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FOSTER WHEELER ENVIRONMENTAL CORPORATION

USACE CONTRACT NO. DACW33-94-D-0002
TASK ORDER NO. 17
TOTAL ENVIRONMENTAL RESTORATION CONTRACT

DRAFT
NEW BEDFORD HARBOR CLEANUP
DREDGE TECHNOLOGY REVIEW

NEW BEDFORD HARBOR SUPERFUND SITE
New Bedford, Massachusetts

April 1999

Prepared for

U.S. Army Corps of Engineers
New England District
Concord, Massachusetts

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Appendix A New Bedford Harbor - Environmental Dredging Technology Matrix

1.0 INTRODUCTION

This report has been prepared as part of Task 20 of Task Order No. 17, OU #1, New Bedford Harbor Superfund Site, New Bedford, Massachusetts - Remedial Design-Dredging Plan Design for the U.S. Army Corps of Engineers (USACE), New England District. This report provides a current assessment of the available dredging and support equipment that will be considered in designing how the dredging will be performed in New Bedford Harbor.

This report provides an assessment of potential dredging technologies that can address a set of specific challenges and criteria that have been identified in previous studies and actual dredging efforts. These include the following:

- Maximize solids content and thereby reduce water volume and water treatment;
- Minimize or reduce resuspension of contaminated marine sediments while dredging;
- Dredge in shallow water depths (1 to 4 feet) and intertidal areas; and
- Perform precision dredging to eliminate potential overdredging, which would add to the volumes of material requiring disposal in Confined Disposal Facilities (CDF);
- Dredge in soils having significant debris;
- Attain relatively high production rates; and
- Minimize or eliminate odors and polychlorinated biphenyl (PCB) volatilization (control floatables and oils with specific emphasis on controlling contaminated oil releases during dredging).

Several preferred dredging technologies have been considered and will be evaluated in more detail.

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2.0 APPROACH

The approach to preparing this document included dividing the following sections into four major areas: Review of Prior Studies, Identification of Dredging Technologies, Evaluation of Dredging Technologies, and Summary and Recommendations.

- **Review of Prior Studies (Section 3.0)** includes information obtained from prior studies, investigations, and direct discussions with USACE staff and the conclusions that were reached. This section also includes sediment characteristic information critical to the evaluation of suitable dredging equipment and methodology. Other observations, including personal communications regarding the Pilot and Hot Spot dredging are included to assist in understanding of the evaluation process.

- **Identification of Dredging Technologies (Section 4.0)** focuses on evaluation criteria in relation to the conditions and experience of previous efforts in New Bedford Harbor; data collection that included performing research and data collection to identify dredge technologies, including acquisition of a specialized database, and review of previous related work by, and for, the Waterways Experiment Station; and characteristics of dredging equipment (dredge types), which includes a detailed discussion of various dredge technologies and their effectiveness in meeting the objectives of the New Bedford Harbor cleanup.

- **Evaluation of Dredging Technologies (Section 5.0)** provides an evaluation of the dredge technologies identified, including preliminary research on resuspension utilizing existing programs and methodologies where practical, as well as reviews of prior case studies where available.

- **Summary and Recommendations (Section 6.0)** provides the decision criteria that influenced the decision-making process, a summary of the findings, and recommendations regarding the components and systems evaluated for use in New Bedford Harbor.

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3.0 REVIEW OF PRIOR STUDIES

Numerous investigations and reports have been completed to describe the nature and extent of contamination and to characterize the physical and chemical properties of the sediments. Studies associated with the actual cleanup methodology, a pilot dredge effort and report, and a "Hot Spot" dredging operation and report were specifically reviewed as part of this study. Reports reviewed included:

1. Report 2 "Sediment and Contaminant Hydraulic Transport Investigations, Feasibility Study of Dredging and Dredged Material Disposal Alternatives," Technical Report EL 88-15, Waterways Experiment Station, USACE, December 1988.

2. Report 10 "Evaluation of Dredging and Dredging Control Technologies, Feasibility Study of Dredging and Dredged Material Disposal Alternatives," Technical Report EL 88-15-10, Waterways Experiment Station, USACE, 1989.

3. Report 11 "Evaluation of Conceptual Dredging and Disposal Alternatives, Feasibility Study of Dredging and Dredged Material Disposal Alternatives," Technical Report EL 88-15-11, Waterways Experiment Station, USACE, July 1989.

4. New Bedford Harbor Superfund Pilot Study - Evaluation of Dredging and Dredge Material Disposal, USACE, New England Division, May 1990.

5. Report on the Effects of the Hot Spot Dredging Operations, prepared by EPA Region 1, USACE New England District, and Roy F. Weston, Inc. after completion of April 1994 to September 1995 dredging.

6. "Final Design Analysis New Bedford Hot Spot Operable Unit Superfund Site," prepared by ERM, Boston. November 1991.

7. "Draft Final Feasibility Study of Remedial Alternatives for the Estuary and Lower Harbor," New Bedford Harbor Superfund Site, prepared by Ebasco Services Incorporated, August 1990.

In addition, discussions were held with the on site USACE staff involved in the Pilot and Hot Spot dredging projects.

3.1 Conclusions of Prior Studies

Previous studies focused on dredging technologies, sediment characteristic data, and direct discussions with on site staff involved in previous dredging operations. In the evaluation phase (Report 11) the following conclusions were reached:

- Low potential for resuspension at the dredgehead is a major requirement for the New Bedford project.

- Dredge systems were assumed to be able to achieve relatively high solids content, probably comparable to production dredging methods or values in the range of 25 to 35 percent solids. Production rates for an 8-inch dredge were estimated at 100 cubic yards/hour (cy/hr).

- The Mudcat, an auger screw type machine, was the top-rated system. A cutterhead and matchbox were also rated highly. No mechanical systems rated high, primarily due to concerns that they would result in resuspension, thus none were recommended for the Pilot Study phase.

- The assumption that a dredge would work 8 hours per day, producing 100 cy/hr was iterated as part of an analysis of material dewatering and treatment.

- Three hydraulic dredges were brought in for the Pilot study, an Ellicott standard cutterhead hydraulic dredge, augerhead hydraulic dredge (Mudcat), and matchbox hydraulic dredge. The following conclusions were reached:
  - The cutterhead dredge proved to be the most effective in minimizing resuspension.
  - The Mudcat was less efficient and less successful in achieving clean-up criteria.
  - The matchbox had low production rates in the range of 25 cy/hr, was able to achieve clean-up criteria and minimize resuspension, but was susceptible to clogging by debris.

- The Pilot Study concluded that the use of a hydraulic dredge (cutterhead) is both a practical and effective method for removing contaminated sediments from New Bedford Harbor. However, to minimize sediment resuspension, large volumes of water were 'codredged' (i.e., high operating vacuums were used on the dredge). Flow rates were between 1,500 and 2,100 gallons per minute (gpm) during dredging with typically only 5 percent solids. Approximately 160 million gallons of decant water was treated during the 16 months of the project (USEPA, 1996).

The September 1998 Record of Decision (ROD) for OU #1 established the principle dredging and disposal methodologies for the New Bedford Harbor cleanup action and are the primary drivers toward analysis of alternative technologies.

- *"Most of the dredging will be done by a cutterhead dredge or its equivalent, since a cutterhead dredge has twice before operated in compliance with project specific control criteria. . . ."*

- *"Contaminated sediment in deeper water and in salt marshes may have to be removed by other methods (e.g., by clamshell bucket or land based excavation) and transported separately to the CDF's".*) (Meany 1998).

3.2 Sediment Characteristics

Critical to the evaluation of suitable dredging equipment and disposal methodology is an understanding of the physical properties of the sediments. The following provides a brief overview of the sediment characteristics as set forth in a number of related reports including Appendix B of Volume 11, of the Engineering Feasibility Study (1989), Appendix 6 of the Pilot Study Report, and the Hot Spot Design Analysis Report (1991).

The typical sediment profile was described as follows in Report 11.

Table 3-1
Typical Sediment Profile

Depth Below Mudline (ft)	Sediment Description	Typical Water Content[1]	Typical Liquid Limit (%)	Sand (%)
0 to 2	Organic SILT with fine sand. Some areas of sandy silt and silty fine sand.	111	105	40
2 to 5	Fine sandy SILT with areas of silty fine sand.	128	117	27
5 to 10	Silty fine SAND with areas of sandy silt.	109	68	53

Note: 1 Water weight divided by dry solids weight.

The sediment grain size appears to change toward the south and east. In the southeast portion of the Upper Harbor and in the area north of the east portion of the Coggeshall Street Bridge, the sediment is predominantly silty fine sand. The water content reported was in the range of 40 to 70 percent and the sand content was 60 to 80 percent. It appears that the PCB concentration in this portion of the harbor is generally low (i.e., 10 to 50 ppm).

In summary, the sediment characteristics in the northern portion of the Upper Harbor indicate predominately silt with low plasticity to organic silt with low plasticity and silty sand. In the high concentration area, the sediment samples typically contained less than 20 to 40 percent sand.

There would seem to be no limitation on the type of dredge equipment that would be suitable for the project based on sediment characteristics.

3.3 Other Observations

Several discussions and personal communications were held with the USACE staff regarding the Pilot and Hot Spot dredging. These discussions provide information not documented in the literature and are included here to assist in the understanding the direction the evaluation process will take.

- The reasons for the low solids in the dredge slurry were numerous and included, pumping only water at start up, a two-pass dredge method, risk aversion of plugging the system and therefore maintaining lower pump pressures by keeping the solids percentage low, pumping up to 20 minutes of water at the end of the days work to clear the lines, and periodically interrupting production dredging to lift the dredge suction to the surface to "skim" floating oils.

- The Hot Spot Report refers to, but does not describe "engineering solutions" that were developed in the field by the USACE staff and on site dredgers. These include "skimming" of floating oils by the dredge because the specialty skimmers (size and type are unknown), as well as absorbent materials (pads, etc.) were ineffective, and use of surfactants (detergent sprays) was prohibited by the U.S. Environmental Protection Agency (EPA). A system was developed during the Hot Spot dredging to attempt to capture the oils at the point of dredging. This system consisted of a large steel semi-circular dome with a separate suction system that was positioned directly over the cutterhead. The effect of this device on capturing the oils and minimizing resuspension (which it may have accomplished as a

secondary effect) was apparently partially successful, but was not formally evaluated for its efficacy.

- The ability of the dredge to operate in shallow waters was addressed in the written documentation in relation to the ability of the equipment to float. However, the operators reported that they needed enough water over the top of the cutterhead to allow it to entrain water and solids for pumping. Thus, even though the equipment might float, dredging could not occur when there was inadequate water depths to work.

- Shallow water also affects the time when start up and shut down of the equipment can occur, and when it is possible to transfer crews to and from the work site. One issue continuously noted throughout the literature deals with resuspension from other related activities, such as small boats, anchors, cables, and silt curtains disturbing the sediments. For example, the crew can only access the dredge when the tide is high, and must leave as the tide falls.

3.4 Summary

The results of the previous work is comprehensive and establishes a basis to understand the problems and issues related to this extremely complex project. The majority of the research and actual dredging work accomplished to date has focused on the Upper Harbor above the Coggeshall Street Bridge principally because the Hot Spots were in this area. Below the bridge a majority of the dredging will occur where the water depths (water depths of greater than 3 feet at mean low water [MLW]) will permit around-the-clock operations if deemed appropriate, and resuspension from grounding the floating equipment will not be a factor.

With this background, any evaluation of additional or new dredging technologies must address and ideally optimize the following:

- Maximize solids content and minimize water content of dredge disposal material;
- Minimize resuspension of contaminated marine sediments;
- Dredge in shallow depths and intertidal areas at all tide levels;
- Minimize overdredging with tight tolerance on vertical/horizontal accuracy;
- Dredge in soils having significant debris;
- Remove and treat/contain oil seeps; and
- Attain relatively high production rates.

4.0 IDENTIFICATION OF DREDGING TECHNOLOGIES

4.1 Introduction

The analysis to date resulted in the selection of a hydraulic dredge system as a preferred technology. With the increasing demands of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process to cleanup contaminated sites, newer dredging technologies have been developed to address removal of contaminated sediments using mechanical and mechanical/hydraulic hybrid systems.

This section focuses on evaluation criteria in relation to the conditions and experience on previous cleanup efforts in New Bedford Harbor; the general characteristics of dredge equipment; and research methodology used to identify and evaluate dredging systems that have been developed or refined since the previous studies and evaluations were performed.

4.2 Evaluation Criteria

This section provides an analysis of objectives and criteria as set forth above in relation to the conditions and experience on previous cleanup efforts in New Bedford Harbor.

4.2.1 Minimization of Resuspension of Contaminated Sediments

A primary requirement of the dredge technology to be employed on the project is minimization of resuspension of contaminated sediments. Resuspension of sediments coupled with odor and release of PCBs to the air during dredging in the project area is a health and safety concern not only for the dredge operator and crew, but also for nearby residential areas. It is noted that a high degree of public concern over dredging operations exists and that only the dredge technologies causing the least resuspension of contaminated sediments will be selected. One of the project controls will be to keep PCB mass release from the Upper to Lower Harbor within set limits.

Resuspension of contaminated sediments by the dredging operation can occur at a number of locations as a result of several activities. The primary instance of resuspension of sediment is at the point of dredging with the physical contact of the excavation mechanism (cutterhead, augerhead, bucket, plain suction) with the dredge surface. The resuspension impact of the basic types of dredges (clamshell/bucket and hydraulic pipeline/cutterhead) on bottom sediments has been documented on several environmental remediation dredging projects. The results of water quality monitoring programs conducted on the projects primarily look at the sediment resuspension associated with dredging and material handling equipment. In most cases the Total Suspended Solids (TSS) concentration is measured at various locations in the water column at varying distances from the dredging operation to estimate the vertical and horizontal distribution of resuspended sediment as a result of the dredging operations. The background suspended sediment may or may not be included in the measurement. The results of water column sampling programs for a number of environmental dredging projects are provided in Table 4-1.

Table 4-1
Comparative Results of Sediment Resuspension by Dredge Type on Selected Projects

Study Project	Dredge Type	Sediment Type	Current Range (ft/sec)	Total Suspended Solids Inc. Background (TSS) (mg/l)			Distance from Point of Dredging (ft)	Average Resuspension Rate (grams/sec)	Max. TSS/ Back-ground TSS	PCB Release (ppb) Dissolved	PCB Release (ppb) Particulate	Cumulative Transport of PCBs (kg)
				Surface	Middle	Bottom						
Savannah River[1] Savannah, GA	Cutterhead	N/A	N/A	19	47	178	200	N/A	N/A	N/A	N/A	N/A
St. John's River[1] Jacksonville, FL	Open Clamshell	N/A	N/A	41	100	280	N/A	N/A	N/A	N/A	N/A	N/A
	Closed Clamshell	N/A	N/A	30	50	84	N/A	N/A	N/A	N/A	N/A	N/A
Black Rock Harbor[2] Bridgeport, CT	Open Clamshell 10cy	sandy, organic clay 90% fines	0.2-0.8	45		69	50 ft	N/A	15.9	N/A	N/A	N/A
Calumet Harbor[2]	Cutterhead (12-in.)	soft organic clay/silt 80% fines	0-0.2	2		5	10 ft	N/A	2	N/A	N/A	N/A
Duwamish Waterway[2] Seattle, WA	Open Clamshell	sandy clayey silt	0.3-1.1	11		26	50 ft	N/A	6.1	N/A	N/A	N/A
James River[2] Norfolk, VA	Cutterhead	silty clay	0.5-2.3	42		86	10 ft	N/A	3.8	N/A	N/A	N/A
New Bedford Harbor[3] Pilot Dredging Project New Bedford, MA	Cutterhead	organic silts and clays	N/A	N/A		94	0 ft	12	N/A	0.6	22.3	N/A
	Augerhead	organic silts and clays	N/A	N/A		1607	0 ft	329	N/A	10.1	200.3	N/A
	Plain Suction	organic silts and clays	N/A	N/A		319	0 ft	46	N/A	0.5	56.9	N/A
New Bedford Harbor[4] Hot Spot Dredging New Bedford, MA	Cutterhead	organic silts and clays	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	52 (240 allowable)

Notes: 1 Source: Guide to Selecting a Dredge for Minimizing Resuspension of Sediment (Hayes, 1998)
2 Source: A Preliminary Evaluation of Contaminant Release at the Point of Dredging, Waterways Experiment Station (Havis, 1988)
3 Source: New Bedford Harbor Superfund Pilot Study, May 1990
4 Source: Report on Effects of the Hot Spot Dredging Operations, New Bedford Harbor Superfund Site (USEPA, 1996)
N/A = Not Applicable

4.2.2 Dredge Support Operations

The sediment resuspension characteristics of the dredge types described above are at the point of dredging. It is important to note that sediment resuspension at the point of dredging is not the only source of contaminant release on a remediation dredging project. On the New Bedford Harbor project, it is clear that the majority of the PCB-contaminated sediments are in shallow water relative to other environmental dredging projects. Ancillary operations to the main dredging activity that can cause significant resuspension of bottom sediments include:

- Spud deployment and removal
- Anchor deployment and removal
- Hull and propeller impacts with bottom sediments (tug, skiff, survey boat)
- Dragging of submerged and shore pipeline.
- In evaluating each of the preferred dredge technologies for application to the New Bedford Harbor project, the resuspension impacts of the entire operation were considered.

4.2.3 Maximization of Percent Solids Concentration

Despite the inclusion of water treatment facilities at the four CDFs proposed for the full-scale remediation, it is incumbent upon the dredge technology employed on the project to maximize the percent solids concentration of the dredged material in order to minimize the volume and cost of water to be removed, transported, and treated. In maximizing the percent solids concentration of the dredge operation, the disposal site capacity requirements will be optimized, while pipeline lengths will be reduced. The minimum requirement of the dredge system will be delivery of the dredge slurry to the CDF with not less than 5 percent solids by weight.

4.2.4 Maximize Production in Shallow Water Environment

The New Bedford Harbor project is unique in that such a large volume of material (450,000 cy) is to be dredged from such an expansive shallow water environment. The average depth of water across the entire Upper Harbor dredge area is only 2 feet MLW. The tidal cycle in New Bedford Harbor is mixed. Mixed tides, also known as irregular semi-diurnal tides, occur twice daily, but exhibit two highs and two lows typically of unequal height. The mean tide range in the harbor is 3.7 feet, while the highest tide does not appear to exceed 5.3 feet MLW and the lowest tide, -1.1 foot MLW. For a floating plant to operate in the harbor for at least four hours per day, it is estimated that the plant could not draw more than 3 feet of water. This takes into account that the dredge plant and other small vessels will require at least 1 foot of water beneath the hull for wave action and squat. The limited operating day of floating plant due to tidal constraints, greatly decreases the overall dredge production. To circumvent the shallow water problem either the dredges chosen to perform the work will be permitted to "dig themselves in" from the deeper lower harbor northward (land-based equipment will be permitted to at least complement the marine dredging portion of the job). It is not known at this time whether it is acceptable for dredging to be performed by terrestrial (land-based) or amphibious means. It is assumed that the dredge and ancillary equipment, including, anchors, spuds, pipeline, and other barges or small craft will be permitted to rest on the emergent surface of the tide flat once the tide has receded.

Performance of the Pilot Study and Hot Spot dredging projects also revealed that significant debris is distributed across the Upper Harbor. Numerous types of industrial debris including cables, bricks, concrete, and ballast stones were encountered and severely impeded the progress of the hydraulic dredges completing the work. The dredge system chosen to complete the full scale cleanup will be

required to have good debris handling capacity in order to minimize the downtime of the dredge operation due to debris cleaning and equipment repairs.

4.2.5 Dredge Accurately to Minimize Dredged Material Volume

To minimize the volume of material to be dredged, transported, and contained within the CDFs, which are projected to have minimal excess storage capacity, it is imperative to perform dredging of the contaminated sediments with a minimal amount of overdredging. Numerous dredge and excavator positioning systems have been developed in recent years to perform tight tolerance "surgical" dredging. Modern horizontal positioning system make use of a Digital Global Positioning System (DGPS) system or Laser Plane system to locate the dredge, boom, or ladder within 1 centimeter horizontal accuracy. Pressure sensors and other manual means of measurement are used to locate the excavator bucket, or dredge head within 1.1 inch vertical accuracy. On the Bayou Bonfouca Superfund Project the dredge Bonacavor, a hydraulic excavator, was able to excavate with overall, measured accuracy of 3 inches in both the horizontal and vertical planes. For the New Bedford Harbor project, with consideration for the sea state, currents, and distance from dredge to shore, a reasonable level of accuracy to expect from the dredge system performing the full-scale remediation would be +/- 20 inches in the horizontal plane and +/- 6 inches vertically.

4.2.6 Remote Discharge

All of the systems under consideration are envisioned to employ pipeline discharge of the material as a high or low density slurry, in some instances up to a mile from the point of excavation. It is unlikely that barges can be used to move dredged material, especially in the Upper Harbor. Material density will vary and, in conjunction with equipment size, discharge distances that slurries can be pumped will also vary. However, the use of booster pumps for traditional hydraulic dredging is a standard procedure where distances exceed the pumping capacity of the point of dredging equipment. Where high-density material is being pumped by a positive displacement pump system, intermediate hoppers, and high solids pumps may be required to move the material.

4.3 Data Collection

Numerous data sources including manufacturer literature and conversations with manufacturers, proceedings from dredging and contaminated marine sediment conferences, and other related technical reports and two databases and accessed as part of the evaluation process. The GLOBALtechs Online Site Remediation Technologies directory was also accessed for the New Bedford Harbor dredge technology evaluation. This database, developed by Environment Canada, contains over 50 of the latest, most innovative remediation technologies available worldwide. The Innovative Dredge Technology Database, developed by Hartman Consulting Corporation, a subsidiary of Foster Wheeler Environmental Corporation, for the USACE WES was also used as a source of potential dredge technologies to be applied to the New Bedford Harbor Cleanup Project.

A dredge technology matrix was developed to summarize the technologies considered for evaluation. Several categories of information were investigated and summarized for each technology. Over 70 dredge systems or technologies were identified and are listed in the Dredge Technology Matrix in Appendix A.

4.4 General Characteristics of Dredge Equipment

To date, only hydraulic pipeline (cutterhead and auger head) and clamshell (open and closed bucket) dredges have been investigated for their effectiveness in meeting the objectives of the New Bedford Harbor cleanup, with particular emphasis during those efforts on identifying and quantifying their sediment resuspension characteristics. The results of these studies in New Bedford and other similar projects are summarized in the following discussion.

4.4.1 Cutterhead Dredge (Hydraulic Pipeline)

It has been established by prior studies that the hydraulic cutterhead (pipeline) dredge, due to its suction capacity, has the greatest potential to minimize resuspension of bottom sediments. Mechanical mixing of the bottom sediments by the rotating cutterhead while swinging through the dredge cut is the primary factor causing resuspension. The effort by the dredger to maximize production can also cause an overloading of the suction capacity of the dredge, causing excess resuspension near the suction mouth. Where cutterhead dredges encounter significant debris (plugging of the cutterhead, suction line, or pump), the dredge will be required to stop pumping for clearing, causing backflushing and subsequent, often significant, resuspension of sediments at the suction intake. As such, sediment resuspension caused by cutterhead dredges generally occurs at the lower portion of the water column. As the dredging in the Upper Harbor occurs in very shallow water, the sediment resuspension at the lower portion of the water column will generally similar to that at the surface.

Controls can be instituted in the operation of the cutterhead dredge to minimize the resuspension potential of the dredge. The pump speed can be manipulated to control the velocity at the suction mouth and resuspension near the cutterhead. The cutterhead rotation speed and the swing speed can also be reduced to minimize the resuspension rate of affected sediments. The depth of cut can also be controlled to avoid overcutting. The practice of cutting near or at the design depth and allowing a large volume of material above the cutterhead to fall into the cutterhead should be avoided, as this can greatly increase the plume, and solids concentration, at the point of dredging. On the New Bedford Harbor Pilot (and Hot Spot) dredging projects, dredging operation controls were employed to keep resuspension of contaminated sediments to minimum.

An Ellicott 370 Dragon Series Hydraulic Cutterhead dredge with 10-inch discharge was used on the Pilot dredging project. The dredge operating controls that proved most effective on the project were as follows:

Cutterhead rotation speed	20 rpm (50 percent of maximum)
Swing speed	0.5 fps (40 percent of maximum)
Pump speed	Maximum rpm
Depth of cut	2 feet
Width of cut	60 feet

4.4.2 Augerhead Dredge (Hydraulic Pipeline)

The hydraulic augerhead dredge acts much like the hydraulic cutterhead dredge, except that the cutting tool is not a rotating basket or cutterhead but a horizontal tiller type cutter or augerhead. As with the cutterhead dredge, the primary causes of sediment resuspension by the augerhead dredge stem from the physical contact of the augerhead with the bottom sediments. While the augerhead dredge can swing to a certain extent to widen the dredge cut, the dredge primarily advances directly forward into the dredge cut. The augerhead performs even more poorly than the cutterhead dredge, causing resuspension of

sediments, when significant debris is encountered in the dredge prism. The debris can lodge in the augerhead's cutter blades and become entangled with the cutting cylinder and the suction intakes. As with the cutterhead dredge the rate of advance into the dredge cut, cutter rotation speed, pump speed, and depth of cut can all be operationally controlled to minimize resuspension.

On the Pilot dredging project, dredging operation controls were employed to keep resuspension of contaminated sediments to a minimum. An Ellicott SP-915 Series Mudcat augerhead dredge with 10-inch discharge was used on the Pilot dredging project. The dredge operating controls that proved most effective on the project were as follows:

Augerhead rotation speed	Full speed
Rate of advance	15 feet per minute
Pump speed	Maximum rpm
Depth of cut	0.5 feet per pass
Width of cut	60 feet
Number of passes	Four - two in the forward direction, two in the in reverse

4.4.3 Open Clamshell Dredge (Mechanical)

Mechanical dredges, the most typical of which is the clamshell bucket dredge, are used where dredged material disposal areas are too far for hydraulic pipeline dredges to pump to efficiently, when minimal water entrainment in the dredge material is required, or where significant debris may be encountered. Without the implementation of operation controls or modifications to the bucket, mechanical dredges generally induce more resuspended sediments than hydraulic dredges operating in the same sediment conditions, both in the upper and lower water column. Sediment loss at the dredging site with a standard open-bucket clamshell has been estimated to be two times greater than sediment loss with a hydraulic dredge (WES, 1989). Resuspension of sediments from operation of open-bucket clamshell dredges is generally due to the impact forces of the bucket with the bottom sediments, spillage of sediment out of the open surface of the bucket, and leakage at the bucket closure seam. The placement and lowering of an empty bucket with residual material on the bucket surface can also be a source of resuspended sediment. It is generally accepted that mechanical dredges perform substantially better than hydraulic dredges in sediments with significant debris, in terms of production capacity and minimization of resuspension of sedimentation.

While a mechanical dredge was not tested during the Pilot dredging project, as no mechanical point of dredging systems with pipeline transport had evolved at that time, the sediment resuspension characteristics of open clamshell mechanical dredge systems have been measured and evaluated on a number of environmental dredging projects. Some of these projects are summarized in Table 4-1.

As with hydraulic dredging systems, mechanical (open clamshell) systems can be operationally controlled to minimize the resuspension of sediment. In general, the operational controls that have proved most effective on the environmental dredging projects are as follows:

- Slowing the rate of bucket lowering;
- Accurate placement of the bucket on the dredge surface;
- Ensuring the bucket is fully closed prior to retrieval;
- Slowing the rate of bucket retrieval;
- Decanting free water atop the full bucket at the surface prior to swinging for disposal; and
- Washing the bucket after material disposal and prior to lowering for the next cut.

The advent of positioning systems and underwater video monitoring systems permit greater accuracy and control of the bucket in the dredge prism. Greater control of the bucket translates into reduction of resuspended sediment. These bucket positioning systems have been more commonly integrated for use with the enclosed clamshell bucket, for maximum resuspension minimization.

4.4.4 Hydraulic Excavator (Mechanical)

The hydraulic excavator is a relatively new type of mechanical dredge, developed in the United States in the early 1990's in response to a Superfund environmental remediation project at Bayou Bonfouca, Louisiana where highly accurate cutting with minimal water entertainment in the dredge material was required, and harbor deepening projects on the east and west coasts where dredging of stiff sands and rock were required. The hydraulic excavator dredge is essentially a backhoe mounted atop a turret on a barge. The excavation process is much the same as conventional backhoe operations where an open excavator bucket is pneumatically controlled by a hinged rigid arm assembly by the operator. Due to the strength and rigidity of the excavator arm and bucket assembly, the hydraulic excavator dredge offers not only excellent breakout forces and debris handling capacity, but also the greatest amount of control of the cutting surface.

The resuspension characteristics of the open hydraulic excavator bucket are similar to that of the open clamshell bucket. However, due to the open-ended bucket and exposed dredged material surface, the potential for resuspension of sediments throughout the water column during the retrieval process is significant. Modifications (i.e., enclosures to the bucket) can be made to limit the resuspension potential of the excavator bucket. The bucket enclosure modification design can be weighed against the debris handling capacity on a job-specific basis to optimize the resuspension minimization characteristics of the hydraulic excavator dredge.

Significant advances in dredge excavation positioning systems and alternative dredged material handling systems have been developed, to optimize the control, debris handling, and production benefits of the hydraulic excavator dredge.

4.4.5 Enclosed Clamshell Dredge (Mechanical)

The excellent accuracy, production, water minimization, and debris handling capacity of mechanical dredges have inspired the development of the closed clamshell bucket for application on environmental dredging projects. The enclosed clamshell bucket was introduced to limit the problem of sediment loss during the digging, retrieval, swinging and lowering phases of the mechanical dredging process. Reports on enclosed bucket systems to reduce suspended sediment in the water column were published in Japan and the United States more than a decade ago (Kaneko, 1984 and Hayes, 1984). The Japanese bucket design was reported to have produced 30 to 70 percent less suspended sediment than a standard clamshell bucket. Some of the first tests conducted in United States compared an enclosed bucket and a standard bucket in the St. John's River, Florida. The water quality monitoring results indicated that the enclosed bucket generated 39 to 56 percent less suspended sediment in the upper water column. This improved water quality in the upper water column was offset by 220 to 330 percent more suspended sediment in the lower water column. It was later resolved that this increase in resuspended sediment on the bottom was a result of a design flaw, whereby the enclosed bucket, with no means of allowing water flow through during the lowering phase, would cause a shock wave, pushing water ahead of the bucket directed downward on the bottom sediments. This design flaw has since been remedied and significant reduction in suspended sediment concentrations over that of an open clamshell bucket has been realized on a number of projects.

Additional measures can and have been taken to increase the accuracy of dredging and decrease the sediment resuspension potential of enclosed bucket mechanical dredges. In addition to the suspended sediment minimization operational controls suggested for the open clamshell dredge above, enclosed bucket dredges can be equipped with state-of-the-art positioning and elevation controls.

The enclosed clamshell is specified for the excavation of approximately 350,000 cy of low level PCB-contaminated sediment in Saginaw River, Michigan being performed for the Detroit District of the USACE. A specific requirement of this project is to rinse the bucket in a special tank on the discharge barge before each pass is made.

5.0 EVALUATION OF DREDGING TECHNOLOGIES

5.1 Introduction

This section describes a set of screening criteria used to evaluate the dredge technologies presented in Chapter 4. Technologies are selected for further evaluation based on their ability to pass this screening while meeting the basic objectives of maximizing solids content, minimizing resuspension, and operating in shallow water. From this screening process a number of specific dredge *components* and *systems* are discussed in relation to their past performance on this and other projects.

5.1.1 Definition of Components and Systems

For the purpose of this analysis, dredging equipment will be divided into ***components*** and ***systems.***

- ***Components*** of a dredge system include:
  1. Point of dredging components include the cutterhead, auger screw, dustpan, and matchbox, as well as various mechanical means, such as clamshell or backhoe excavator bucket.
  2. Support components include the support barge or pontoon, jack-up platforms, and amphibious systems.
  3. Discharge components include pumps, pipelines, barges, and trucking.

- ***Systems*** are the combination of the point of dredging component with a support and discharge component. For example, the typical cutterhead suction dredge combines the cutterhead supported by a barge and pumps to discharge though a pipeline. A typical mechanical system would include the clamshell bucket, crane, crane barge, and haul/dump barge.

5.2 Preliminary Screening Criteria

The following criteria were developed considering the physical features of the Upper Harbor, environmental protection requirements, lessons learned from the Pilot Hot Spot dredging, and used to develop a set of specific components and systems for possible evaluation and utilization in the New Bedford Harbor cleanup.

1. The 10-inch Ellicott cutterhead used in the Pilot Study and Hot Spot dredging will be the base system used to compare alternatives. If an alternative cannot equal the Ellicott's 35 cy/hr production rate at the percent solids content achieved in the Pilot Study (5 percent), it is dropped.

2. Due to the potential for debris, only systems with some means of mechanically working the bottom sediments, such as a cutterhead, auger, or bucket (excavator, clamshell, etc.) will be considered. This criteria eliminates systems such as the matchbox (which has already been proven unsuitable), or pneumatic systems from further consideration.

3. Material transport from the dredge site to disposal will most likely be by pipeline only. Barging is deemed inappropriate, as it would result in significant resuspension due to tug operations and barge grounding, while trucking on city streets would require water-tight transporting containers, decontamination of vehicle for each trip and result in a large number of daily trips.

4. It will be assumed that floating oils will be handled by separate equipment and will not be the responsibility of the dredge. However, consideration will be given to any system that appears to either limit the amount of oil that may surface during dredging by capturing it as part of the dredge operations, or that can recover the oil once on the surface without increasing water volumes. (It is recommended that an adequately sized dedicated skimmer system be developed that will pump directly to a water treatment plant.)

Certain dredge technologies were eliminated from further consideration because they clearly would cause significant levels of resuspension and would not be able to equal the production rates of those already tested. Further, a number of the systems identified are simply re-named or re-labeled versions of a similar system that, as will be seen, pass the screening level. Finally, there are a number of older systems for which there is no available information, implying they fell out of favor when originally tested, or there is little or no operational experience for a particular system in the United States that can be used to make an informed assessment of their production capabilities on the New Bedford Harbor cleanup project.

5.3 Screened Components

5.3.1 Point of Dredging Components

Point of dredging components that have proven or that appear suitable based on preliminary screening criteria include:

- Traditional hydraulic cutterhead dredge. Proven technology as demonstrated by the Pilot and Hot Spot dredging project. Capable of removing sediments and moderate sized debris. Creates high volumes of water. No new basic hydraulic cutterhead systems have been developed in the past 10 years. As a system it is limited in its ability to address the shallow water issue. However, a cutterhead has been proven to successfully meet accuracy and resuspension requirements.

- Hydraulic excavator (backhoe). Traditional open bucket, used in a wide range of systems. Recent systems include close tolerance bucket positioning systems. Excellent capability to remove debris, minimizes water content, with new electronic positioning system is highly accurate. However, the traditional open bucket may create an unsuitable level of resuspension without modifications or operational controls.

- Closed clamshell as developed by Dry Dredge is designed with a unique sealed clamshell to remove sediments at in situ moisture content. The clamshell is mounted on a rigid boom for precise vertical and horizontal control and is slowly pressed into the sediment and closed with hydraulic cylinders. This design eliminates scouring during excavation, produced only minimal bottom disturbance, is highly accurate, and can handle debris. Resuspension is associated with mud clinging to the outside of the bucket that may wash off as it is raised and lowered.

- Visor Grab as developed by HAM. Working on an excavator arm the bucket is fairly wide and includes a revolving visor flap that is closed by means of hydraulic cylinders. When the grab has been filled, the visor is closed before the grab is raised to empty the contents. A rubber strip along the edge of the visor ensures a watertight seal. This design produces minimal bottom disturbance, is highly accurate, and can handle debris. If an open bucket is used, this system may result in an unsuitable level of resuspension.

- Level cut is a clamshell system that can be operated by a conventional crane. The bucket has overlapping side plates, seals, and a closed top and makes a level cut in the bottom at precise depth, thus maintaining high solids content. This design eliminates scouring during excavation is highly accurate and can handle debris. Resuspension is associated with mud clinging to the outside of the bucket that may wash off as it is raised and lowered. This component has been specified for the upcoming Saginaw River, Michigan project, which removes approximately 350,000 cy of low level PCB-contaminated sediment. The project is administered and managed by the Detroit District of the USACE for the PRPs.

5.3.2 Support Components

Support components that pass preliminary screening include:

- Traditional barge or pontoon supports. Shortcomings principally associated with floats is their limited ability to operate in shallow and intertidal waters. However, this is a proven system for supporting both hydraulic and mechanical excavators.
  - Amphibious support systems. A number of systems have been identified as amphibious, implying they can support point of dredging equipment when floating, as well as in shallow or "no" water conditions. These include:
  - Amphibex, from Normrock Industries
  - Aquarius Systems
  - LGP track-mounted excavator
  - DRE Technologies Dry Dredge has an amphibious undercarriage option.

  No specific research has been located that addresses resuspension from these types of equipment. However, the rather high level of interaction by the tracks or arms with the sediments suggests that significant resuspension will occur. To be effective, these systems would not drag themselves around in unexcavated contaminated areas, but rather would excavate and move into the cleaned space, possibly mitigating resuspension of contaminated materials. Whether this is feasible remains unknown. These systems pass the preliminary screening stage and will be considered for further analysis.

- Jack-up systems such as the Crawl Cat by IHC Holland is a small barge with legs fitted with crawler tracks. As with the amphibious systems there is no specific data that addresses resuspension from this type of equipment and as with the amphibious systems, they pass the preliminary screening stage and will be considered for further analysis.

5.3.3 Discharge Components

Discharge components that pass preliminary screening include:

- Traditional centrifugal pumps associated with hydraulic dredge such as the Ellicott cutterhead dredge or Mudcat, with suction from the cutterhead discharging directly to a pipeline. Slurry concentrations from 5 to 25 percent solids by weight discharging unlimited distances when using intermediate booster pumps. This is a proven system.

- High solids concentration pumping systems include:
  - DRE Technology Dry Dredge System, the discharge method is used in conjunction with a closed clamshell, which dumps to a hopper. A positive displacement pump (like a concrete pump) is used to pump 25 to 75 percent solids by weight a distance of up to

2,000 feet. Although not yet proven, greater distances can possibly be achieved by using intermediate hoppers and pumps.

- Bean Technical Excavation slurry processing unit (SPU), in conjunction with open or closed bucket discharging to a hopper where a computer managed mixing system is used to create an optimum slurry density of 15 to 40 percent solids by weight, which is hydraulically pumped distances up to 5,000 feet. Longer distances are possible with intermediate booster pumps. It may be possible to recycle the mixing water needed to create the optimum density slurry back from the discharge point in lieu of adding make-up water at the point of dredging, thereby reducing overall water volumes for treatment.

5.4 Screened Systems

For a number of alternative dredge technologies under consideration for the project, no or limited water quality monitoring programs have been conducted on projects performed by the dredge technology. For this study, an attempt to correlate the data obtained from the dredge types investigated has been made to describe the resuspension potential of these alternate dredge types (see Table 5-1).

Several manufacturers have assembled systems that incorporate the components described above. It should be noted that much of actual performance information on a particular project has come from the manufacturers as part of their promotional materials. Additional investigation into these dredges to determine if they were in fact operating in similar site conditions (such as soft sediments, shallow tidal waters, and restrictions on resuspension) may need to be performed to determine if these systems would meet the operational criteria for the New Bedford Harbor Dredging project.

The final dredge ***systems*** considered for further investigation were ranked as follows:

- **High** – Those dredge systems that meet minimum project requirements for the criteria evaluated. These systems offer cost savings and efficiencies that have the greatest potential for successful execution on the project. Successful application of the technology for the criteria evaluated on the New Bedford Harbor Pilot Dredging Study, Hot Spot Dredging, or other similar contaminated sediment removal project were also rated high.

- **Medium** – Those dredge systems that meet minimum project requirements for the criteria evaluated but do not have a proven or established track record for application in the field. These systems have the potential for successful execution on the project, and should be researched and evaluated further in the field to confirm performance criteria.

- **Low** – Those dredge systems that do not meet minimum project requirements for the criteria evaluated and do not appear to provide a sufficient improvement to the overall New Bedford Harbor dredging program. No further study is envisioned in these areas, either because the technology requires significantly more development, or it does not indicate potential cost savings.

Table 5-1
Removal Technology

Dredge Technology	Bean Modified Bonacavor Slurry Processing Unit	Normrock Amphibex Amphibious Dredge	Aquarius Amphibious Excavator	DRE Technologies Dry Dredge	Ellicott Modified Hydraulic Cutterhead Dredge	IHC Holland Crawl-Cat Cutter Suction Dredger	LGP Truck-Mounted Excavator
Draft (ft)	3	Amphibious	Amphibious	2.5	2.5	Amphibious	Amphibious
Excavator Size (est.)	1.5 cy	0.5 cy	0.5 cy	1 cy	12"	N/A	1.75 cy
Transport System Size	8"-10"	8"	Barge/Truck Only	6"	12"	12"	Barge/Truck Only
Estimated Hourly Production (cy/hr)	50-70	20-40	20-40	40-60	20-40	20-40	50-150
Resuspension Minimization	Good	Poor	Poor	Good	Good	Poor	Poor
Estimated Percent Solids (by weight)	15-40%	5%	60-80%	20-50%	2-7%	2-7%	60-80%
Overall Rating	High	Medium	Medium	High	High	Medium	Medium

5.4.1 Bean TEC Hydraulic Excavator Bonacavor (Overall Rating - High)

The Bean Technical Excavation Corporation (Bean TEC) hydraulic excavator *Bonacavor* was designed and built to meet the rigid dredging accuracy, percent solids concentration, and debris handling requirements of the Bayou Bonfouca Superfund Project. The dredging portion of the project was completed successfully in 1993 with the removal of approximately 170,000 cy of creosote poly aromatic hydrocarbon (PAH) contaminated material.

Sediment Resuspension Minimization (Rating - High)

With modifications to the excavator bucket with an enclosure and bucket material handling operational controls established, the point of dredging resuspension potential for the BeanTEC hydraulic excavator is considered fair. The superior positioning and control feature of the excavator also serves to minimize resuspension potential. The excavator bucket is probably the best digging tool in terms of debris handling. The production capacity and resuspension minimization characteristics of this system are minimally affected by debris.

The sediment resuspension minimization rating of the *Bonacavor* hydraulic excavator on an overall operation's basis is high considering that it is a floating plant with pipeline transport system. The dredge advance mechanism is optimally the spud carriage system from a production standpoint, however, a smaller hydraulic excavator(s) could be configured to work on wires and anchors.

Percent Solids Maximization (Rating - High)

To maximize the percent solids concentration of the dredge slurry and minimize the cost of treating water on the Bayou Bonfouca Project, the SPU was designed and integrated with the *Bonacavor* hydraulic excavator. The SPU measures and monitors the in-situ water content of the material dredged and placed in a hopper, and injects only as much water as is necessary to keep the slurry moving to the treatment and disposal site. On the Bayou Bonfouca Project, the *Bonacavor* achieved an average percent solids concentration of 27 percent by volume ~~weight~~ (approximately 48 ~~70~~ percent by weight ~~volume~~).

Product Optimization (Rating - High)

To perform effectively in the Upper Harbor, a smaller version, or versions of the *Bonacavor* hydraulic excavator would need to be constructed. The hydraulic excavator dredge offers high production capacity in terms of setup and cycle time. The actual production capacity of the hydraulic excavator of this type will depend on the size and capacity of a backhoe able to fit on small barge that draws not more that 3 feet of water. It is estimated that a smaller and lighter version of the hydraulic excavator could be constructed that could achieve an overall production rate in the range of 50 cy/hr. The production output of the hydraulic excavator is also not affected by debris as significantly as other mechanical and hydraulic dredge systems. Debris retrieved by the excavator bucket is separated out over a grizzly atop the SPU hopper, and placed on debris barges floated alongside the dredge, and will be placed in the CDF or other approved off-site facility once the debris barge is full.

Dredging Accuracy (Rating - High)

The excavation accuracy of the *Bonacavor* is the highest attained on an environmental remediation project completed to date. The overall dredging accuracy was measured to be 3 inches in both the horizontal and vertical planes. This level of accuracy was achieved by installing a excavator positioning system, which measured and monitored the dredge (barge) position relative to the waterway and dredge

prism with a Laser Plane system established on shore and on the dredge. The tight horizontal and vertical accuracy of the excavator bucket was obtained over the dredge cut (grid) using a series of pressure sensors located along the excavator arm and leading edge of bucket. Measurements from the sensors were translated to the operator's heads up display, which showed the position of the excavator in relationship to the dredge prism in real time. As this project was performed in a relatively protected waterbody with minimal waves, currents and tides, it is likely that the *Bonacavor* type hydraulic excavator could attain a dredging accuracy of ±20 inches in the horizontal plane and +/- 6 inches vertically.

5.4.2 Amphibex and Aquarius Amphibious Dredged (Overall Rating - Medium)

The Amphibex and Aquarius Amphibious excavators are barge mounted backhoes, capable of turning 360 degrees. These systems work optimally in water depths of 8 to 13 feet, but can also work on emergent shoreline and tide flats according to the manufacturers. The excavators are mounted atop barges that have been fitted with "legs" with cylindrical wheels that provide mobility.

Sediment Resuspension Minimization (Rating - Low)

With modifications to the excavator bucket with an enclosure and bucket material handling operational controls established, the point of dredging resuspension potential for amphibious dredges is considered fair. The excavator bucket is probably the best digging tool in terms of debris handling. The production capacity and resuspension minimization characteristics of this system are minimally affected by debris.

The sediment resuspension minimization rating of the amphibious dredges on an overall operations basis is low due to the high degree of contact of the dredge "legs" and "wheels" with the bottom sediment.

Percent Solids Maximization (Rating - Low)

The Amphibex amphibious excavator can operate in either straight mechanical or hydraulic transport modes. As such the percent solids concentration can vary from as low as 2 percent solids by weight to perhaps as high 70 percent solids. Because the mechanical dredging would require transport by barge, this system would most likely provide low percent solids in hydraulic mode. The Aquarius amphibious excavator only operates in mechanical dredging and transport modes. The combination of a high solids content SPU type or DRE-Dredge positive displacement type material transport system could be considered for adaptation to the amphibious dredges if the dredges meet or exceed the other project criteria.

Product Optimization (Rating - High)

The theoretical production capacity of an amphibious dredge working the Upper Harbor is good considering that the dredge could continue to operate in shallow and intertidal areas. In mechanical dredging mode, Amphibex amphibious excavator is rated for 50 cy/hr production. In hydraulic mode, the production rate would most likely be in the range of 20 cy/hr. The Aquarius amphibious excavator is rated for production in the 20 cy/hr range. Both excavators have good debris handling capability.

Dredging Accuracy (Rating - High)

The excavation accuracy of the amphibious excavators would be expected to be good (high) if the systems were outfitted with an accurate DGPS or other positioning system. It is anticipated that the

hydraulic excavator could attain a dredging accuracy of +/- 20 inches in the horizontal plane and +/- 6 in vertically.

5.4.3 DRE Technologies - Dry Dredge (Overall Rating - High)

The DRE Technologies - Dry Dredge is a relatively new environmental dredging technology that integrates a closed bucket mechanical dredge with a positive displacement pump for high solids dredged material transport.

Sediment Resuspension Minimization (Rating - High)

The resuspension minimization characteristics at the point of dredging appear to be good (high). With good operational controls the Dry-Dredge enclosed bucket should offer low resuspension of bottom sediments. The boom used to locate the bucket appears to provide good control and positioning accuracy of the bucket.

The sediment resuspension minimization rating of the Dry Dredge on an overall operation basis is high considering that it is a floating plant with pipeline transport system. The dredge advance mechanism is optimally a spud system from a production standpoint, however, the system could be configured to work on wires and anchors.

Percent Solids Maximization (Rating - High)

The Dry Dredge provides the highest percent solids concentration of any of the dredges with pipeline transport systems evaluated in this study, due to the use of a positive displacement pump. The clamshell is pressed into the dredge cut and closed with hydraulic chambers. Excavated sediments are screened, mixed, and pumped with solids contents as high as 70 percent solids by volume ~~weight~~ (65 ~~95~~ percent solids by weight ~~volume~~). The system has been designed to eliminate the need for large disposal areas and expensive water treatment facilities. The Dry Dredge has performed a number of small projects and demonstrated high percent solids excavation and transport.

Product Optimization (Rating - High)

The Dry Dredge 30 cubic feet model is advertised to have a production capacity of 75+ cy/hr. The maximum pumping distance of the dredge is 2,000 feet. It is not known how the dredge handles debris, or to what extent encountering significant large industrial debris would effect production capacity. The production output of the Dry Dredge would likely not be affected significantly by debris. The Dry Dredge appears to have not completed large scale environmental remediation dredging. The actual production capacity of the Dry Dredge is estimated at 50 cy/hr at the point of dredging. It is not known at this time whether an additional positive displacement booster pump can be used to extend the pumping distance of the Dry Dredge system up to the 4,000 to 6,000 feet required to reach the CDF along some pipeline routes. However, such a system seems possible.

Dredging Accuracy (Rating - High)

The excavation accuracy of the Dry Dredge is likely high due to the rigid boom connection between the excavator and barge. The Dry Dredge, making use of state-of-the-art positioning equipment, should be able to attain a dredging accuracy of +/- 20 inches in the horizontal plane and +/- 6 inches vertically.

5.4.4 Ellicott Hydraulic Dredge (Overall Rating - High)

An Ellicott 370 Dragon Series hydraulic cutterhead dredge performed the best of the three hydraulic dredges tested in the Pilot Dredging Study, and was subsequently used on the Hot Spot Dredging project in 1995.

Sediment Resuspension Minimization (Rating - High)

The resuspension minimization characteristics at the point of dredging for hydraulic cutterhead dredges have been documented to exceed those of other hydraulic and mechanical dredging systems. With good operational controls the hydraulic cutterhead dredge should offer the lowest resuspension of bottom sediments. It is advised that a valve be installed on the suction line to minimize backflushing and significant resuspension of sediments, when dredge pumping must cease to clear the cutterhead, suction pipe or pump of debris. Based on the Pilot and Hot Spot dredging projects, Debris is expected to be encountered on the full-scale remediation

The sediment resuspension minimization rating of a small hydraulic dredge on an overall operations basis is high considering that it is a floating plant with pipeline transport system. The dredge advance mechanism is a spud system that does provide another point source(s) of sediment resuspension. The system cannot effectively be configured to work on wires and anchors.

Percent Solids Maximization (Rating - Medium)

The Ellicott 370 provides typical percent solids concentrations for a hydraulic cutterhead dredge, which is not good. The dredge was able to attain a working percent solids concentration of 5 percent (by weight) on the Pilot Dredging study.

Product Optimization (Rating - High)

The Ellicott 370 should be capable of providing production rates in the 25 to 35 cy/hr range provided significant debris is not encountered. The hydraulic pipeline dredge system lends itself well to pumping long distances. For distances over approximately 3,000 feet. It is likely that the Ellicott 370 would require a booster pump to optimize production, however, this is a very standard technique with this type of equipment. As discussed, encountering significant large industrial debris will adversely effect production capacity on the hydraulic cutterhead dredge, more so than with a mechanical dredge.

Dredging Accuracy (Rating - Medium)

Hydraulic cutterhead dredges can be configured to work in "surgical" dredging mode. While the location of the cutterhead is more difficult to monitor against the dredge surface than an excavator bucket, advanced positioning systems can be used to locate the cutterhead in the horizontal and vertical planes with close accuracy. The Ellicott hydraulic cutterhead dredge could likely attain a dredging accuracy of +/- 20 inches in the horizontal plane and +/- 9 inches vertically.

5.4.5 Crawl Cat Cutter Suction Dredge - IHC Holland (Overall Rating - Low)

The Crawl Cat Cutter Suction Dredge, developed by the Dutch dredge developer IHC Holland, is essentially a hydraulic cutterhead dredge with legs. The Crawl Cat is an amphibious dredge in that it can work as a floating dredge, on tide flats, and along shorelines. The hydraulic cutterhead dredge is

mounted on a jackup barge with four independently controlled height adjustable trackpoles. Mobility of the dredge is provided by hydraulically driven tracks located at the base of each trackpole.

Sediment Resuspension Minimization (Rating - Low)

The resuspension minimization characteristics at the point of dredging for the Crawl Cat are much the same as that for the Ellicott or other hydraulic cutterhead dredge. With good operational controls the hydraulic cutterhead dredge should offer the lowest resuspension of bottom sediments at the point of dredging. It is advised that a valve be installed on the suction line to minimize backflushing and significant resuspension of sediments, when dredge pumping must cease to clear the cutterhead, suction pipe, or pump of debris. Based on the Pilot and Hot Spot dredging projects, debris is expected to be encountered on the full-scale remediation.

The sediment resuspension minimization rating of the Crawl Cat on an overall operations basis is low considering that it has four legs and crawler tracks that are always in contact with the bottom sediments.

Percent Solids Maximization (Rating - Medium)

The Crawl Cat likely provides typical percent solids concentrations for a hydraulic cutterhead dredge.

Product Optimization (Rating - High)

The theoretical production capacity of the Crawl Cat dredge working the Upper Harbor is good considering that the dredge could continue to operate in shallow areas where a comparable floating system would not be able to advance. However, because hydraulic suction dredge systems require water over the suction intake, it would likely not be able to work in water depths shallower than 2.5 to 3 feet. The Crawl Cat should be capable of providing production rates in the 25 to 35 cy/hr range provided significant debris is not encountered. The hydraulic pipeline dredge system lends itself well to pumping long distances with booster pumps.

Dredging Accuracy (Rating - Medium)

Hydraulic cutterhead dredges such as the Crawl Cat can be configured to work in "surgical" dredging mode. While the location of the cutterhead is more difficult to monitor against the dredge surface than an excavator bucket, advanced positioning systems can be used to locate the cutterhead in the horizontal and vertical planes with close accuracy. The Crawl Cat could likely attain a dredging accuracy of +/- 20 inches in the horizontal plane and +/- 9 inches vertically.

5.4.6 Low Ground Pressure (LGP) Track-Mounted Excavator (Overall Rating - Medium)

A variety of track-mounted excavators have been developed to access shallow water marsh environments for dike construction, dredge material disposal operations, pipeline crossings and other tasks where LGP vehicles are required. The primary manufacturers of these machines are the WILCO Company and Quality Industries, both located in Louisiana. Both companies adapt conventional backhoe, crane bucket, dragline, and other excavator types to ruggedized, self-propelled tracked assemblies that can travel over low bearing capacity soils and shallow water environments. Quality Industries also produces a floating amphibious tracked excavator that makes use of outboard pontoons and spuds for flotation and mobility in deeper water. Foster Wheeler Environmental Corporation successfully used this type of track-mounted excavator to excavate and transport PCB contaminated sediments to shore for treatment

on a sediment remediation project in New Jersey. These systems work optimally in shallow water depths and emergent shoreline and tide flats, and can turn 360 degrees.

Sediment Resuspension Minimization (Rating - Low)

With modifications to the excavator bucket with an enclosure and bucket material handling operational controls established, the point of dredging resuspension potential for the LGP track-mounted excavator is considered fair. The excavator bucket is probably the best digging tool in terms of debris handling. The production capacity and resuspension minimization characteristics of this system are minimally affected by debris.

The sediment resuspension minimization rating of the LGP track-mounted excavator on an overall operation basis is low due to the high degree of contact of the tracks with the bottom sediment.

Percent Solids Maximization (Rating - Medium)

The LGP track-mounted excavator can only operate in mechanical mode. There appears to be no efficient way of adapting a high slurry concentration transport system to the LGP track-mounted excavator, which has no deck space for a pump. The percent solids concentration can be as high 70 percent solids due to the mechanical excavation means of the LGP track-mounted excavator, but the material transport would have to be by haul barge or more likely over road using trucks.

Product Optimization (Rating - Medium)

The LGP track-mounted excavator would likely best perform on the project in a complementary role to the marine dredging operation. The LGP track-mounted excavator could perform well in the intertidal areas at low tide where the marine dredges are having difficulty accessing. The production capacity of the LGP track-mounted excavator would vary depending upon the bearing capacity of the intertidal sediments and the size equipment that could access the dredge areas. Production capacity of the LGP track-mounted excavator will also depend upon the available mode of material transport from the point of excavation to the CDF.

Dredging Accuracy (Rating - Medium)

The excavation accuracy of the LGP track-mounted excavator would be expected to be good (high) as the excavator is emergent, and the dredge prism is easily seen and measured. Where a floating track-mounted excavator might be used, the dredge could be outfitted with an excavator positioning system to provide real time excavator control while dredging below the waterline. It would be anticipated that the LGP track-mounted excavator could attain a dredging accuracy of +/- 20 inches in the horizontal plane and +/- 6 inches vertically.

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6.0 SUMMARY AND RECOMMENDATIONS

6.1 Background

New Bedford Harbor can be divided into an Upper Harbor area above the Coggeshall Street Bridge and the Lower Harbor below the Coggeshall Street Bridge. Shallow subtidal, intertidal, and marsh areas that limit the ability of floating equipment to operate one to two hours around high tide characterize the Upper Harbor. For example, in a large portion of the Upper Harbor, operations of 3 to 4 hours per tidal cycle can be expected. Deeper water exists in portions of the southern region of the Upper Harbor and at all of the contaminated areas of the Lower Harbor adequate for floating equipment to operate at all tide levels.

6.2 Decision Criteria

The following background factors that influence the decision-making process (including items identified in previous reports) are associated with this study.

1. Conventional hydraulic cutterhead pipeline dredging is capable of achieving cleanup criteria and minimizing resuspension/recontamination. However, very low overall solids content (5 percent during the Hot Spot dredging project) during conventional hydraulic dredging results in a significant volume of water requiring treatment.

2. All systems considered were estimated to be able to achieve comparable production rates of the equipment used in the Pilot and Hot Spot Dredging work of at least 25 to 35 cy/hour. Where tidal conditions allow operating days of 20 hours, daily production rates of 1,000 to 2,000 cy/day may be possible. However, when operating in shallow tidal and intertidal waters, daily production rates can drop to as low as 100 cy/day or less for a three hour operation window, regardless of equipment type. Deeper areas of (depths greater than 4 feet at MLW) Upper Harbor and all of the Lower Harbor dredging is expected to achieve the 1,000 to 2,000 cy/day production rates whether hydraulic or mechanical methods are used.

3. The extent, size, and amount of debris are unknown. While no additional information defining debris is available at this time, it is important to keep this issue in mind when analyzing dredge systems and select systems that either manage debris, or are only minimally impacted when debris is encountered.

6.3 Summary of Findings

For the purpose of this study, dredging equipment was divided into three components; point of dredging, support, and discharge.

6.3.1 Point of Dredging Components

At least two mechanical point of dredging components; (1) the DRE Dry Dredge Technologies Clamshell and; (2) the Level Cut Clamshell as part of the DRE-Technologies Dry Dredge and the BeanTEC Hydraulic Excavator *Bonacavor* have been rated high for their accuracy and precision to accomplish the work, and are effective in limiting resuspension. To further minimize resuspension the bucket can be washed in a clean water tank prior to each cut. Production rates are anticipated to be at least equal the hydraulic system used in the Pilot and Hot Spot dredging.

6.3.2 Support Components

Traditional hydraulic cutterhead dredge technology such as the Ellicott Hydraulic Cutterhead rated high.

Floating equipment cannot operate at low tides in shallow and intertidal areas and is disruptive to the bottom when grounded at low tides. However, floating equipment was proven to cause minimum resuspension after grounding.

Amphibious systems were identified and evaluated where possible. These systems rely on tracks or arms to move through or on the sediments, suggesting considerable "working" of the bottom sediments and thus real potential for resuspension/recontamination. The advantage of these systems is they are not as tidally dependent in the shallow and intertidal areas as is floating equipment. However, these systems require further evaluation because no specific reports or documentation were located that discussed resuspension.

6.3.3 Discharge Components

Two newer discharge components were identified. These include the DRE Dry Dredge Technologies positive displacement pump system, or the SPU as developed by Bean Dredging. When used in conjunction with the closed clamshell methods, solids content is significantly improved by both systems over conventional hydraulic methods, and production rates are anticipated to be equal to or better than hydraulic systems.

6.4 Recommendations

Any successful dredge system must be flexible and capable of modifications to operate in varying conditions typically encountered in the field.

6.4.1 Point of Dredging

The mechanical point of dredging BeanTEC Hydraulic Excavator *Bonacavor* and the DRE-Technologies Dry Dredge should seriously be considered for field testing of resuspension and production rates on the New Bedford Harbor sediments. It is envisioned that this test could be performed using smaller equipment off a small barge, with the dredged material placed on a barge for rehandling to the existing CDF. A water quality monitoring program should be performed to assess the system's resuspension potential.

Consideration should be given to field testing the high density pumping systems described above. However, it is recognized that while it is a fairly simple process to use available equipment to operate a specialty bucket, a considerable effort would be needed to set up and run a slurry pumping system.

If mechanical point of dredging equipment is found to have minimal resuspension effects with either operational controls or modified buckets, mechanical or hydraulic point of dredging methods are appropriate in both the shallow Upper Harbor, as well as the deeper Upper Harbor and all of the Lower Harbor areas to be dredged.

In the near shore marsh areas, low ground pressure equipment working on crane mats is likely the only alternative available. Use of this equipment may greatly expand the operating day for the contractor, reducing the total project time. Transport alternatives include the high solids or slurry systems for

pumping to a CDF, or if permitted, rehandling and trucking may be the only alternative to pumped discharge for these sediments.

6.4.2 Floating Equipment

Lacking further research on the resuspension potential of amphibious systems, it is recommended that floating equipment be used where water depths permit them to be operated even though daily operations may be limited to a short time during high tide.

Floating equipment requires water depth of approximately 4 feet, while land-based equipment can likely effectively work only marsh areas. Floating equipment is deemed acceptable as a means of supporting both hydraulic and mechanical dredge systems.

6.4.3 Land-Based Equipment

Based on the limits a land-based system can reach offshore, and a floating system can reach toward shore, a potential gap exists in the very shallow Upper Harbor intertidal zone between areas that can be reached by floating equipment and those that can be reached by land based equipment. An analysis is needed to determine if such a gap exists, how large it is, and how to go about dredging in this zone. While not specifically recommended pending further analysis, an amphibious system may be the only reasonable solution for this particular zone, and as with the marsh areas, would greatly expand the operating day for the contractor, reducing the total project time.

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APPENDIX A

New Bedford Harbor - Environmental Dredging Technology Matrix

New Bedford Harbor
Environmental Dredging Technology Matrix

DREDGE TECHNOLOGY	MANUFACTURER	DREDGE TYPE	STAGE	COUNTRY	PLANT SIZE	DRAFT (ft)	PRODUCTION CAPACITY (CY/HR)	SOLIDS CONCENTRATION (% SOLIDS BY WT)	DREDGE TOLERANCE (VERTICAL) (FT)	RESUSPENSION MINIMIZATION	MOBILITY	DEBRIS HANDLING	PROJECTS COMPLETED	LOCATION	MEDIA	QUANTITY (CY)
AMPHIBIOUS EXCAVATOR	Aquatrip Systems	Mechanical	Commercial	USA	0.5 cy	0.5	10 - 30	50% - 70%	0.8 - 1.0	Poor	Portable	Good				
AMPHIBIOUS EXCAVATOR (AMPHIBEX)	Normrock Industries, Inc.	Mechanical or Hydraulic	Commercial	Canada	0.5 cy / 8-in	1.5	15 - 55	5% - 70%	0.8 - 1.0	Poor	Portable	Good	Bluffer Park	Carborough, Ontano, Canada		46,000
													Welland River	Ontario, Canada	Metal residue	13,000
AQUAMOG	Aquatics Unlimited	Hydraulic or Mechanical Attachments	Commercial	USA	9-in	6 ft	20 - 55	5% - 70%	0.8 - 1.0	Good w/ operational controls	Portable	Good				
AUGER DREDGER (HAM 291)	HAM, Dredging and Marine Contractors	Hydraulic, adaptable to a Mud Cat	Commercial	Netherlands					0.5 - 1.0		Waterborne	Fair		Ketelmeer Lake, The Netherlands	silt, sand, peat	
BACKHOE DREDGE	Various	Mechanical	Commercial	USA	Various	8	50 - 100	60% - 80%	0.8 - 1.0		Waterborne, Portable	Good				
BARRACUDA	Dredging Supply Company	Hydraulic	Commercial	USA	8 - 12 - in	4	25 - 300	2% - 7%	1	Good w/ operational controls	Waterborne	Good				
BOVACAVOR ENVIRONMENTAL HYDRAULIC EXCAVATOR	Beaal Technical Excavation Corp.	Hydraulic or Mechanical	Commercial	USA	1 - 65 cy	3 - 10	60 - 70	10% - 60%	0.5	Good w/ operational controls	Waterborne	Good	Bunker Hill Superfund Remediation			100,000
CABLE ARM ENVIRONMENTAL BUCKET	Cable Arm, Inc.	Mechanical	Commercial	USA	1 - 65 cy	3 - 10	20 - 2000	60% - 90%	0.5	Good w/ operational controls	Portable	Good	Toronto Harbour	Great Lakes, Canada	contam	325
													Hamilton Harbor	Great Lakes, Canada	contam	
CLAMSHELL DREDGE (w/ digging bucket)	Various	Mechanical	Commercial	USA	1 - 65 cy	3 - 10	20 - 2000	60% - 80%	0.8 - 1.0	Poor	Waterborne	Good			Contaminated sediments	
CLAMSHELL DREDGE (w/ enclosed bucket)	Various	Mechanical	Commercial	USA	1 - 65 cy	3 - 10	20 - 2000	60% - 90%	0.8 - 1.0	Fair	Waterborne	Good			Contaminated sediments	
CLAMSHELL DREDGER (twin hull dredge, catamaran or mining)	IHC Holland	Mechanical	Commercial	Holland	1 - 15	3 - 5	20 - 300	60% - 80%	0.8 - 1.0	Fair	Waterborne	Good				
CRAWL-CAT CUTTER SUCTION DREDGER	IHC Holland	Hydraulic	Commercial	Holland	8 - 12 -in	6	25 - 320	2% - 7%	0.8 - 1.0	Poor	Truck	Fair				
CUTTER SUCTION DREDGER	IHC Holland	Hydraulic Cutterwheel	Commercial	Holland	8 - 12 -in	4.5 - 6	25 - 320	2% - 7%	0.8 - 1.0	Fair	Waterborne	Fair				
DEEP CUTTER-SUCTION DREDGER (LAURUM)	Ballast Nedam Dredging	Hydraulic	Commercial									Poor	Inland Reclamation	Woerden, The Netherlands	medium sand	1,700,000

New Bedford Harbor
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DOP SUBMERSIBLE DREDGE PUMPS	DE GROOOT NIJKERK	Hydraulic adaptable to a Mud Cat	Commercial	Holland							Portable	Poor				
DRY DREDGE MODEL 16-17-60	DRE Technologies	Mechanical (Sealed Clamshell), Positive Displacement Pump	Commercial	USA		2.5	40 - 60	20% - 50%	0.8- 1.0	Good	Portable	Good	Lake Dredging	Hendersonville, Tennessee		
													Maint. Dredging of chem. waterwater pond	Louisville, Kentucky		
													International Paper	Camden, Arkansas		
													Brown's Lake Dredging	Vicksburg, Mississippi		
EDDY PUMP	Soil-Flo LLC	Hydraulic	Inactive	USA	N/A	1.5	200 -300	60% - 80%	N/A	low turbidity	portable	Poor	Clapa Dam and Rock Creek 1994	Feather River, California	sand	10000
ENVIRONMENTAL DREDGER "ED"	Conbar International	Hydraulic	Commercial	Italy and UK		2						Fair				
ENVIRONMENTAL & HAZARDOUS DREDGE MODEL 8-180/245	Dredging Specialists	Hydraulic w/ Cutterhead	Commercial	USA						slurry pinch valve		Fair				
ENVIRONMENTAL DISC CUTTER (VECHT)	Baggermaatschappij Holland BV	Hydraulic, adaptable to a Mud Cat	Commercial	Netherlands								Fair		Ketelmeer Lake, *The Netherlands*	silt, sand, *peat*	
ENVIRONMENTAL DREDGER	IHC Holland N.V.	Cutter Suction Dredger	Full Scale Demo.	Netherlands								Fair				
ENVIRONMENTAL HYDRAULIC DREDGE	Consolidated Dewatering Inc.	Hydraulic - augerhead with separation of sludge and water	Inactive	Canada								Fair				
FLOATING CLAMSHELL DREDGE	American Mechanical Dredge	Mechanical	Commercial	Germany				60% - 80%			Waterborne	Good				
FLOATING PIER RECLAMATION METHOD	Toyo Construction Co. Ltd		Commercial	Japan			300 - 550				Disassemble from, reassemble					
HIGH-DENSITY SLUDGE TRANSPORT METHOD	Toa Corporation		Commercial	Japan			500 - 750									

New Bedford Harbor
Environmental Dredging Technology Matrix

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HORIZONTAL CLOSING ENVIRONMENTAL GRAB	Boggemeer-sharpt Bosman BV	Mechanical	Commercial	Netherlands								Good				
HYDRAULIC SUCTION DREDGE	Dredging Specialists	Hydraulic	Commercial	USA		need minimum of 60 cm	200-360	2% - 7%		low turbidity	setup: 10 days breakdown: 6 days	Fair	Baxter Water Treatment Plant 1994	Philadelphia, Pennsylvania	settling pond sediments	545,000
IRIS METHOD	Tri Corporation	Mechanical	Commercial	Japan			No.1: 100 No.3: 130 No.5: 130	70% - 80%			Hard ground					
MARSH BUGGY EXCAVATOR (3/4 cy - 13/4 cy)	Wilco Marsh Buggies & Draglines, Inc.	Mechanical	Commercial	USA	3/4 - 1 3/4 cy	shallow amphibious	50 - 200	60% - 80%	0.5-1.0	Poor	Portable / Land Based	Good				
MUD CAT	Ellicott International	Hydraulic horizontal screw auger mounted on a hydraul. oper. boom, 8" line	Commercial	USA	10 - 12 in	2.5	20 - 85	2% - 7%	0.8 - 1.0	low turbidity	portable	Fair				
												Fair	Cannon Mills Holding Pond	Concord, North Carolina	silt	170,000
												Fair	Upper Simmons Reservoir	Rhode Island		293,000
												Fair	Harbor Town Marina	Hilton Head, South Carolina	Silt	88,000
												Fair	Marina at Pleasure Island	Port Arthur, Texas	Silt	
												Fair	Test Demonstration	Ventura Keys, CA	Silt	
												Fair	Marathon Battery Superfund Project	Hudson River, New York	contam	
												Fair	Hartge Yacht Yard	Galesville, MD		
												Fair	Rod and Reel Marina	Chesapeake Beach		
												Fair	Fishing Creek Landing - Marina	Ches. Beach, MD		
												Fair	Herrington Harbor So.	Ocean City, MD		
												Fair	W. Ocean City Fishing Center	Ocean City, MD		
												Fair	Marsh Harbor W.	Ocean City, MD		
											portable	Fair				
										minimized	Portable	Fair	Silver Creek Reservoir	Silver Creek, New York	silt	15,000
												Fair				

New Bedford Harbor
Environmental Dredging Technology Matrix

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MUD CAT (MODIFIED)	Ellicott	Hydraulic	Commercial	Canada							Portable	Fair	Welland River	Canada	contam	
MUD CAT 370-MC915 MULTIFUNCTION DREDGE	Ellicott	Hydraulic	Commercial	USA				2% - 7%				Fair				
MUD CAT, SERIES 370	Ellicott	Hydraulic	Commercial	USA	12 in	2.5	20-65	2% - 7%			one truck	Fair	Hawk Cove Channel Dredging	Edgemere, Maryland		
NO. 1 WATER REFRESHER (HIGH DENSITY DREDGING SYSTEM)	Honma Corporation	Hydraulic	Commercial	Japan						low turbidity		Poor				
NO. 2 CLEAN SWEEPER	Wakachiku Construction Co. Ltd	Hydraulic, High Density Sludge Dredger	Full Scale Demo	Japan						low turbidity	portable					
OOZER-PUMP DREDGING METHOD	Toyo Construction Co. Ltd	Hydraulic	Commercial	Japan									Minamata Port 1983, Kasumigaseki Bottom-Sludge Project 1992, Barato River Project	Japan		
PIN POINT DREDGING	DE GROOT NIJKERK	Hydraulic														
PIRANHA	Dredging Supply Company	Hydraulic	Commercial	USA				2% - 7%				Yes				
PIT HOG DREDGE	Liquid Waste Technology, Inc.	Hydraulic	Commercial	USA			100 - 350				setup: 6 days breakdown: 5 days	Yes	City of Dallas Sedimentation Lagoon	Dallas, Texas	wastewater sludge	28,400
PNEUMA DREDGING PUMP	Pneuma s.r.l.	Pneumatic	Commercial	Italy			300 - 750	40 - 50%		low turbidity		Poor	Gibraltar Lake Restoration	Santa Barbara, California	silt, clay	933,400
													Collingswood Harbor, Environment Canada study	Canada	contam	
PNEUMATIC TYPE SAND PRESSURIZED DEEING SHIP	Penta-Ocean Construction Co. Ltd	Pneumatic	Commercial	Japan												
PONTOON / TRACK MOUNTED EXCAVATOR	Quality Industries	Mechanical	Commercial	USA	3/4 - 2 cy	shallow amphibious	50 - 200	60% - 80%	0.8- 1.0	Poor	Portable / Land based	Good				
PULSE AIR TYPE HIGH DENSITY SLUDGE TRANSPORT SHIP	Rinkai Construction Co. Ltd	Pneumatic	Commercial	Japan							Portable	Good	Chiba and Saijima Prefecture	Japan		65,000
REACT DREDGING SYSTEM	Bedrock Resources, Inc.	Hydraulic, Fluidization, Hopper Overflow	Bench Scale	Canada						Low Turbidity						

New Bedford Harbor
Environmental Dredging Technology Matrix

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ROTOMITE 180P	SRS Crisafulli	Hydraulic	Commercial	USA		6	200-300	8.2% avg			Portable	Good	City of Everett Wastewater Treatment Plant, Dredge Demonstration	Everett, Washington	sludge	
ROTOMITE SLUDGE DREDGE	CP Environmental	Hydraulic	Inactive	USA						Low Turbidity			Exhibit B 1992	Texas	mill waste	
SCOOP/SWEEP DREDGE	Dredging International		Commercial	Belgium						Low Turbidity		N/A				
SHARK	Dredging Supply Company	Hydraulic	Commercial	USA						Fair		Good				
SLICE CUTTER SUCTION DREDGER (WADDENZEE)	Ballast Nedam Dredging	Hydraulic, adaptable to a Mud Cat	Commercial	Netherlands						N/A		Good		Ketelmeer Lake, The Netherlands	silt, sand, peat	
SLUDGE VAC SERIES DREDGE	Dredging Specialists	Hydraulic Cutterhead	Commercial	USA						N/A		Good				
STUMP	Nautilus Dredge and Dock Co.	Hydraulic	Commercial	USA			sand/silt: 300slurry: 70-90 debris:40 - 60			Low Turbidity	Portable	Good				
SWAN METHOD	Penta-Ocean Construction Co. Ltd	Mechanical, Rotating Bucket Type	Commercial	Japan				80%		Low Turbidity		Poor	1994 Gamagori Port and Harbor Environmental	Aichi, Kanto Design		
TANK TYPE AIR PRESSURIZING METHOD (NOS. 1, 2, & 5)	Saeki Kensetsu Kogyo Co. Ltd	Pneumatic	Commercial	Japan			50 - 75				Portable					
TOYO PUMP DREDGE		Hydraulic													contaminated sediments	
TRAMROD DREDGE		Hydraulic / Submerged auger-type		USA											Sediments contaminated	
TRASH SKIMMER	Ellicott International			USA												
VACUUM CLAM DREDGE	Sanexen Environmental Services, Inc.	Hydraulic, Mechanical, Water to solids ratio minimized	Full Scale Demo	Canada		6	5 - 8			Low Turbidity	cycle: 10 days, breakdown: 5 days		Chippewa Creek Cleanup 1997	Welland, Ontario, Canada	Hydrocarbon sludge	1700
VERSI-DREDGE	Innovative Material Systems Inc.	Hydraulic	Commercial	USA												
VISCOUS EXCAVATOR	Dredging Supply Company, Inc.	Hydraulic	Commercial	USA												
VISOR GRAB	Hollandsche Aanneming Maatschappij bv	Mechanical	Commercial	Canada		6				Low Turbididty		Yes	Wayne Jones / Matchadash Bay	Matchadash Bay, Ontario	50% wood waste mixed with silt	

New Bedford Harbor
Environmental Dredging Technology Matrix

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WATER-REFRESHER HD-110	Honma Corporation	Hydraulic	Full Scale Demo	Japan				High Density			10 ton truck/trailer	No				
WATERMASTER	Aquamec Ltd	Mechanical Fluidization	Commercial	Finland								Yes				
WESTERN DREDGER	Western Dredge Inc.	Hydraulic	Commercial	USA								Yes	[illegible]	[illegible]	[illegible]	[illegible]
YOUNGSMAN, WEED AND SEDIMENTATION REMOVAL	Marine Construction and Dredging, Inc.	Hydraulic, Fluidization	Commercial	USA		6						Yes				