UPPER MISSISSIPPI RIVER SYSTEM
ENVIRONMENTAL DESIGN HANDBOOK

CHAPTER 4

DREDGING

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DREDGING

4.1 Resource Problem

Large river ecosystems support a variety of habitats, of which, backwaters area an integral component. Backwater habitats support many popular sport fishes, waterfowl, shorebirds, and wading birds. Backwaters are also quiet areas off the main channel where people and animals alike can seek refuge.

Because of the widespread loss of backwater and secondary channel depth and depth diversity due to the high rates of sediment, fish habitat quality has decreased, especially in the winter when such areas provide refuge from harsh conditions in main channel areas.

Many Upper Mississippi River System (UMRS) backwaters have been degraded by excessive amounts of sediment emanating from the basin, tributaries, and mainstem sources. This degradation is in the form of loss of depth, poor sediment quality, poor water quality, and sediment resuspension that blocks light required by aquatic plants.

Backwater sedimentation and loss is especially pronounced in lower pools of the Illinois River where sediment from the row crop dominated landscape continues to be excessive. Streambank erosion throughout the basin is another important source of sediment that fills the backwaters.

One solution to this degradation problem is backwater dredging. Backwater dredging typically consists of dredging channels with fingers (dredged channels that extend out away from the main dredge cut). The depth and size (length and width) of the dredge cut depends on several site specific factors.

The sediment dredged to create depth diversity in the backwaters can be used to enhance aquatic areas with islands or terrestrial areas with increase topographic diversity, which promotes the growth of mast trees.

4.2 Dredging for Environmental Restoration

4.2.1 Design Considerations

4.2.1.1 Sedimentation Rates. Sedimentation rates are used to calculate the actual depth of dredging required for the project. Biologists usually provide a depth of water needed to achieve a suitable habitat, either for aquatic vegetation or fish habitat. The depth of dredging is found by taking this provided depth and adding on the expected sediment that will settle in the dredge cut over the life of the project.

Historically, determination of sedimentation rates has been base on sound engineering judgment and the best data available at the time. One such source for sedimentation rates data is the Upper Mississippi River Cumulative Effects Study. In addition, some sampling has been done without recording such information as the climatic conditions when the sample was collected and the coordinates for the sample location. This data helps to look at general trends but cannot be replicated to accurately monitor sedimentation rates over time.

Sedimentation rate estimates will need to be analyzed on a site by site basis using the most recent data available, ideally from the project site or at least from sites with similar features. Table 4.1 is a listing of calculated sedimentation rates for various EMP projects along the Mississippi and Illinois Rivers.

Table 4.1. Sedimentation Rates for Various EMP Projects

Site	River System	River Mile	Years from which Average Rate was Determined	Average Sedimentation Rate (DPR) [1] (in/yr)	Date Project Completed
Andalusia	Mississippi	463.0 – 462.0	1936 – 1987	0.50	Sep1994
Bertom McCartney Lakes	Mississippi	602.8 – 599.0	1938 – 1988	0.39	Oct 1991
Big Timber	Mississippi	445.0 – 443.0	1938 – 1988	0.51	Oct 1994
Brown's Lake	Mississippi	546.0 – 544.0	1930 – 1987	0.45	Sep 1990
Cottonwood Island	Mississippi	331.0 – 328.5	1938 – 1994	0.46	May 2000
Long Island (Gardner)	Mississippi	340.2 – 332.5	N/A	0.21	Sep 2004
Peoria Lake	Illinois	181.0 – 162.0	N/A	1.5	Oct 1996
Pool 11 Islands	Mississippi	592.0 – 583.0	1938 – 1950 1951 – 1995	0.61 0.13	Jul 2005
Potters Marsh	Mississippi	526.0 – 522.5	1938 – 1990	0.25	Dec1995

[1] DPR stands for Definite Project Report and is a planning document for EMP projects

When calculating sedimentation rates for a project, it is important to account for flood events. Flood events drastically increase the sediment delivery of any river and therefore can skew a sedimentation rate that has been calculated for any time frame. Pre-project monitoring, for example, a sediment gage or cross-sectional surveys also aid in the development of an accurate sedimentation rate.

Furthermore, a newly dredged channel in the backwater can act like a sediment trap until it reaches an undeterminable equilibrium. Therefore, in post-project monitoring, the sedimentation rates calculated may be higher than previously estimated. Once the channel and sediment load reaches equilibrium, the sedimentation rate should decrease.

4.2.1.2 Dredge Method. There are two basic categories of dredges, mechanical and hydraulic. Both types of dredges are designed to maximize the quantity of material dredged. While selecting dredge equipment for a project, it should be noted that most dredges are not well suited to efficiently work within small tolerances such as ± 0.1 feet in elevation or in maintaining very specific side slopes.

4.2.1.2.1 Mechanical Dredging. Three types of mechanical dredges include backhoe, clamshell, and dragline. Figure 4.1 shows a schematic of a mechanical dredge and a photograph of a clamshell bucket.

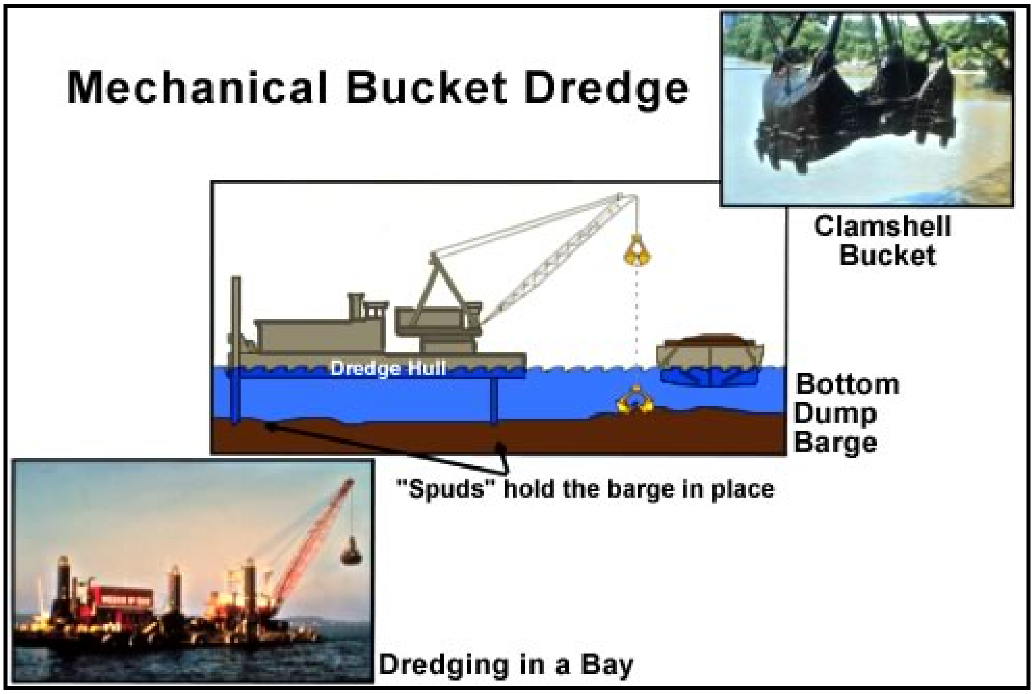

Figure 4.1. Clamshell Dredge

Mechanical dredges are capable of dredging hard packed material and also have the ability to remove debris. For the most part, these types of dredges can work in relatively tight areas and are efficient for side casting material from dredge cut to placement site. Photograph 4.1 shows a clamshell dredge side casting material during the construction of Mud Lake, part of the Pool 11 Islands EMP project. Mechanical dredges are also efficient for transporting material over long haul distances (greater than two miles) and have relatively low mobilization costs. As compared with hydraulic dredging, mechanical dredging does not have the issue of managing return water.

Mechanical dredging generally has lower production rates when compared to hydraulic dredging. It is also difficult to retain fine/loose material in conventional buckets. Mechanical dredging is also inefficient for transporting material over short haul distances (less than two miles). Furthermore, it is not recommended that mechanical dredging by itself be used for contaminated material.

Photograph 4.1. Clamshell Dredge Side Casting Material at Mud Lake, IA

Floating Excavator. A floating excavator as seen in photograph 4.2 is a normal hydraulic excavator with a different undercarriage that gives the excavator a very low ground pressure. This very low ground pressure allows the excavator to work in marsh/wetland type environments where a normal excavator or typical dredge cannot reach.

Photograph 4.2. Floating Excavator

As stated previously, floating excavators are ideal for those hard to reach places and are highly mobile. However, they are not as efficient as the other types of machines discussed earlier in this chapter.

4.2.1.2.2 Hydraulic Dredging. Four types of hydraulic dredges include cutterhead pipeline, hopper, suction, and dustpan. For ecosystem dredging, the hopper, suction and dustpan dredges are not viable options due to their size and difficulty in maneuvering. Therefore, this section will focus on the cutterhead pipeline dredge. Figure 4.2 shows a schematic of a cutterhead pipeline dredge and a photograph of the cutterhead.

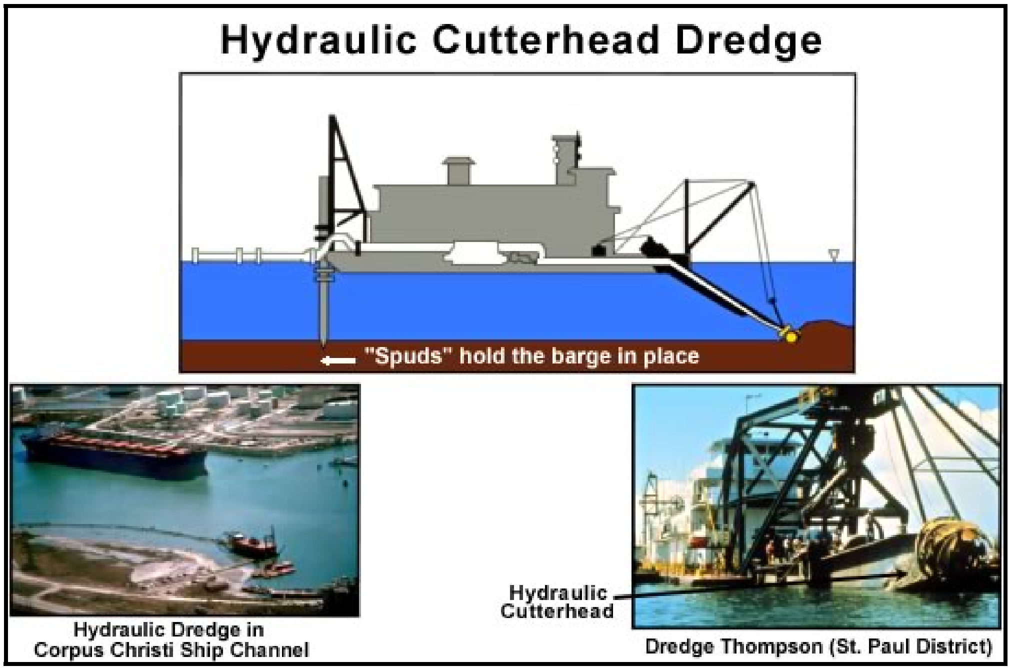

Figure 4.2. Hydraulic Cutterhead Pipeline Dredge

Cutterhead pipeline dredges are sized based on the discharge pipe inside diameter and are typically available from 8-inch to 20-inch with larger applications reaching 36-inches or more. Table 4.2 shows the various EMP projects that have used hydraulic dredging in their construction.

Table 4.2. Hydraulic Dredge Sizes at Various EMP Projects

Project	River System	River Mile	Dredge Quantity (CY)	Size of Cutterhead (in)
Bertom McCartney Lakes	Mississippi	602.8 – 599.0	400,000	16
Long Island (Gardner) Division	Mississippi	340.2 – 332.5	83,000	8
Big Timber	Mississippi	445.0 – 443.0	143,000	8 – 10
Brown’s Lake	Mississippi	546.0 – 544.0	370,000	10 – 14

Cutterhead pipeline dredges are capable of excavating most types of material and can even dredge some rock without blasting. Unlike mechanical dredging, hydraulic dredging allows for direct placement of material into a placement site. Hydraulic dredging also allows for the ability to pump almost continuously which results in higher production rates than mechanical dredging. This method is also very cost effective if within economical pumping distances of placement site (less than 2 miles).

Cutterhead pipeline dredges, however, have a difficulty with coarse sand in high currents. In general, these types of dredges are sensitive to strong currents. Therefore, provisions should be made in the plans and specifications of any project to allow for down time for dredging in case of flood events. Another provision to put in the specifications is the passage of other motor vessels as the pipelines and/or wires associated with hydraulic dredging may obstruct navigation. Other disadvantages of this type of hydraulic dredging are that cohesive material and debris can block cutterhead which can in turn reduce efficiency. The dredging slurry is 80 to 90% water (the other 10 to 20% is sediment) which can cause difficulties in obtaining and administering a water quality permit. Since this water has to be returned back to the source, return water management must be incorporated into any design. Lastly, hydraulic dredging also has high mobilization costs when compared to mechanical dredging.

High Solids Dredging. High solids dredging, also known as Dry DREdge™, is a very useful technique. This technique utilizes mechanical dredging to produce a slurry that is 80% solids, thus resulting in a relatively clean effluent. This technique can be used to fill geo-tubes, which can in turn be used to build form the outer ring of an island. High solids dredging is one of the only techniques suitable for building islands out of a highly silty material. This technique is also used when contaminants are present in the sediment.

4.2.1.3 Production Rates. Production rates are the amount of material, usually measured in cubic yards (CY), a dredge can remove per unit of time, usually expressed per hour. Production rates are useful to help determine the construction schedule of a project. Production rate estimates should be one of the basic components in determining the length of a construction contract. When estimating the production rate, research should be done so that the production rate accurately depicts what will occur in the field.

4.2.1.4 Dredge Cut Dimensions. Dredge cuts for environmental restoration are very site specific. There are several factors that should be taken into consideration when designing a channel. Some factors are biological concerns, logistics of dredge equipment mobilization, and hydrology and hydraulics.

Determination of the desired dredging depth includes assessment of typical water level elevations, present low-flow winter regulations, desired maintained water depth and projected sedimentation over the project life. Typically, the maintained water depth is determined from the anticipated maximum ice depth and the desired maintained water depth below that ice. A rule of thumb for the upper Midwest is to allow for a maximum ice depth of two feet and a desired water depth of two to four feet below the ice. This translates to a maintained water depth in the four to six foot range with six feet being a commonly accepted depth. It should be noted however that flow conditions can alter the formation of ice, for example, higher flows does not allow the water to freeze; therefore, a hydraulic analysis should be done to determine what flows will be present and if that flow will allow ice to form.

Caution should be used to avoid dredging to elevations greater than those required to establish the maintained water depth as this could result in the loss of littoral habitat.

Width of the dredge cut will be determined by existing channel conditions, project requirements, placement site capacity, and project funding. Typically, dredge cuts are designed based on a bottom width. Table 4.3 lists various dredge cut dimensions for various EMP projects.

In-depth geotechnical analysis needs to be performed to determine the type of material that is being dredged so that the proper side slopes can be designed. In some cases, the channel has been dredged with vertical side slopes, and the material is allowed to slough to its natural angle of repose. This helps to minimize the project cost by reducing actual dredging time and quantities.

Table 4.3. Dredge Cut Dimensions for Various EMP Projects

Project	River System	River Mile	Width (ft)	Depth (ft)	Slope (H:V)
Andalusia	Mississippi	463.0 – 462.0	30-60	7	2:1
Cottonwood	Mississippi	331.0 – 328.5	50	7	Vertical
Long Island (Gardner) Division	Mississippi	340.2 – 332.5	50	7.5	Vertical
Potter's Marsh	Mississippi	526.0 – 522.5	50	8-10	2:1
Big Timber	Mississippi	445.0 – 443.0	30-50	4-9	2:1
Brown's Lake	Mississippi	546.0 – 544.0	30	9	2:1
Pool 11 Islands	Mississippi	592.0 – 583.0	33	8	3:1

4.2.1.5 Deep Holes. Deep holes are dredged "pockets" of deeper water that provide habitat for fish. Deep holes are typically dredged to a depth of 20 feet below the flat pool elevation and vary greatly in size. Either a mechanical or hydraulic dredge can be used to construct a deep hole, depending on the size. For smaller deep holes, a mechanical dredge should be used as it will be difficult to maneuver the cutterhead on a hydraulic dredge. Special attention should be paid to the sedimentation rates in the area of the deep hole as these cuts have more of a tendency to act like sediment traps.

4.2.2 Monitoring the Dredge Cuts. Monitoring of the dredge cuts should start as soon as they are constructed. Monitoring this early will aid in the determination of the sedimentation rates for the new dredge cut. To maintain consistency, survey monumentation should be coordinated with any individual who could monitor the project. These individuals could include surveyors, hydrologists, fish biologists, etc. The survey monuments should be positioned such that they will be easily used and not deteriorate through the life of the project.

4.2.3 Common Problems Associated with Dredging. Most difficulties in dredging do not shut the operation down for long periods of time. The most common problem associated with hydraulic dredging is damaging the cutterhead. Another problem is access into backwater sites. Most problems, except for equipment failures, can be avoided by obtaining as much information about the bathymetry and hydraulics of the site and providing that in the plans and specifications that the contractor will utilize to construct the project.

4.2.4 Lessons Learned

- Document assumptions made about production rates estimated during the planning and plans and specifications phase of a project. This documentation will help evaluate a contractor's proposal to construct the project. Also, document the contractor's actual production rate to add to record for future reference.
- Always keep in mind the water quality restrictions on return water. This can drastically alter the method of sediment removal.

- Make sure the contractor is aware of the flooding frequency of the area.
- Layout the schedule of the project such that the likelihood of the contractor mobilizing twice is minimal.
- Dredging is very site specific – each reach of any river has its own characteristics that need to be studied and monitored to achieve a lasting design.
- Estimating the sedimentation rate during planning and plans and specifications phases is vital to the success of the project. If the sedimentation rate is significantly inaccurate, the project may have to be dredged midway through the life of the project at the sponsor's expense.
- Inlet channels that are directly perpendicular to the flow path of the main channel typically silt in faster than an inlet channel that is not.

4.2.5 Case Studies

Bertom and McCartney Lakes (UMRS River Mile 602.8 to 599.0). This project incorporated a partial closing structure, fish and mussel rock habitat, and dredging to meet project objectives. Dredging features included deep water habitat, an increase in dissolved oxygen (DO), and a minimum water depth of six feet over the project life with a 10 foot minimum depth adjacent to the railroad tracks. Dredged material was used to build a kidney shaped island with a perched wetland. The island has significant waterfowl populations.

Brown's Lake (UMRS River Mile 546.0 to 544.0). This project included construction of deflection levee, a water control structure, improved inlet side channel, side channel excavation, lake dredging, terrestrial dredged material placement, and planting of mast trees.

The dredging components included the inlet channel improvement to reorient the mouth downstream to minimize debris and bedload sediment from reaching the new water control structure.

In addition, lake dredging was performed to maintain a minimum water depth of five feet below flat pool elevation. Deep holes that were 20 feet in depth were dredged for diversity. The placement site was replanted with mast trees.

Peoria Lake Enhancement (Illinois Waterway River Mile 181.0 to 162.0). This project included construction of a forested wetland management area, a barrier island, and restoration of a flowing side channel.

The barrier island was constructed using mechanically dredged soft sediments with gentle placement on the adjacent site using multiple passes for island stability. A minimum seven cubic yard clamshell bucket was included in the dredging scope. This requirement slightly increase the mobilization costs (the contractor was from Louisiana) but it drastically reduced the per unit cost of dredging the material. A clamshell bucket was selected because it can excavate large soil masses without significantly disturbing the internal strength of the soil and it produces the least turbidity compared to dragline or backhoe buckets. This type of dredging was selected due to its cost effectiveness, maximization of soft sediment placed on the island that promotes re-establishment of vegetation for habitat enhancement.

4.2.6 References

U.S. Army Corps of Engineers, *EM 1110-2-5025, Dredging and Dredged Material Disposal* March 25, 1983.

U.S. Army Corps of Engineers, *EM 1110-2-5026, Dredged Material Beneficial Uses* June 30, 1987.

U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, *EPA-823-B-98-004, Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual, Inlands Testing Manual*, February 1998.

U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, *EPA842-B-92-008*, *Evaluating Environmental Effects of Dredged Material Management Alternatives – A Technical Framework*, November 1992.

U.S. Army Corps of Engineers, *Dredging Operations Technical Support Program*. http://el.erdc.usace.army.mil/dots/dots.html

U.S. Army Corps of Engineers, *Dredging Operations and Environmental Research*. http://el.erdc.usace.army.mil/dots/doer/doer.html

4.3 Dredged Material Placement and Uses in Environmental Restoration

4.3.1 Design Considerations. Placement sites for dredged material may be located upland out of the floodway, along the bankline, or in water. They may be Confined Disposal Facilities (CDF) incorporating perimeter berms to confine the dredged material and return water, if applicable, or open sites allowing easy access for placement sites and shaping of the dredged material. A list of potential placement sites that meet project goals and objectives should be developed for evaluation.

Over the years, more efficient and worthwhile uses of dredged material, rather than just storing it on the bankline or in a CDF, have been developed. This trend has greatly impacted the use of dredge material in environmental restoration. Dredged material is used to build islands, construct levees or berms, and create floodplain depth diversity.

4.3.1.1 Conventional Placement of Dredged Material. Once a list of potential placement sites has been developed, a search of existing databases, maps and other sources should be completed to identify any known issues or concerns. Some possible issues or concerns are:

- Impacts to wetlands, endangered species, water quality, aquatic, and terrestrial species
- Floodway conveyance, flood heights, and flood storage impacts
- Existing land uses
- Real Estate issues
- Hazardous, Toxic, and Radioactive Waste (HTRW) concerns
- Beneficial uses

4.3.1.2 Restoration Uses for Dredged Material

Island. The main restoration use for dredge material is for island building. This is a very beneficial use because the haul distance from the dredge cut to the island site is usually very minimal. In most instances, the material is sidecast to build the island. Refer to Chapter 9, *Island Design* for more information on island building.

Levee. Dredged material can also be used to build a new levee or strengthen an existing levee as part of a moist soil unit. Attention needs to be paid to the type of material being dredged so that the proper side slopes and compaction requirements are met. This will help ensure stability of the structure. Refer to Chapter 3, *Localized Water Level Management* for more information on levees and moist soil units.

Floodplain Depth Diversity. Dredged material can be placed in a variety of places to increase floodplain depth diversity and habitat. Dredged material can be placed on existing islands, banklines, and uplands. These areas are typically planted with mast trees. Refer to Chapter 7 of this handbook to for more information on floodplain restoration.

4.3.2 Lessons Learned

- The sediment to be dredged should be thoroughly tested for contaminants. If the tests results show an unacceptable level of contaminants in the sediment, an environmental engineer should be consulted. Presence of contaminants in sediment can severely limit what can be done with that sediment.

- Typical permits required for dredging and dredged material placement include NEPA, CWA section 404(b)(1) compliance, state floodplain permit, section 401 water quality certifications and if applicable, a state floodplain construction permit and CDF permit

- When placing dredged material in and around mature trees, the depth of the material should be minimized so as to not kill the trees

4.3.3 Case Studies

Potter's Marsh (UMRS River Mile 526.0 to 522.5). Included construction of a sediment trap, dredging was done in the upper/lower sloughs and embayment areas creating both shallow and deep water habitat, pothole excavation, and construction of a managed marshland.

Dredged material was placed in a confined disposal site located in an area of secondary growth adjacent to Central Island. The location and shape of the placement site were defined so as to not inundate the lower lying marshland areas downstream and to the east as well as the heavy timber and natural potholes to the north.

Column settling analyses were performed to determine the required detention time and total for initial dredged material containment. The dredged material needed about 25 hours of settling time and required an initial volume of approximately 1.75 times larger than the in situ sediments. Based on these analyses the interior area of the placement site needed to be 35.5 acres with a perimeter dike of 14 feet in height.

The dredged material was placed to an initial depth of 12 feet, settling to a depth of 8 to 10 feet after the first year. At that time, the perimeter dike upper surface was lowered to approximately 2 to 3 feet above the dredged material.

After settlement of the dredged material, an approximate 32.5 acre marshland was constructed on the confined placement site.

Long Island (Gardner) Division (UMRS River Mile 340.2 to 332.5). Included side channel restoration and protection within O'Dell Chute including a closure structure along with shoreline protection and reforestation.

The material dredged from O'Dell Chute and the closure structure access channel was placed on a 184 acre agricultural field on the eastern end of Long Island. It was determined that up to 8 inches of the sandy dredged material could be incorporated into the existing soil and still support the reforestation plan. To ensure that this depth was not exceeded, a 60 to 80 acre site was used. A berm was constructed on three sides of the placement site to ensure the dredged material settled out before draining to Long Island Lake. The berm is 2 feet in height with 2H:1V side slopes. It was assumed that the fine to medium sand making up the dredged material would settle quickly, therefore a column settling analysis was not performed.

4.3.4 References

U.S. Army Corps of Engineers, *EM-1110-2-5027, Confined Disposal of Dredged Material*, September 30, 1987.

U.S. Army Corps of Engineers *ERDC/EL TR-03-1, Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities Testing Manual, Upland Testing Manual,* January 2003,

U.S. Army Corps of Engineers, *ERDC-TN-DOER-C18, Confined Disposal Facility (CDF) Containment Features*, August 2000.

U.S. Army Corps of Engineers, *ERDC TN-DOER-C18, Confined Disposal Facility (CDF) Containment Features: A Summary of Field Experience*, August 2000.