dredged material, and were repaired quickly.

In 1984 and 1985, dye tracer studies were conducted at four CDFs in Wisconsin (Kenosha, Manitowoc, Milwaukee and Kewaunee) in order to evaluate the movements of return water through dikes and the potential for unexpected containment loss (Pranger and Schroeder 1986). A dye tracer study was conducted. Dye tracer studies involve the introduction of highly visible fluorescent tracer dyes inside of the CDF. The area outside of the CDF is then closely monitored for traces of dye passing through the dike. The pattern of dye outside the CDF indicates how evenly or unevenly water has seeped through the dike. These tests showed that return water was being "channeled" at locations where the stone dikes joined with existing sheet pile breakwaters or piers. Modifications to the dikes were made to eliminate this channeled flow and preclude an unacceptable loss of dredged material particulates at these locations.

In 1985, during construction of the Chicago Area CDF dike, monitoring suggested that the plastic liner that had been installed was compromised. A dye tracer study at the Chicago CDF confirmed that the liner was not performing as designed. After consulting with EPA and the Illinois EPA, the Corps constructed a blanket of sand along the interior face of the CDF dike to prevent migration of dredged material.

Dredged Material Placement

Dredging at Federal harbors and channels in the Great Lakes is conducted by private contractors using plans and specifications that contain specific requirements for dredged material handling and environmental protection. The Corps routinely monitors the performance of these contractors to assure that they are placing dredged material inside CDFs in a manner that prevents spillage and maintains compliance with water quality standards. This monitoring is done by Corps inspectors who visit CDFs and meet with the contractors on a daily basis during dredging and disposal operations. The dredging contractor and Corps' inspector prepare separate daily reports of their performance and inspections.

CDF Discharges and Contaminant Release

Effluent and Seepage Through Dikes. Almost all CDFs, upland or in-water, were planned and designed so that the return water, or effluent discharges to a river, harbor or lake. The Corps must receive a certification from the state that this discharge complies with state standards. In most cases, water quality compliance of the CDF return water is monitored using total suspended solids (TSS), which provides a reliable measure of the efficiency of the CDF in retaining dredged material particulates (Palermo and Thackston 1988; Thackston and Palermo 2000). Other parameters may be monitored as conditions of the state water quality certification.

Figure 35: Water Quality Monitoring

Routine water quality monitoring at CDFs is generally conducted during the dredging operation and may include monitoring of the effluent at the discharge (weir overflow or filter cells) and mixing zone. In some cases, the monitoring includes the dredge discharge, CDF pond, open water sites around the CDF, and monitoring wells. Water quality monitoring is performed by private contractors and the results are provided to the Corps. The Corps routinely submits monitoring data to the appropriate state agencies, and others as requested. The fact sheets on individual CDFs (Appendix A) describe routine monitoring practices.

When the effluent from a CDF approaches the target criteria, dredged disposal operations are ceased until water quality compliance is restored through changes in disposal operations, facility operations or treatment operations. CDFs have rarely exceeded target water quality standards. In most cases, the facility must be operated for several years and nearly filled before the settling efficiency inside the CDF becomes limited and effluent water quality approaches standards. When facilities do become filled, dikes have been raised to provide additional capacity and dredging operations have been restricted to methods that will dispose very little water and virtually eliminate return water flow.

Routine monitoring has demonstrated that water discharged from CDFs during dredging and disposal operations consistently meets state water quality standards. In a 1985 letter to the Corps, EPA Region 5 acknowledged this, but indicated that less was known about the long-term release of contaminants through permeable CDF dikes. EPA and the Corps formed the Interagency CDF Work Group to determine the significance of these releases. A number of special studies were conducted in cooperation with the Work Group.

The first efforts to quantify the mass of contaminants lost from CDFs during active and inactive periods were conducted for the existing Chicago Area CDF (Miller 1985) and for a proposed CDF design for Indiana Harbor (Chicago District 1986). This analysis was based on a mathematical model of the CDF, which estimated the total flow of water and associated contaminants through permeable dikes. A more sophisticated model was developed for the Saginaw Bay CDF (Velleux and Endicott 1988; Myers 1991), and supplemented with dye studies of water movements through the dikes and chemical analysis of CDF influent and effluent (Schroeder and McEnroe 1988). The model predicted the near-field transport and far-field impacts of PCBs expected to migrate through the facility's dike walls. The total predicted release of PCBs from the CDF though this pathway was very small (250 grams over 5,000 days).

The results of mathematical modeling indicated that the levels of persistent contaminants (like PCBs) migrating through permeable CDF dikes would be far below that detectable by conventional water quality monitoring procedures (Martin and McCutcheon 1992; Myers et al 1996). A pilot study was conducted at the Saginaw CDF to examine the efficacy of biological testing procedures for CDFs (Rathbun et al 1988; Kreis et al 1992; Velleux et al 1993). The study utilized the deployment of caged fish and plants on the outside of the CDF dikes. It also utilized biological surrogates, which are devices intended to accumulate contaminants in quantities analogous to organisms in the same environments. The results of the biomonitoring study suggested that no significant contaminant transport occurred during the sediment disposal operations through this pathway.

A different kind of biomonitoring study was conducted at the Chicago Area CDF (Dorkin et al 1988). This study measured PCB concentrations in the tissues of fish, crayfish and periphyton collected at locations inside the CDF, immediately outside the CDF dikes and at a remote location in the harbor. The results of this study did not show a statistical difference between PCB body burdens in plants and animals collected in the harbor at near and far locations outside the CDF.

Releases to Groundwater

The leaching of contaminants from dredged material into groundwater has not been a significant concern at most Great Lakes CDFs. In part, this is because less than half of the CDFs were constructed at upland sites, and most of these were located in areas near the lake that did not rely on groundwater for potable or industrial supply. Groundwater wells were installed for monitoring at some upland CDFs and at the landward side of a few in-water CDFs.

The mobility of persistent contaminants from dredged material is limited by a number of physical and chemical factors. For example, fine-grained dredged material exhibits a very low permeability (sometimes less than 10^{-7} cm/sec) in column leaching tests (Environmental Laboratory 1987). Cap and cover technologies can be used to control leachate generation, although this has only been applied at a few, filled CDFs. An engineered cap and cover was designed for the CDF in Michigan City, Indiana using the Hydrologic Evaluation Landfill Procedure (HELP) model, developed by the Corps for the EPA (Schroeder et. al. 1988).

A series of research studies were conducted in relation to the proposed CDF for Indiana Harbor, Indiana (Environmental Laboratory 1987) that developed laboratory procedures for evaluating the potential for contaminant leaching from dredged material. Batch and continuous flow leach tests showed the majority of the contaminants to be bound tightly to the sediment, and also predicted the probable maximum leachate contaminant concentrations (Hill et al 1988; Myers and Brannon 1991; Myers et al 1992; Brannon et al 1994). The Sequential Batch Leaching Test (SBLT) was also applied to evaluate the potential for leachate contaminant loss at the proposed CDF for Waukegan Harbor, Illinois (Environmental Laboratory 1999). A field-based demonstration project to measure leachate at the Buffalo (Dike #4) CDF was initiated, but equipment problems precluded any meaningful data (Myers 2001, personal communication).

Releases to the Atmosphere

Volatilization is a contaminant loss pathway that has only been considered for dredged material management at a few sites, and the procedures for evaluating this pathway are still in the developmental stage. Volatilization studies examine the loss of contaminants from the surface of the CDF directly into the air. This is especially relevant where the dredged material contains high levels of volatile contaminants (e.g., polynuclear aromatic hydrocarbons or polychlorinated biphenyls) which could create localized air quality problems near the CDF or could contribute to overall contaminant loadings to the region.

Volatilization can occur from either exposed or submerged sediments. Modeling studies

(Thibodeaux 1989) have indicated that the losses from sediments directly exposed to air are greater than from those that are submerged. This has been verified for farmland application of sludge but not directly for sediments in CDFs. A study was conducted of the volatilization rates from the Chicago Area CDF at Calumet Harbor, Chicago using equilibrium partitioning theory and field sampling (Semmler and Holson 1994). The study showed that volatile flux of PCB from sediment to water to air may be a significant loss pathway. It also conceptualized CDF management strategies to minimize loss of volatile contaminants, including wind barriers and maintenance of high organic carbon content in the surficial sediment layer.

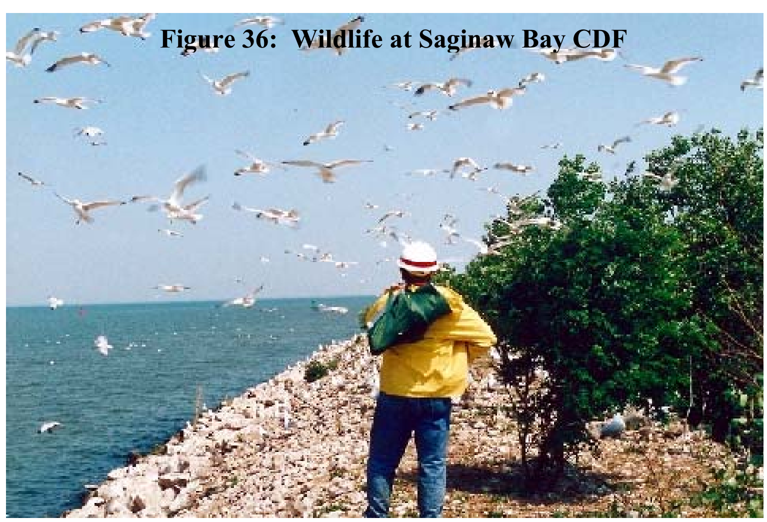
The most comprehensive modeling and laboratory volatilization studies were conducted for the Indiana Harbor CDF (Semmler 1990; Price 1997). The results of these studies were used to evaluate human health risk and the potential for odor generation at the proposed CDF (Chicago District 1998). Additional studies of volatilization have been conducted with sediments from the Grand Calumet River and the Indiana Harbor, including a controlled field simulation experiment using a modified volatile organic carbon (VOC) flux chamber (Environmental Laboratory 1997; Price 2000). The results indicated that measured field VOC fluxes were significantly lower than laboratory and model predictions.

Dewatering and Consolidation

For the most part, dredged material dewatering and consolidation inside a CDF has been largely unmonitored. Exceptions are CDFs where the ponded water inside is monitored to facilitate drainage and promote drying. The compaction and consolidation of dredged material is monitored visually and occasionally by survey. Anecdotal information and observations at existing, Great Lakes CDFs indicate that most dredged material has consolidated by about 25-30 percent after five to ten years (Miller 1997).

Vegetation and Wildlife

Figure 36: Wildlife at Saginaw Bay CDF



Plant growth and animal use of CDFs may be monitored because of a variety of concerns. Wildlife within some CDFs is monitored in conjunction with management plans negotiated with state and Federal resource agencies. The presence and nesting of migratory birds is tracked at some CDFs to avoid any unnecessary disturbances by disposal operations. The extent and type of vegetation is periodically monitored at some CDFs to identify conditions that may limit access by contractors, require clearing, and support overall wildlife management decisions.

PCBs and other contaminants have been detected in Great Lakes fish, birds, and other plant and animals species. The environment created by CDFs can prove attractive to many wildlife species. The still waters contained within the dikes can be desirable resting sites for waterfowl. Shallow waters provide ideal environments for many wetland plants and animals. Plants growing in soils formed from dredged material may take up contaminants and pass those contaminants to animals that feed on the plants. Burrowing species such as earthworms and some mollusks may absorb contaminants directly from the dredged material and pass those contaminants on to species that feed on them. Biological monitoring studies have been conducted at a few Great Lakes CDFs to evaluate migration and uptake of contaminants.

The types of plants and animals inhabiting CDFs and the bioaccumulation of dredged material contaminants has been extensively studied at the Times Beach CDF in Buffalo, New York (figure 37). This facility was constructed in 1976, but was only partially filled, in part, because of concerns raised by the local Audubon chapter about the high quality habitat that it supported. This CDF was used as a laboratory for long-term studies of bioaccumulation by aquatic and terrestrial plants and animals and possible effects on organisms including growth, reproduction, vitality and carcinogenicity (Marquenie et al 1987; Marquenie et al 1990; Stafford et al 1991).

Figure 37: Times Beach CDF Buffalo, NY

The sedge, *Cyperus esculentus* was planted at various locations in the Times Beach CDF dredged material and harvested after 45 days. The uptake of organic pollutants was insignificant. Levels of cadmium, chromium, iron and possibly arsenic were higher than normally found in wetland plant communities of the Great Lakes. Earthworms incubated in CDF sediments were found to have increased levels of heavy metals, PCBs, and PAHs. Fish samples collected from the open water at the CDF did not accumulate elevated levels of heavy metals, but did have elevated levels of PCBs and PAHs. In addition, there were significant numbers of tumors found on the fish, especially carp, which were in contact with the contaminated sediments.

In a separate study, the U.S. Fish & Wildlife Service (FWS) evaluated contaminant bioaccumulation in birds living in a CDF that might feed on insects or fish. The FWS introduced tree swallows and nesting boxes for them on the Renard Island CDF in Green Bay, Wisconsin and along the lower Fox River (Ankley et al. 1994). Tree swallows are thought to forage primarily on insects emerging in the River and Bay, which spend a significant time in contact with the contaminated bottom sediments, and can accumulate contaminants in their tissues. The birds were allowed to inhabit the nesting boxes during the nesting season, when they would remain relatively close to their nests. Contaminant uptake would thus be from the local environment. Tissue concentrations of PCBs, furans, and dioxins were found to be similar in the tree swallows that had nested on the CDF to those found in the birds that had nested near the river, but away from the CDF.

The bioaccumulation of PCBs from dredged material was also examined in the Chicago Area CDF (Dorkin et al 1988). This study measured PCB concentrations in the tissues of fish, crayfish and periphyton collected within the CDF. The concentrations of PCBs in wildlife collected from within the CDF were higher than those collected in the adjacent harbor, and the levels found were very consistent with those projected using a theoretical approach (equilibrium partitioning).

Coordination and Outreach

The perceptions of the public towards dredging and confined disposal facilities have been quite varied. Most people have a general understanding of what dredging is, but are unfamiliar with how dredged material is managed. Public knowledge of CDFs is very limited and fashioned by the controversy surrounding a particular CDF. The perceptions of resource agencies toward CDFs have also been quite varied, even within a single agency. It is not uncommon that only one individual within a state or Federal agency deals with CDF projects. All too often, this individual may coordinate with the Corps and other agencies on CDF-related environmental issues for a limited time. When this person leaves the agency or is reassigned, the institutional knowledge on CDFs by that agency is lost, and has to be rebuilt. To a large extent, the institutional knowledge on Great Lakes CDFs resides in only a handful of scientists and engineers.

The concerns that have been expressed by the public and resource agencies about specific CDFs or confined disposal in general might be summarized as follows:

- opposition to any fill or disposal site (not in my back yard);
- concerns about the impacts of a CDF at a particular site on noise, odors, aesthetics, or property values;
- concerns about the impacts of contaminants released from CDFs on human health (water supplies, beaches, groundwater, fisheries, airborne releases, etc.);

- concerns about the impacts of the sediment contaminants in the CDF on wildlife, and;
- preference for treatment of sediment contaminants as an alternative to confined disposal.

In order to address agency and public concerns about CDFs and dredging, the Corps and EPA have coordinated with other international, Federal and state resource agencies and facilitated public outreach.

Interagency Coordination

The Corps of Engineers coordinated with the EPA and other Federal and state resource agencies in the planning of each individual CDF through the scoping and review of environmental impact assessments in accordance with the National Environmental Policy Act (NEPA), Fish & Wildlife Coordination Act, Clean Water Act, and other Federal statutes. The Corps coordinated with state resource agencies on the operation and monitoring of individual CDFs to assure compliance with state water quality standards.

Beyond the level of individual CDFs, the Corps and EPA have formed or participated in several interagency committees and working groups to address a variety of issues related to dredging, contaminated sediments and CDFs:

- IJC Dredging SubCommittee (1979-1989);
- Interagency CDF Work Group (1986-1988);
- ARCS Engineering & Technology Work Group (1988-1994);
- Confined Disposal Alternatives Work Group (1991-1995), and;
- Great Lakes Dredging Team (1996-present).

The Dredging SubCommittee was formed under the Water Quality Board of the International Joint Commission (IJC) as directed by Annex 7 of the Great Lakes Water Quality Agreement. This SubCommittee developed binational guidance on dredged material testing and evaluation, compiled a register of dredging projects (IJC 1982), and facilitated workshops on technical issues, including a forum on Great Lakes CDFs (IJC 1986b). The Dredging SubCommittee, which was later renamed the Sediment Subcommittee, became inactive in 1989.

The Interagency CDF Work Group was formed by EPA and the Corps in order to evaluate the environmental significance of contaminant releases through CDF dikes. This issue had been elevated primarily in regard to the release of polychlorinated biphenyls (PCBs) from existing and proposed in-water CDFs. This Work Group met eight times over three years and completed a number of actions, including: an inventory of data on existing CDFs (USEPA 1990); prioritization of CDFs for further study; mass balance modeling of contaminants at CDFs (Miller 1985; Chicago District 1986; Velleux and Endicott 1988; Myers, T.E., 1991), and;

biological monitoring of contaminant releases from CDFs (Rathbun et al 1988; Kreis et al 1992; Velleux et al 1993).

The USEPA Great Lakes National Program Office established interagency working groups in 1988 to implement the Assessment and Remediation of Contaminated Sediments (ARCS) Program authorized by Section 118(b)(3) of the Clean Water Act amendments of 1987 (USEPA 1994b). The ARCS Engineering Technology Work Group evaluated and compared alternatives for managing contaminated sediments, including confined disposal, treatment technologies and in-place capping. The Work Group prepared literature reviews of contaminated sediment remediation technologies (Averett et al 1989), planned and implemented a series of laboratory and pilot-scale demonstrations of technologies for treating sediment contaminants, and prepared technical guidance documents on contaminated sediment remediation alternatives (USEPA 1994a; Myers et al 1996; Palermo et al 1998).

EPA Region 5 initiated the Confined Disposal Alternatives Work Group in cooperation with the Corps to oversee the development of a technical guidance document on CDF design (Richardson et al 1995). This CDF design guidance document was developed to help the EPA and state resource agencies evaluate proposals for confined disposal of contaminated sediments originating from Superfund and other environmental cleanup projects in the Region. The manual borrowed extensively from guidance and experience developed at Great Lakes CDFs.

In response to the report and recommendations of the Interagency Working Group on the Dredging Process (MARAD 1994), the Corps and EPA initiated a regional dredging team for the Great Lakes in 1996. The Great Lakes Dredging Team (GLDT) is an active partnership of Federal and state agencies created to assure that dredging of U.S. harbors and channels in the Great Lakes and connecting channels is conducted in a timely, cost-effective and environmentally responsible manner. The Dredging Team has provided a forum for state and Federal agencies to discuss technical as well as policy issues related to dredging. Among the Team's priorities is the promotion of the beneficial use of dredged material as an alternative to confined disposal and a means to prolong the useful life of existing Great Lakes CDFs. The Dredging Team has worked in partnership with the Great Lakes Commission to develop white papers and pamphlets on Great Lakes dredging issues (GLDT 1999), dredged material decision making (GLDT 1998) and beneficial use (GLDT 2001).

The eleventh biennial report of the International Joint Commission (IJC 2002) contains a recommendation for the U.S. and Canadian governments to consider expanding the membership of the Great Lakes Dredging Team to include Canadian agencies as full members in order to provide a continuing forum for international coordination of Great Lakes dredging issues, consistent with Annex 7 of the Great Lakes Water Quality Agreement.

Public Outreach

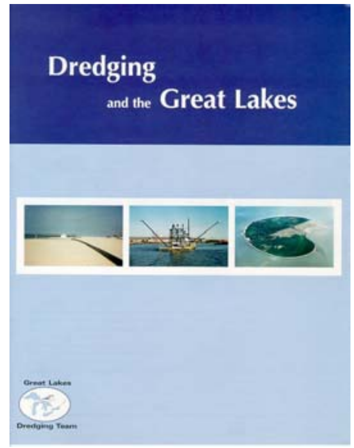
The Corps has sought public input as part of the planning for individual CDFs. This input has typically been solicited as part of the scoping process in which potential sites for CDFs are identified, and through the public review and comment on environmental assessments and impact statements. CDFs are especially sensitive to public perception, since the Corps cannot construct one without a non-Federal sponsor, typically a state or local governmental agency.

The Corps and EPA have conducted or participated in a number of workshops and conferences with other agencies, international organizations, academia and professional societies to facilitate public outreach on Great Lakes CDFs. Examples of these efforts include:

- A Forum to Review Confined Disposal Facilities for Dredged Materials in the Great Lakes, sponsored by the Dredging Subcommittee to the Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario, 1986;
- Workshop on Innovative Technologies for Contaminated Sediments, sponsored by USEPA, Cincinnati, OH, June 1990;
- Assessing and Treating Contaminated Sediments, a short course at the University of Wisconsin, Madison, WI, November 1991;
- Dredged Material Testing & Evaluation Seminar, sponsored by the Corps and EPA, Ann Arbor, MI, July 1993;
- Symposium on Dredging, Remediation, and Containment of Contaminated Sediments, sponsored by the American Society for Testing Materials, Montreal, Quebec, June 1994;
- A special session on CDFs at the 1995 International Joint Commission Biennial Meeting on Great Lakes Water Quality, Duluth, MN, September, 1995;
- A special session on CDFs at the Great Lakes Contaminated Sediment Strategy Workshop, sponsored by EPA, Chicago, IL, June 1996;
- CDF Workshop, sponsored by USEPA Region 5, Chicago, Illinois, August 1996;
- Dredged Material Testing & Evaluation Seminar, sponsored by the Corps and EPA, Buffalo, NY, October 1998;
- U.S.-Japan Experts Meeting on the Management of Bottom Sediments Containing Toxic Substances (biennial through 1997);
- International Conference on Great Lakes Research (annual), and;
- Corps of Engineers Water Quality Seminar (biennial);

The Corps has published a number of pamphlets and brochures with general information about dredging for a national audience. Regionally, the Corps, EPA, IJC, and Great Lakes Dredging Team have prepared and distributed brochures, pamphlets and white papers with general information about Great Lakes dredging and CDFs targeted at a non-technical audience:

- "Environmental Aspects of Dredging Activities on the Great Lakes" (IJC 1975);
- "Great Lakes Confined Disposal Facilities," a white paper prepared by the Corps Great Lakes & Ohio River Division and updated several times between 1989 and 1998 (Miller 1998);
- "A Citizen's Guide on Contaminated Sediments," prepared by the Lake Michigan Federation for the EPA (LMF 1995);
- "Dredging on the Great Lakes ," a foldout brochure prepared by the Corps Detroit District (Detroit District 1993);



- "Dredging and the Great Lakes," a brochure on Great Lakes dredging and disposal issues (GLDT 1999), and;
- "Beneficial Use of Dredged Material," a brochure on alternatives for beneficial use of dredged material (GLDT 2001).

Technical staff from the Corps and EPA have delivered numerous presentations on the management of contaminated sediments to civic and environmental groups, local governmental agencies, and groups working on Remedial Action Plans (RAPs). A number of Internet web sites have also been developed to disseminate information about dredging and CDFs to Great Lakes stakeholders. These include:

www.glc.org/dredging/	Great Lakes Dredging Team homepage
www.lrd.usace.army.mil/gl/dmm/	USACE Great Lakes – Dredged Material Management
www.epa.gov/glnpo/	USEPA Great Lakes Program homepage
www.epa.gov/glnpo/gltem/	Great Lakes Dredged Material Testing Manual
www.wes.usace.army.mil/dots/	Dredging Operations Technical Support

Environmental Performance

This evaluation has considered the environmental performance of Great Lakes CDFs in terms of compliance with environmental laws and regulations, significance of contaminant releases, impacts on fish and wildlife resources, in comparison with other alternatives, and from a cumulative perspective.

Environmental Compliance

Great Lakes CDFs have been planned, constructed and operated in accordance with applicable Federal and state laws and regulations. For each facility, a number of actions have been completed before construction began, including:

- an environmental assessment or impact statement that described the potential impacts of CDF construction and operation was prepared, with opportunity for public and agency review and comment, in accordance with the National Environmental Policy Act;
- the FWS prepared a coordination report which describes the fish and wildlife resources potentially impacted by the CDF;
- an evaluation of the dredged material and the potential impacts of CDF construction on water quality and aquatic resources was prepared in accordance with Section 404(b)(1) of the Clean Water Act;
- state resource agencies have certified that the proposed CDF is consistent with approved coastal zone management plans, and;
- state resource agencies have issued or waived a certification of compliance with state water quality standards, as required under Section 401 of the Clean Water Act.

The Corps has fully complied with these regulatory requirements for existing CDFs. The dredged material evaluation, as required by Section 404(b)(1) of the Clean Water Act, is used to determine which materials may be suitable for open water disposal and aquatic beneficial use. The Corps and EPA have developed a regional testing manual for dredged material decision making (USEPA/USACE 1998b). In addition, the Corps has sought to develop long-term strategies for managing dredged material on a project-specific basis in cooperation with local, state and Federal stakeholders. Examples of this are the Long Term Dredged Material Management Plan within the context of Maumee River Watershed Sediment Management Strategy (Buffalo District 2001) and Duluth-Superior Harbor Phase II Final Dredged Material Management Plan (Detroit District 1988).

Environmental compliance during dredging may include operating within time slots that are intended to minimize impacts on fish migration in some rivers and streams. These dredging windows vary from state to state, and may increase dredging costs. The Corps and EPA are working with the Great Lakes Dredging Team in an effort to develop a regional approach for dredging windows.

Environmental compliance during CDF disposal operations is linked to effluent quality. In most cases, suspended solids are used as the indicator for determining if the effluent is meeting state water quality standards. Over the past 40 years, the effluent or return water from CDF operations has exceeded conditions of the state water quality certification on only a handful of occasions (USEPA 1990). This record is especially impressive considering that these facilities are not a continuous, point discharge, but are operated for a few weeks or months during dredging operations that may occur every year or may be several years apart.

Significance of Contaminant Releases

A CDF, like any pollution control technology, will release some amount of the contaminants it handles. The amount released will vary, depending on the types and concentrations of contaminants in the dredged material, CDF design parameters, and operating procedures. Modeling and monitoring of Great Lakes CDFs has demonstrated that the most significant pathway for contaminant loss is through suspended solids discharged with CDF effluents during active disposal operations (Miller 1985; Chicago District 1986; Velleux and Endicott 1988; Myers 1991; Martin and McCutcheon 1992). This pathway is the most intensively monitored and consistently complies with state water quality standards. CDFs that accommodate hydraulically dredged material typically receive a slurry that contains about 10 percent suspended solids by weight and return an effluent with 100 mg/l or less suspended solids. This level of efficiency (> 99.9% removal) is comparable to wastewater treatment facilities. Much higher solids retention efficiencies are achieved when CDFs are filled with mechanically dredged material because the effluent volume discharged is negligible (USEPA 1990; USEPA 1994a; Myers et al 1996; Miller 1998).

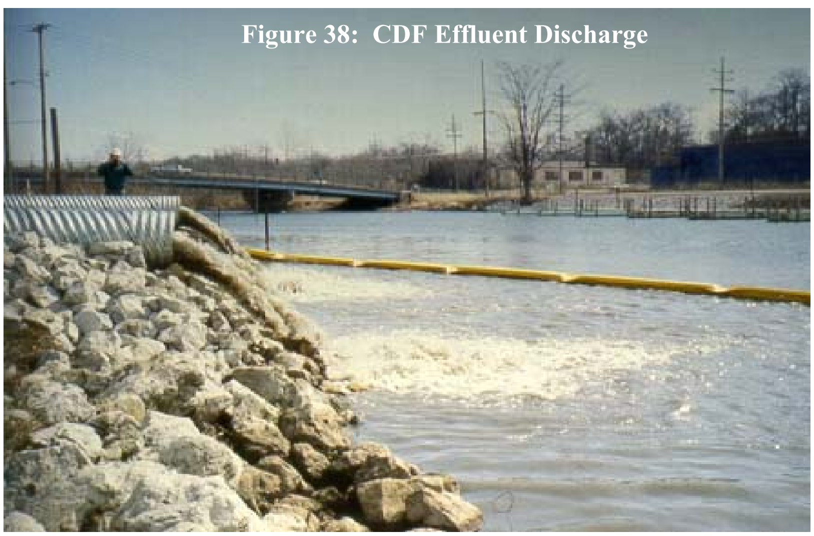


Figure 38: CDF Effluent Discharge

Of the other pathways, the long-term release of contaminants through in-water CDF dikes was the subject of collaborative studies by EPA and the Corps. These studies confirmed that the release of contaminants through CDF dikes during inactive periods was far less than the releases during disposal operations (Miller 1985; Chicago District 1986; Velleux and Endicott 1988;

Myers, T.E., 1991; Myers et al 1996). The releases through this pathway were found to be so small that they could be calculated using computer models, but couldn't be detected by conventional or biological monitoring techniques (Rathbun et al 1988; Kreis et al 1992; Velleux et al 1993; Dorkin et al 1998).

Laboratory and modeling studies on contaminant releases from CDF leachate to groundwater indicate that the strong physical/chemical bonding that holds contaminants to sediment particles precludes a significant loss by this pathway, especially when the dredged material remains permanently saturated as is the case at in-water CDFs (Environmental Laboratory 1997; Hill et al 1988; Myers and Brannon 1991; Myers et al 1992; Brannon et al 1994; Myers et al 1996). Some nutrients and low toxicity metals do have the capability to leach appreciably, but the significance of these losses is limited or has been addressed by CDF design features.

The loss of contaminants by airborne pathways may be significant at a very limited number of sites having dredged material with highly elevated levels of certain kinds of contaminants. This pathway is being intensively studied for the proposed Indiana Harbor CDF, which has volatile and semi-volatile contaminants at levels far greater than those found in most other Great Lakes sites (Semmler 1990; Price 1997; Chicago District 1998). In hindsight, the overall loss though this pathway at Great Lakes CDFs may have been minimized by the use of in-water CDFs, which limit volatilization by maintaining most of the dredged material in a permanently saturated condition.

The overall efficiency of Great Lakes CDFs in retaining contaminants reflects the efficiency of their suspended solids removal in effluents discharged during disposal operations, the dominant loss pathway (Myers et al 1996). Based on water quality monitoring and modeling studies, CDFs are retaining more than 99.9 percent of the contaminants they receive.

Impacts on and Fish Wildlife Resources

The impacts of CDFs on fish and wildlife resources of the Great Lakes can be considered from many different perspectives. From a purely physical standpoint, most in-water CDFs destroyed a footprint of lake bottom and overlying water column that may have been locally significant, but generally within a port or harbor area where the aquatic habitat had already been disturbed. In many cases, the benthic habitat lost was often of poor quality because the sediments contained the same contaminants as the dredged material within the navigation channel. The perimeter of the CDF dikes, with its stone substrate and cavities, created a reef-like habitat that is likely of greater value locally than the flat lake bottom that the CDF consumed. Most of the upland CDFs were constructed on properties that had little habitat value, including sites that had some previous disposal history.

Virtually all Great Lakes CDFs have become thickly vegetated and attractive to a variety of avian, terrestrial and aquatic wildlife. In a few cases, the wildlife usage has become so significant that efforts to protect them has limited use of the CDF for its original purpose. Extensive monitoring studies have shown that some, but not all contaminants in dredged material will bioaccumulate in fish and wildlife within CDFs. In general, uptake of metals is not a significant issue and vegetation has not shown much potential for bioaccumulation. PCBs and other hydrophobic organic contaminants will accumulate in the tissues of fish inside CDF ponds, and may be a significant source of contamination to animals that feed on them (Marquenie et al 1987; Dorkin et al 1988; Marquenie et al 1990; Stafford et al 1991).

Figure 39: Saginaw Bay CDF, MI

The Corps has coordinated closely with state and Federal resource agencies in the management of fish and wildlife resources within Great Lakes CDFs. Based on this coordination and regional experience, the most prudent management practices include:

- allow vegetation on CDFs to promote dewatering, control dust and reduce volatilization;
- control animal populations where necessary through the use of noisemakers and predator images, and;
- drain or sterilize CDF ponds where significant bioaccumulation of contaminants is observed or predicted.

Comparison to Alternatives

In order to gauge the environmental performance of Great Lakes CDFs and consider their overall impacts, it is useful to make comparisons to other alternatives, including no action (no dredging), advanced treatment technologies, and sediment remediation actions.

If the approximately 90 million cubic yards of contaminated sediments in Great Lakes CDFs had not been dredged, navigation channels would have continued to silt in unabated, and shallow depths would have created unsafe conditions for navigation by deep-draft vessels. For a time, larger ships would be able to plow through soft sediments, but eventually channels would be inaccessible to all but the smallest vessels. The consequences would have been dire for the local and regional economies of the Great Lakes and its communities. In addition, contaminated sediments would be more readily resuspended in the shallow channels, and transported downstream to the harbor and open lake by river currents, propeller wash and periodic high flows during heavy rains and spring floods. This additional loading of sediment contaminants to the Great Lakes would have aggravated water quality problems and water use impairments, including fish consumption limitations, at least locally if not basin-wide.

Figure 40: Sediment Loading From St. Joseph River, MI

Technologies for treating sediment contaminants have been thoroughly evaluated at Great Lakes sites (Buffalo District 1969, USEPA 1994b), and the EPA and Corps continue to evaluate promising, cost-effective technologies (Olin and Bowman 1996; Olin et al 1999). However, there is a misperception by some that treatment technologies could eliminate the need for confined disposal facilities. Extensive studies have shown that if all of the contaminated sediments that were placed into CDFs had been treated, without consideration for cost, there might still be about as many CDFs present as currently exist. Most of the dredged material inside Great Lakes CDFs have a variety of contaminants (i.e., nutrients, metals and organics), and no single treatment process is capable of addressing all types of contaminants. A combination of technologies might destroy some contaminants, while others (i.e., metals) are inert. Processes that can treat sediment contaminants are generally less efficient with materials having moderate and lower levels of contaminants and have very specific requirements for pre-treatment and pre-conditioning the dredged material. In most cases, a CDF would be necessary to facilitate the dewatering, water treatment, and storage requirements for the treatment of a large volume of contaminated sediments. In addition, CDFs may also be needed for the long-term management of treated residues that still contain levels of contaminants that preclude

Figure 41: Demonstration of Composting Technologies with Dredged Material at Milwaukee CDF, Milwaukee, WI

unrestricted disposal or beneficial use (USEPA 1994a).

The environmental impacts of the Great Lakes CDFs might also be viewed in comparison to sediment remediation activities conducted by Federal and state agencies through Superfund, Natural Resources Damage Recovery, enforcement actions under the Clean Water Act, Clean Air Act, RCRA and other authorities, and negotiated settlements with industries and municipalities outside of these programs. Since 1985, over forty contaminated sediment remediation actions have been conducted in the U.S. portion of the Great Lakes and tributaries (USEPA 1998, USEPA 2000). These actions have resulted in the remediation of about 3 million cubic yards of contaminated sediments. Dredging and confined disposal to landfills and on-site facilities was the selected remedial alternative for contaminated sediments at most of these sites. Technologies to decontaminate sediments were employed at only two sites, and in-situ remediation methods were used at another two.

Figure 42: Cleanup Dredging at Saginaw River, MI

Significant environmental improvements have resulted from the removal of contaminated sediments, regardless of the reason for the dredging. Sediment cleanup projects have removed about 3 million cubic yards of the most highly contaminated sediments, while navigation dredging has removed about 90 million cubic yards of moderately to highly contaminated sediments. A cursory analysis suggests that the total mass of some contaminants (in particular PCBs) removed by cleanup projects would be greater, despite the lesser volume of sediments. For other types of contaminants (metals and nutrients), the mass removed by navigation dredging is likely to be far greater.

Confined disposal is the most widely used method for managing contaminated sediments removed for navigation or cleanup purposes because it is the most dependable, cost-effective means available. The environmental benefits and costs of navigation dredging and confined disposal of contaminated sediments at Great Lakes harbors and channels are very comparable to the benefits and costs of sediment cleanup at these same waterways.

Cumulative Impacts

In order to address the cumulative effects of an action, we need to balance its positive and negative impacts, including direct and indirect impacts. This report represents the first attempt to develop a sense of the "net" impacts of the CDFs, as a whole, on the Great Lakes ecosystem. Because these facilities have impacted a variety of the resources in the ecosystem, it is not reasonable to expect a simple quantitative solution. The positive and negative impacts are not always comparable (i.e., apples and oranges), and the indirect impacts may be subject to various interpretations.

In order to provide some structure to this evaluation, the impacts of CDFs are summarized below in a tabular form with respect to physical, chemical and biological integrity of the Great Lakes.

Physical Integrity
2,600 acres of lake/river bottom habitat lost from CDF construction
890 acres of upland area converted to fill
180,000 lineal feet of aquatic stone dike habitat created
2,500 acres of lakefront or riverfront lands created with potential recreational, habitat or commercial uses
54 harbors and channels were maintained at safe depths for navigation
90 million cubic yards of sediments removed, which if transported to downstream river, harbor and lake could have adversely impacted water intakes, spawning grounds, bathing beaches and other physical resources

The construction of in-water CDFs has caused the loss of open water and benthic habitat. The habitat created by the stone dikes of the CDF provided valuable habitat for fish spawning, hiding, and feeding. The dikes and mounded dredged material within the CDF have provided nesting habitat for migratory waterfowl that has become very important in some locations (e.g., Saginaw Bay and Green Bay). The in-water CDFs have provided shoreline protection and fast land which have become integral parts of local waterfront and recreation development plans, although the ultimate use of the CDF lands has not yet been determined by local interests at many sites.

The construction of upland CDFs has caused the conversion of about 890 acres of upland property to landfill. In some cases, the property already had some disposal history or was a pit or borrow area. The construction of the CDF limited future commercial and residential use of the property, but enabled use as an open, green space or for recreational development.

The CDFs enabled the removal of about 90 million cubic yards of sediments from Great Lakes tributaries and harbors. This reduced the loading of sediments to the Lakes, which might foul water intakes, cover spawning and other nearshore habitat, and reduce water depths in private marinas and docks adjacent to the Federal channel. The CDFs also enabled the Corps to keep Federal channels at safe depths for navigation, which provided substantial economic benefits to local and regional economies.

Chemical Integrity
Short-term release of contaminants during disposal operations, in compliance with state water quality standards with a small mixing zone
Short-term release of volatile contaminants to air at a few CDFs during and after disposal operations
Long-term release of trace levels of contaminants to adjacent lake or river through permeable dikes
Long-term release of trace levels of contaminants to groundwater from upland CDFs
90 million cubic yards of sediments with an undetermined mass of toxic and persistent contaminants permanently removed from aquatic ecosystem
Total release of contaminants from CDFs is estimated to be less than 0.1 percent of the mass of contaminants disposed

The majority of contaminants that are released from Great Lakes CDFs are transported with water drained from these facilities during dredging operations, which represent a relatively brief period of time. These discharges are routinely monitored and been shown to consistently meet state water quality certification requirements. The mass of contaminants released at other times may be calculated, but is not detectable with conventional or advanced monitoring techniques. The efficiency of CDFs in retaining sediment contaminants is on the order of 99.9 percent, although this is considered a highly conservative estimate.

Perhaps the most significant impact of the CDFs is the removal of 90 million cubic yards of contaminated sediments from Great Lakes tributaries and harbors, which includes over 65 million cubic yards from designated Areas of Concern. The total mass of contaminants removed and placed into CDFs has not been determined, but appears to be of a level that is comparable to that removed by all sediment cleanup projects on the Great Lakes to date. Although authorized to support navigation dredging needs, the Great Lakes CDFs have probably done as much to restore beneficial uses at Great Lakes Areas of Concern as any other action.

Biological Integrity
Elevated levels of bioaccumulative contaminants in fish and wildlife inhabiting the site, until CDF is closed
Potential for increased bioaccumulation of contaminants in animals visiting or feeding on wildlife inside the CDF
Increased productivity and diversity of biological communities in urban lakeshore areas.

The impacts of CDFs on biological integrity, particularly in-water CDFs, pose the most challenging value judgement for resource managers. During the time CDFs are being filled, they provide habitat opportunities that may be lacking in the surrounding urban environment. However, the habitat created inside the CDF is transient, and will change as the CDF becomes filled. In addition, this is a contaminated habitat, and some fish and wildlife that inhabit or visit the site may uptake some of these contaminants.

The Corps has invested significant effort to research the potential for plant and animal uptake of contaminants at CDFs, and the lessons learned are made available to the resource managers from the Corps, Fish & Wildlife Service, and states who coordinate site-specific resource management plans. The biological resource challenges at CDFs highlight the importance of coastal wetland habitat to the region, and the need to restore critical habitat throughout the basin.

Future Directions and Needs for CDFs

In 1992, a study by the U.S. General Accounting Office (GAO) concluded that the need for future CDFs to contain contaminated dredged materials will grow. Although some factors may have changed since that report was released, its conclusion is still valid. There will be a continuing need for CDFs to manage contaminated dredged material from Great Lakes harbors and channels for the following reasons (GAO 1992):

- soil erosion and the other sources of sediments are largely unabated, and are exacerbated by increased development and urban sprawl, especially near the Lakes;
- while Federal and state programs have significantly reduced the loadings of pollution to the Great Lakes, not all sources have not been controlled or eliminated;
- viable alternatives for treatment of sediment contaminants are in the early stages of development, have limited ability to address low levels of diverse contaminants, and are far more costly than confined disposal, and;
- new sediment guidelines and criteria are expected to be more stringent than existing ones, resulting in lesser amounts of material being designated as suitable for disposal in the open waters.

While the above factors would seem to project a marked increase in the demand for new CDFs, one other factor that has moderated this effect is the non-Federal cost-sharing requirement for all new CDFs authorized by Section 201 of the Water Resources Development Act of 1996. Many Great Lakes communities that have Federal navigation projects do not appear to have capability to cost share a new CDF. In addition, the scoping and selection of potential sites for a new CDF can become quite contentious and a political liability that local elected officials seek to avoid where possible. Consequently, there is an increasing demand to extend the useful life of existing

CDFs rather than construct new facilities.

Activities that are being pursued to reduce the need for new CDFs and prolong the useful life of existing facilities are summarized in the following sections, followed by a discussion of emerging issues related to CDFs.

Source Control

The levels of contamination in bottom sediments in Great Lakes tributaries have seen considerable reductions over the past 40 years due to advances in wastewater treatment, elimination of combined sewers and remediation of contaminated sites, both upland and aquatic. The massive investment in wastewater technology and pollution prevention by industries and municipalities has dramatically reduced the loadings of nutrients, metals, and organic matter to bottom sediments. For example, figure 35 shows a vertical profile of PCBs in bottom sediments at a location in the Chicago River not dredged in many years that documents the effects of the pollution prevention (Chicago District 1983). The separation or mitigation of combined sewers has shown a rapid response in sediment contamination levels. Continued improvements in point source controls are expected from the more stringent water quality standards developed in response to the Great Lakes Initiative (GLI). These changes should further reduce the levels of toxic and persistent contaminants that are adsorbed onto bottom sediments.

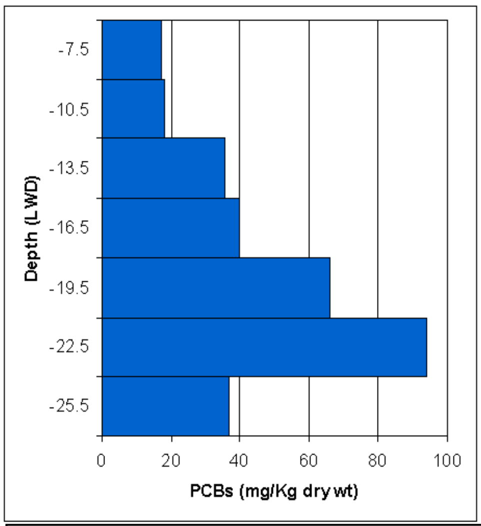


Figure 43: Profile of PCB Concentrations with Depth in Chicago River, Chicago, IL

The impacts of point source controls have been so dramatic that in many tributaries to the Great Lakes, the contamination in older sediment deposits is the main limitation to water quality and aquatic habitat restoration (IJC 1997). Remedial Action Plans (RAPs) and Superfund are targeting many of these contaminated sediment deposits. The Great Lakes Legacy Act should provide funding for a significant number of sediment remediation actions at Great Lakes Areas of Concern in the immediate future.

The implementation of point source controls and remediation of contaminated sediment hot spots continue to address the major sources of external and in-place sediment contamination in the Great Lakes. However, these actions will not eliminate the need for dredging, nor for confined disposal. The sources of sediments (soil erosion from agricultural lands, forested areas, urban runoff, and stream bank erosion) are largely unabated, as are many of the non-point sources of pollution (agricultural fertilizers and pesticides, urban runoff, and atmospheric deposition). Soil conservation and non-point source controls are the next crucial steps in the long-term management of Great Lakes bottom sediments.

Existing Department of Agriculture programs for promoting soil conservation can significantly reduce the loadings of sediments into Great Lakes tributaries. Under Congressional authority (Section 516(e) of WRDA 1996), the Corps is working with state and local governments in developing computer models of Great Lakes tributaries in order to evaluate the effects of soil conservation and nonpoint pollution prevention measures on sediment loadings to Federal navigation channels. A study conducted by the Corps and Natural Resources Conservation Service demonstrated techniques to promote no till farming and other soil conservation measures in the Maumee River Basin and showed how these practices could significantly reduce maintenance dredging at Toledo Harbor (NRCS 1998). An economic study conducted by the Ohio State University demonstrated that the costs of implementing soil conservation may actually pay for itself in terms of the reduced costs from dredging and confined disposal (Sohngen 2001).


Figure 44: Buffer Strip

The development of watershed plans and total maximum daily loads (TMDLs) by state resource agencies holds the potential for long-lasting reductions to sediment contaminants in Great Lakes tributaries. However, the process of TMDL development and implementation through voluntary and regulatory controls, as well as the effects of soil conservation and non-point pollution prevention programs on future dredging and CDF needs will not be immediate.

CDF Modifications

Raising the elevation of dikes is often the least costly alternative to increase the capacity of existing CDFs and prolong their useful life. This option also has the advantage of limited environmental controversy, since no new "footprint" is created or impacted. A variation on this approach is to construct low berms interior to perimeter dikes using dredged material from within the CDF. This idea has more applicability to facilities with a larger surface area than to smaller facilities. In general, dike raising and interior berms can provide additional capacity at a far lower unit cost (per cubic yard) than new CDF construction. However, these options may not be consistent with the planned use of the CDF by the local sponsors, and progressive dike raising can not be continued indefinitely.

Another alternative for increasing the capacity of existing CDFs is to enhance dredged material consolidation through more active dewatering processes. The compression and consolidation of dredged material inside a CDF from self-weight contributes 25 to 30 percent additional capacity over a 10 to 15 year filling cycle (USEPA 1996). The Corps has evaluated the feasibility of dewatering technologies including wick drains and subsurface drains to decrease material consolidation time requirements (Long and Grana 1978; USACE 1987), but few have been applied at Great Lakes CDFs .

Reclaiming Usable Material from CDFs

The Corps and EPA have worked with the Great Lakes Dredging Team to promote beneficial use of dredged material as an alternative to new CDFs, where appropriate. About 20 percent of the sediments dredged from Great Lakes harbors and channels are used for beneficial purposes, including beach and littoral nourishment, construction fill, landscaping, and landfill cover (Miller 1998).

As contamination levels in sediments have declined, some of the material being placed into CDFs may now be suitable for beneficial use. Several port authorities have taken the initiative in identifying potential uses for dredged material as an alternative to placement in CDFs that have limited remaining capacity. In addition, the Corps and EPA have worked in collaboration with states and ports to evaluate ways to "mine" usable materials from previously disposed dredged material in CDFs (Adams et al 1997; Cadet et al 1997; Miller et al 1997). The EPA and Corps have conducted laboratory evaluations and field demonstrations of equipment to process contaminated dredged material so that clean, usable materials might be reclaimed (Olin and Bowman 1996; Olin et al 1999). Over 1,000,000 cubic yards of clean sand has already been removed from the Erie Pier CDF (figure 45) after being separated from the fine-grained silts and clays by a soil washing process.

Figure 45: Sand Mining at Erie Pier CDF, Duluth, MN

The ability to reclaim usable materials from CDFs is case specific. The physical and chemical character of the dredged material, costs of processing and transportation, and local market for the "product" material need to be evaluated to determine feasibility. The report of a task group formed by the Great Lakes Commission to evaluate the obstacles to beneficial use of dredged material (GLC 2001) included a number of specific recommendations to state and Federal agencies to address regulatory gaps and inconsistencies, limiting authorities, funding priorities, and public outreach. The Great Lakes Dredging Team is acting on several of these recommendations, including a regional testing and evaluation manual for upland beneficial use.

Emerging Issues

At many of the Great Lakes Areas of Concern, existing CDFs represent the least costly alternative for the management of materials to be dredged from areas outside the authorized navigation channels as part of proposed sediment cleanup projects. However, existing CDFs were constructed with Federal funds appropriated for the operation and maintenance of navigation projects. Placement of cleanup dredgings inside existing CDFs will reduce the capacity remaining for navigation dredging, and may force state and local agencies who are advocates for navigation to cost-share a new CDF several years earlier. In addition, the levels of contamination present in dredged material from cleanup projects may be significantly higher than those already in the CDF.

Multi-purpose CDFs are facilities that are planned and designed to accommodate contaminated sediments dredged for navigation and environmental restoration purposes. The Indiana Harbor CDF (under construction) is an example of a multi-purpose CDF where the bulk of capacity will be reserved for navigation dredging, but a significant portion made available for sediments dredged from cleanup projects resulting from one or more settlements between the EPA, State of Indiana and local industries or municipalities. In contrast, the CDF proposed for the Ashtabula River, Ohio will have only a small portion of its capacity for navigation dredging, with the bulk reserved for environmental dredging performed under the authority of Section 312 of WRDA 1990, as amended.

Summary and Conclusions

Contaminated bottom sediments are present in many of the Federal navigation projects in the Great Lakes and at every one of the Areas of Concern designated under the Great Lakes Water Quality Agreement. Restrictions on dredging activities is one of the beneficial use impairments identified in the Agreement. The Corps of Engineers (Corps) dredges about 4 million cubic yards of sediments annually from Great Lakes projects. About half of these dredged materials are contaminated to a degree that restricts their disposal.

Through Section 123, PL 91- 611, as well as project-specific authorities, the Corps has constructed and/or operated 45 confined disposal facilities, or CDFs to manage contaminated sediments dredged from Great Lakes harbors and channels. Over 90 million cubic yards of contaminated sediments have been removed from Federal channels and placed in these CDFs during the past forty years. This report presents a summary of information about the Great Lakes CDFs and an analysis of their performance and overall impacts on the Great Lakes environment.

Individual CDFs have been planned, sited, and designed in cooperation with non-Federal sponsors and with full opportunity for public and agency review and input. These facilities have been constructed and operated in accordance with applicable Federal and state environmental regulations. The size, shape, and design features of individual CDFs have been selected to fit dredging needs of the harbor(s) and channel(s) served, the physical and chemical characteristics of the dredged material, local conditions and resources, and the interests of the non-Federal sponsor.

Extensive research on the management of contaminated dredged material has been conducted under programs authorized by Section 123 of PL 91-611, subsequent Corps research programs, site-specific investigations, as well as studies and demonstrations conducted in cooperation with the U.S. Environmental Protection Agency (EPA). A fundamental finding of these investigations was that the contaminants associated with dredged material bind tightly to the sediment particles and do not readily dissociate from them. This property has greatly simplified the management of contaminated dredged material.

CDFs are designed to permanently contain the sediment particles within a diked area, facilitate the removal of excess water, and provide the necessary measures to protect the environment. Over half of the CDFs were constructed in the water with stone dikes that were intended to be permeable and allow the movement of excess water, while retaining the sediment particles inside. Upland CDFs were constructed of earthen dikes, in most cases using local materials. All CDF designs are unique, although many dike designs and features for water removal and environmental protection adapted from conventional wastewater and landfill technologies are comparable.

The Corps and EPA have coordinated extensively on the siting, design and performance of Great Lakes CDFs at site-specific and regional levels. This coordination has involved other Federal agencies, states, the International Joint Commission, and the full range of stakeholders in the Great Lakes region.

The Corps has monitored CDFs for purposes including: to ensure that dike construction and disposal operations were accomplished in accordance with project designs and contract specifications; to ensure that the effluent discharged from the CDF is in compliance with state water quality standards; to track fish and wildlife use of the site, and; to address site-specific or general concerns about CDF performance or impacts. When monitoring has shown a problem with CDF performance, the Corps has rapidly implemented changes to design or operational procedures after consulting with the state and local sponsor.

Overall, the performance of CDFs and their impacts on the Great Lakes ecosystem may be summarized:

- construction of in-water CDFs has caused the loss of about 2,600 acres of open water and benthic habitat;
- construction of upland CDFs has converted about 890 acres to landfill, and limited its future use;
- CDFs have created about 180,000 lineal feet of stone reef habitat for fisheries and nesting habitat for migratory waterfowl along urban shorelines that have lost much of their wildlife habitat;
- CDFs have created additional shoreline and about 2,500 acres of fast land suitable for recreation and some other uses;
- in general, CDFs retain greater than 99.9 percent of the contaminants they receive with dredged material;
- effluent discharges from CDF have consistently met standards as provided by state water quality certification;
- long-term releases of contaminants from CDFs may be calculated using computer models, but can not be detected with conventional or advanced monitoring techniques, and are not considered ecologically significant;
- fish and wildlife living within the CDF will uptake some contaminants from the dredged material, and there is a potential for increased uptake of contaminants in wildlife that visit the site, and;
- CDFs have enabled the removal of 90 million cubic yards of contaminated sediments from tributaries and harbors, significantly decreasing the mass of contaminated sediments at several Areas of Concern, and reducing the loading of sediments and contaminants to the Great Lakes.

While pollution prevention and control measures have achieved significant reductions in the loadings of contaminants to Great Lakes waters, the reservoir of historic deposits of contaminated sediments as well as the continued inflow of contaminants from non-point sources will prolong the need for CDFs into the near future.

Less than half of the Great Lakes CDFs are still operating, and most of these have less than five years capacity remaining. In contrast to the existing CDFs which were all constructed at Federal expense, future CDFs, constructed under the authority of Section 201 of WRDA 1990, will require non-Federal sponsors to provide 25-35 percent of construction costs, in addition to lands, easements and rights-of-way. Measures to prolong the use of existing CDFs are being evaluated by the Corps, EPA and several CDF sponsors. Preventative measures, including soil conservation and non-point pollution prevention, offer the most long-lasting return. Another promising option is the use of dredged material for beneficial purposes like construction fill, landfill cover, and landscaping.

On balance, the benefits to the Great Lakes ecosystem of the CDF program far outweigh its costs. The habitat lost from CDF construction appears to be substantially offset by the habitat gained, although the habitat types were different and not readily comparable. The benefits to local and regional economies from continued channel maintenance are highly significant, and the new lands created by in-water CDFs hold considerable potential for recreation and other uses. The efficiency of CDFs in retaining contaminants is comparable to other pollution control technologies, and discharges have routinely met state water quality certification requirements. Finally, the CDFs and navigation maintenance dredging have facilitated the removal of 90 million cubic yards of contaminated sediments from Great Lakes tributaries and harbors, which represents a significant contribution to the overall implementation of Remedial Action Plans and Lakewide Management Plans.

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