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FINAL DRAFT DETAILED ANALYSIS OF REMEDIAL TECHNOLOGIES FOR THE NEW BEDFORD HARBOR FEASIBILITY STUDY

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EBASCO

REM III PROGRAM

REMEDIAL PLANNING ACTIVITIES AT SELECTED UNCONTROLLED HAZARDOUS SUBSTANCE DISPOSAL SITES WITHIN EPA REGIONS I-IV

EPA CONTRACT 68-01-7250

EBASCO SERVICES INCORPORATED

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NOTICE

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NOTICE

The costs for the remedial technologies that are presented in this report are estimated for a stated set of conditions such as volume of sediment removed, equipment capacities and production rates, and containment volumes. These conditions do not represent optimized solutions for implementing the remedial technologies. An analysis of cost versus site-specific and process-specific variables will be incorporated into the detailed evaluation of remedial alternatives as part of the New Bedford Harbor FS.

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EXECUTIVE SUMMARY

INTRODUCTION

This report presents the results of the detailed analysis of potential non-removal, removal, treatment and disposal remedial technologies for PCB- and metals-contaminated sediment in New Bedford Harbor. This analysis was conducted in accordance with CERCLA Feasibility Study (FS) guidelines (EPA OERR/OWPE, June 1985), the requirements of the revised National Contingency Plan (NCP) effective February 1986, and the Superfund Amendments and Reauthorization Act (SARA) of October 1986.

The purpose of this work was to analyze potentially applicable technologies for New Bedford Harbor on the basis of three major criteria: effectiveness, implementation, and cost. The effectiveness of each technology was assessed on the basis of reliability and whether it would significantly and permanently reduce the toxicity, mobility, or volume of hazardous constituents. The implementation of a technology considered factors relating to the technical, institutional, and administrative feasibility of installing, monitoring, and maintaining that technology. The costs associated with a specific technology were estimated on the basis of direct and indirect capital costs, and operation and maintenance expenses.

Potential impacts to public health and the environment were considered. However, attainment of federal and state applicable or relevant and appropriate requirements (ARARs) for the protection of public health and the environment will be evaluated in depth during the detailed analysis of remedial alternatives.

As a result of this detailed analysis, technologies determined to be applicable for New Bedford Harbor will be used in the scoping, and subsequent screening and analysis of remedial alternatives.

The following paragraphs provide a brief description of the technologies analyzed and their applicability to the Hot Spot, Estuary, and Lower Harbor and Bay feasibility study areas. Figure E-1 summarizes the technologies that were retained for subsequent development of remedial alternatives. Table E-1 summarizes the cost estimates for each of the technologies retained.

NON-REMOVAL TECHNOLOGIES

CAPPING

Capping has been retained as an applicable technology for selected areas of New Bedford Harbor. Capping of the contaminated sediments would significantly reduce the mobility and hence the bioavailability of the contaminants. Natural materials such as

NON-REMOVAL

- CAPPING
- HYDRAULIC CONTROLS
  - EARTHEN EMBANKMENTS
  - SHEETPILE
- SOLIDIFICATION

REMOVAL

- HYDRAULIC DREDGES
  - CUTTERHEAD
- SPECIAL PURPOSE DREDGES
  - REFRESHER
  - PNEUMA
  - MUDCAT
- EXCAVATION
  - WATERTIGHT CLAMSHELL

TREATMENT

(SEDIMENT)

- THERMAL
  - INCINERATION
- PHYSICAL
  - SOLVENT EXTRACTION
  - SUPERCRITICAL FLUID EXTRACTION
  - SOLIDIFICATION
  - VITRIFICATION
- CHEMICAL
  - ALKALI METAL DECHLORINATION
- BIODEGRADATION

(WATER)

- DEWATERING
  - BELT FILTER PRESS
  - GRAVITY THICKENING
  - PLATE & FRAME PRESS
  - VACUUM FILTRATION
- TREATMENT
  - COAGULATION/ FLOCCULATION/ PRECIPITATION
  - SEDIMENTATION
  - FILTRATION
  - CARBON ADSORPTION

DISPOSAL

- IN-HARBOR
- SHORELINE
- UPLAND
- OFFSITE
- OCEAN

FIGURE E-1
TECHNOLOGIES RETAINED FOR DEVELOPMENT OF REMEDIAL ALTERNATIVES
NEW BEDFORD HARBOR

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TABLE E-1

COST ESTIMATES* FOR REMEDIAL TECHNOLOGIES
RETAINED AFTER DETAILED ANALYSIS
NEW BEDFORD HARBOR

Technology	Basis of Cost Estimates	Cost Range (Millions)
NON-REMOVAL		
Capping		
Hot Spot (>2000 ppm)	20 acres	6.5 - 10.0
Estuary	100 acres	50.0 - 65.0
Lower Harbor (>50 ppm) & Bay	50 acres	4.1 - 4.8
Hydraulic Controls		
Hot Spot (>2000 ppm)	Earthen Embankment	2.8 - 3.7
	Sheetpile	4.3 - 5.9
Other Areas (>50 ppm)	Earthen Embankment	1.2 - 4.9
	Sheetpile	2.0 - 7.0
Solidification		NA
REMOVAL		
Hydraulic Dredge (Cutterhead)	10^4 - 10^6 cy	0.2 - 3.5
Special Purpose (Mudcat)	10^3 - 10^6 cy	0.15 - 3.4
TREATMENT (SEDIMENT)		
Incineration	10^4 - 10^6 cy	6.0 - 600.0
Vitrification	10^4 - 10^6 cy	8.0 - 800.0
Solidification	10^4 - 10^6 cy	2.3 - 96.0

* Cost estimates do not include costs of supporting requirements.

TABLE E-1 (cont.)

COST ESTIMATES* FOR REMEDIAL TECHNOLOGIES
RETAINED AFTER DETAILED ANALYSIS
NEW BEDFORD HARBOR

Technology	Basis of Cost Estimates	Cost Range (Millions)
Solvent Extraction	5×10^5 cy	102.0
Supercritical Fluid Extraction	5×10^5 cy	108.0
KPEG	5×10^5 cy	94.0
Biodegradation	10^5 cy	10 - 20
TREATMENT (WATER)		
Dewatering	$10^4 - 10^6$ cy	5.0 - 36.6
Water Treatment	$10^4 - 10^6$ cy	1.3 - 13.5
DISPOSAL		
Ocean Dumping	$10^4 - 10^6$ cy	0.1 - 3.6
Shoreline (unlined)	$10^4 - 10^6$ cy	1.8 - 36.0
Upland	$10^4 - 10^6$ cy	5.0 - 52.0
Offsite	$10^4 - 10^6$ cy	2.7 - 270.0
Island Construction	10^6 cy	20.0

* Cost estimates do not include costs of supporting requirements.

clean sediments, sands, and gravel would be used for the cap. Clay caps are not recommended due to: (1) low bearing strength of in situ sediments preventing compaction of the clay; (2) high rates of erosion and scouring of unconsolidated clay; and (3) excessive length of time for clay to settle in the deeper subaqueous areas. Caps constructed from geotextiles or impermeable membranes would not be practicable due to the logistical problems of placement, seaming, and prevention of sediment resuspension during installation operations. Capping will be considered for the Hot Spot area (approximately 26 acres), and areas in the estuary (approximately 100 acres) and Lower Harbor and Bay (approximately 50 acres) where PCB concentrations are in excess of 50 ppm in the sediment. The use of hydraulic controls will be required in the Hot Spot and Estuary during installation of a cap. Placement of caps in the Lower Harbor and Bay would be conducted using subaqueous diffusers.

HYDRAULIC CONTROLS

Hydraulic controls, such as sheet piles and earthen embankments or dikes, are considered to be applicable for use at New Bedford Harbor only when used in conjunction with a suitable in situ treatment technology that stabilizes or detoxifies contaminated sediments. Hydraulic controls coupled with in situ treatment would significantly reduce the mobility of PCBs. Six areas within New Bedford Harbor have been identified as potential candidates for applying hydraulic controls. These discrete areas range in size from 2.1 to 32.6 acres.

IN SITU BIODEGRADATION

In situ biodegradation has been eliminated from further consideration as a treatment technology for New Bedford Harbor sediments. Although extensive research on in situ biodegradation of PCBs is being conducted in the academic and industrial sectors, no conclusive demonstrations have been performed either on the bench-scale or pilot-scale level.

SOLIDIFICATION

Pending further information, in situ solidification has been retained for potential application in selected areas of New Bedford Harbor such as the Hot Spot in the Upper Estuary or in deeper areas of the Lower Harbor. This technology would significantly reduce the mobility of PCBs in the sediments. Although in situ solidification of sediments has not been demonstrated in the United States, a number of solidification projects have been conducted in Japanese harbors using the deep cement mixing (DCM) method to solidify and strengthen sediments. Bench-scale tests would need to be conducted to determine the feasibility and optimal conditions (i.e., solidification agent, depth of solidification) for solidifying sediments in New Bedford Harbor.

REMOVAL TECHNOLOGIES

MECHANICAL DREDGES

Mechanical dredges evaluated in this report were the clamshell dredge and the watertight clamshell dredge. Both dredges were determined to be unsuitable for use at New Bedford Harbor due to: (1) excessive vessel draft and insufficient vertical clearance under the Coggeshall Bridge preventing access and subsequent use of these dredges in the Upper Estuary; (2) excessive volumes of dredged sediment from overexcavation due to limited control over vertical accuracy; and (3) greater resuspension of sediments during dredging operations compared with other dredging technologies (e.g., hydraulic dredges).

HYDRAULIC DREDGES

The cutterhead dredge has been selected as the best hydraulic dredge technology for removing sediments in areas of New Bedford Harbor with a water depth of ten feet or less. Operational controls and structural modifications of this dredge will allow the removal of contaminated sediments with minimal overexcavation and sediment resuspension. The operational controls should include electronic positioning of the dredgehead and monitoring and regulation of cutterhead rotation and horizontal swing speed. Structural modifications should include installation of a hood over the dredgehead to minimize suspended sediment migration and the use of an 8- to 10-inch Eddy dredge pump, which has a greater pumping efficiency at higher solids compared to the centrifugal dredge pump.

SPECIAL PURPOSE DREDGES

Three special purpose dredges have been retained for use in New Bedford Harbor. The MUDCAT dredge, a small hydraulic dredge equipped with a horizontal auger, can be used in all areas of the Estuary (including the Hot Spot) and in areas of the Lower Harbor and Bay with water depths of ten feet or less. High production efficiencies, coupled with a high degree of control over dredging precision and accuracy, make the MUDCAT an ideal dredge to use in removing contaminated sediment with minimal resuspension. The pneuma pump dredge and the refresher dredge were identified as possible back-up dredge systems for selected areas of New Bedford Harbor.

EXCAVATION

The watertight clamshell was retained as an excavation technology suitable for use in shoreline areas (in both the Estuary and Lower

Harbor and Bay) inaccessible by a conventional dredge. The watertight clamshell is essentially a modification of a conventional clamshell bucket and is designed to minimize the draining of free water and hence sediment resuspension as the water impacts the sediment.

TREATMENT TECHNOLOGIES - SEDIMENT

ADVANCED BIOLOGICAL METHODS

Advanced biological methods for treatment of PCBs in new Bedford Harbor sediments have been retained, pending further information. Biological treatment of the contaminated sediments would result in reduction of the toxicity and volume of the PCB residues. The results of planned bench-scale tests are needed to determine the feasibility and optimal process conditions for biodegradation of New Bedford Harbor sediments.

SOLVENT EXTRACTION

The amine-based B.E.S.T. process and the supercritical fluid process of CF Systems are potentially applicable solvent extraction technologies for New Bedford Harbor sediments. Both processes would permanently and significantly reduce the toxicity and volume of PCB-contaminated sediments by physically removing the PCBs in the liquid phase of the extraction process. The

B.E.S.T. process has been successfully implemented on a full-scale to treat oil sludge waste contaminted with PCBs. However, the results of planned bench-scale tests are needed for both processes in order to determine the feasibility and optimal process conditions for treating PCB-contaminated sediments in New Bedford Harbor.

SOLIDIFICATION

Solidification will be retained as a potential treatment technology for New Bedford Harbor sediments, pending further information. Solidification is a proven technology for substantially reducing the mobility and toxicity of inorganic contaminants. The technology is not well proven for organics, although demonstration projects for the solidification of organics are currently underway, including a project being performed as part of the Superfund Innovative Technology Evaluation (SITE) program. The results of planned bench-scale tests are needed to determine the feasibility and optimal process conditions for the solidification of New Bedford Harbor sediments.

VITRIFICATION

Although vitrification has not been demonstrated for sediments, this treatment technology will be retained pending the results of bench-scale testing in the fall of 1987. Vitrification would permanently reduce the toxicity, mobility, and volume of the contaminated sediments by destroying organics and immobilizing inorganics in a glass-like product.

ALKALI METAL DECHLORINATION (KPEG)

The potassium-polyethylene glycol (KPEG) process has been retained for possible application at New Bedford Harbor. The KPEG process would permanently and significantly reduce the toxicity of PCB-contaminated sediments by removing chlorine atoms from the PCB molecules leaving a dechlorinated, and much less toxic, biphenyl molecule as a residue. Although KPEG is not a field-proven process, bench and pilot scale tests results at other sites indicate that KPEG may work at New Bedford. Bench scale testing of New Bedford Harbor sediments will be conducted during the fall of 1987.

INCINERATION

Incineration is a well proven treatment technology for the destruction of organics and is considered to be the most reliable of the destruction/detoxification processes for treating New Bedford Harbor sediments. Post treatment steps may be required to treat metals in the sediment. Combined with a solidification step for the ash, incineration would provide a permanent and significant reduction in the mobility and toxicity of PCBs in New Bedford Harbor sediments.

SUPERCRITICAL WATER OXIDATION

It has been determinined that supercritical water oxidation is not a feasible treatment process for New Bedford Harbor sediments. The process has not been demonstrated to be feasible for use on sediments on even the bench scale level. Furthermore, at solids concentrations which could reasonably be handled at high pressures (20 percent solids or less), the costs of processing sediments are significantly higher than incineration which would achieve the same benefits with greater reliability at lower cost.

TREATMENT TECHNOLOGIES - WATER

DEWATERING

Sediment dewatering will be a necessary support activity for many of the removal, treatment, and disposal actions implemented at New Bedford Harbor. Four dewatering technologies have been found to be applicable for dewatering New Bedford Harbor sediments: (1) belt filter press; (2) gravity thickening; (3) plate and frame press; and (4) vacuum filtration. Each of these dewatering technologies has been effectively used to dewater industrial and municipal wastewater treatment sludges for years. Dewatering of New Bedford

Harbor sediments will serve to reduce the volume of sediment to be treated or disposed, and will reduce the energy requirements of any thermal treatment process or other processes requiring a reduced moisture content feed stream.

WATER TREATMENT

Water treatment will be a necessary support activity for sediment removal, dewatering, treatment, and disposal actions implemented at New Bedford Harbor. The primary benefit of water treatment is the permanent reduction in the toxicity and mobility of PCB and toxic metals present in the effluents produced by the remedial processes. A water treatment process train applicable for treating remedial process effluents at New Bedford Harbor would consist of the following technologies: coagulation/flocculation/precipitation, sedimentation, filtration, and carbon adsorption. The component technologies of this process train have been successfully demonstrated for years at industrial and municipal wastewater treatment facilities.

DISPOSAL TECHNOLOGIES

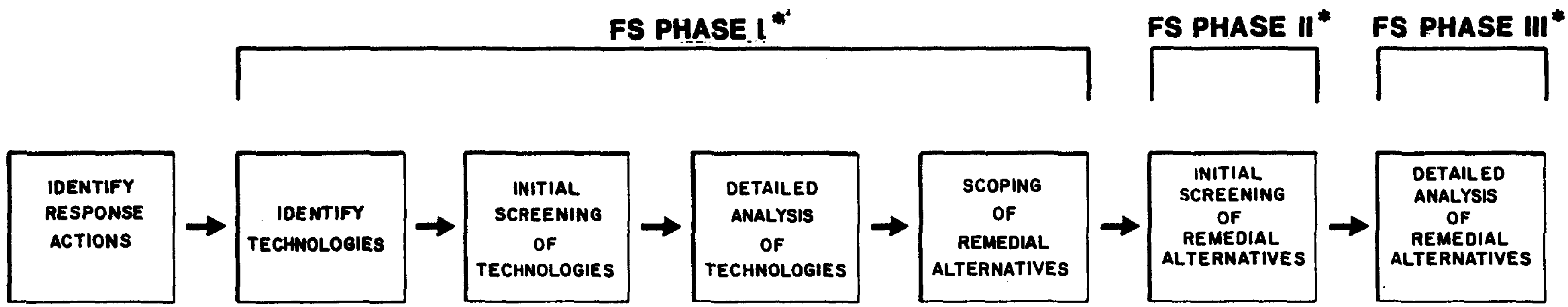
Five siting options have been identified for the disposal of New Bedford Harbor sediments: (1) in-harbor, including confined aquatic disposal (CAD) cells and island construction; (2) shoreline facilities constructed of earthen and/or synthetic materials; (3) upland sites within a 10-mile radius of the harbor that could be developed as secure landfills; (4) offsite approved chemical waste landfills; and (5) designated ocean disposal sites. With the exception of the CAD cell alternative, which is currently being evaluated by the U.S. Army Corp of Engineers (USACE), all of the siting options are technically feasible to construct and contain dredged sediments.

1.0 INTRODUCTION

1.1 PURPOSE

This report describes the detailed analysis of potential removal, non-removal, detoxification/destruction, and disposal actions/technologies for the PCB- and metals-contaminated sediment in New Bedford Harbor. The analysis has been conducted under Tasks 18, 19, 21, 23, and 24 of the New Bedford Harbor Feasibility Study. This work builds upon the results of the initial screening and review of remedial actions/technologies discussed in previous reports: "Non-Removal and Removal Technologies: Initial Screening Report," (E.C. Jordan, April 1987); "Detailed Evaluation of Detoxification/Destruction Technologies: Initial Screening Report," (E.C. Jordan, January 1987); and "Description of Alternate Disposal Sites Ranking and Selection," (E.C. Jordan, November 1986).

The detailed analysis of technologies is the third step in Phase I of the FS process as outlined in the EPA OWSER Directive, "Interim Guidance on Superfund Selection of Remedy" (December 24, 1986). Figure 1.1 shows the FS process for New Bedford Harbor. As a result of this detailed analysis, actions/technologies determined to be applicable for New Bedford Harbor will be used in the scoping of remedial alternatives in the last step of FS Phase I.



* **EPA OSWER DIRECTIVE DECEMBER 24, 1986:**
"INTRIM GUIDANCE ON SUPERFUND SELECTION OF REMEDY"

FIGURE 1-1
FS PROCESS FOR NEW BEDFORD HARBOR

Non-removal actions are those technologies which control exposure to, contain, isolate or treat by biological, chemical, or physical means, the PCBs and metals in sediments without removing the sediments.

Removal actions are those technologies which would remove PCBs and metals from the harbor bottom by removing sediment where the contaminants are located.

Detoxification/destruction technologies are those treatments which destroy PCBs or which render the PCBs/metals less toxic and/or less mobile by chemically or physically altering these compounds. Consideration of detoxification/destruction technologies is consistent with the emphasis in SARA on permanent remedies which significantly and permanently reduce the mobility, toxicity, or volume of hazardous wastes.

The non-removal, removal, detoxification/destruction, and disposal technologies subjected to detailed analysis are presented in Figure 1-2.

1.2 REPORT ORGANIZATION

This report presents a voluminous amount of material compiled during the detailed analysis of technologies. The information in this report will serve as the primary resource for conducting

NON-REMOVAL

- CAPPING
- HYDRAULIC CONTROLS
  - EARTHEN EMBANKMENTS
  - SHEETPILE
- SOLIDIFICATION
- BIODEGRADATION

REMOVAL

- MECHANICAL DREDGES
  - CLAMSHELL
  - WATERTIGHT CLAMSHELL
- HYDRAULIC DREDGES
  - CUTTERHEAD
  - PLAIN SUCTION
  - HOPPER
- SPECIAL PURPOSE DREDGES
  - CLEAN-UP
  - REFRESHER
  - AIRLIFT
  - PNEUMA
  - OOZER
  - MUDCAT
- EXCAVATION
  - DRAGLINE
  - CLAMSHELL
  - WATERTIGHT CLAMSHELL

TREATMENT (SEDIMENT)

- THERMAL
  - INCINERATION
  - SUPERCRITICAL WATER OXIDATION
- PHYSICAL
  - SOLVENT EXTRACTION
  - SUPERCRITICAL FLUID EXTRACTION
  - SOLIDIFICATION
  - *VITRIFICATION*
- CHEMICAL
  - ALKALI METAL DECHLORINATION
- BIODEGRADATION

(WATER)

- DEWATERING
- TREATMENT

DISPOSAL

- IN-HARBOR
- SHORELINE
- UPLAND
- OFFSITE
- OCEAN

FIGURE 1-2
TECHNOLOGIES FOR DETAILED EVALUATION
NEW BEDFORD HARBOR

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subsequent steps in the FS process: scoping, screening, and detailed analysis of remedial alternatives.

Chapter 2.0 provides an overview of the problem at New Bedford Harbor. The study areas currently being addressed in the New Bedford Harbor FS are described in terms of their physical features and location. Physical characteristics of the sediments in each of the study areas is discussed and the range of concentrations of PCBs and metals found in the sediments are described.

Chapter 3.0 discusses the criteria that were used for the detailed analysis of technologies.

Chapters 4.0 through 8.0 present the detailed analysis of technologies grouped in non-removal, removal, treatment (with sections for both sediment and water), and disposal categories. Technologies within each category are discussed in separate sections. Each section begins with a qualitative description of the technology followed by a detailed discussion of the effectiveness, implementation, and cost analysis conducted for that technology. A summary at the end of each section presents the conclusions on the applicability of that technology for use at New Bedford Harbor. Report references are compiled at the end of this report.

2.0 PROBLEM DEFINITION

The selection of non-removal and/or removal technologies is dependent on the physical characteristics, sediment types, and contaminant concentration in each of the three geographical study areas within the New Bedford Harbor site.

2.1 DESCRIPTION OF STUDY AREAS

The areas being studied for non-removal/removal response action of the contaminated sediments are: the Acushnet River Estuary area, the Hot Spot area within the Estuary, and the Lower New Bedford Harbor and Upper Buzzards Bay area (Figure 2-1).

2.1.1 Acushnet River Estuary

The Acushnet River Estuary is defined as the section of the Acushnet River between the Wood Street Bridge to the north and the Coggeshall Street Bridge to the south. A mean low water volume of 25,524,000 cubic feet has been estimated for this area. At mean high water this area encompasses approximately 202 acres. Water depths associated with the Estuary vary considerably. At mean low water the greatest water depth is 18 feet at the Coggeshall Street Bridge. Following the center of the river channel north towards the Wood Street Bridge the water depth drops to six feet and reaches two feet at the Estuary head. Mean tidal ranges are 3.8

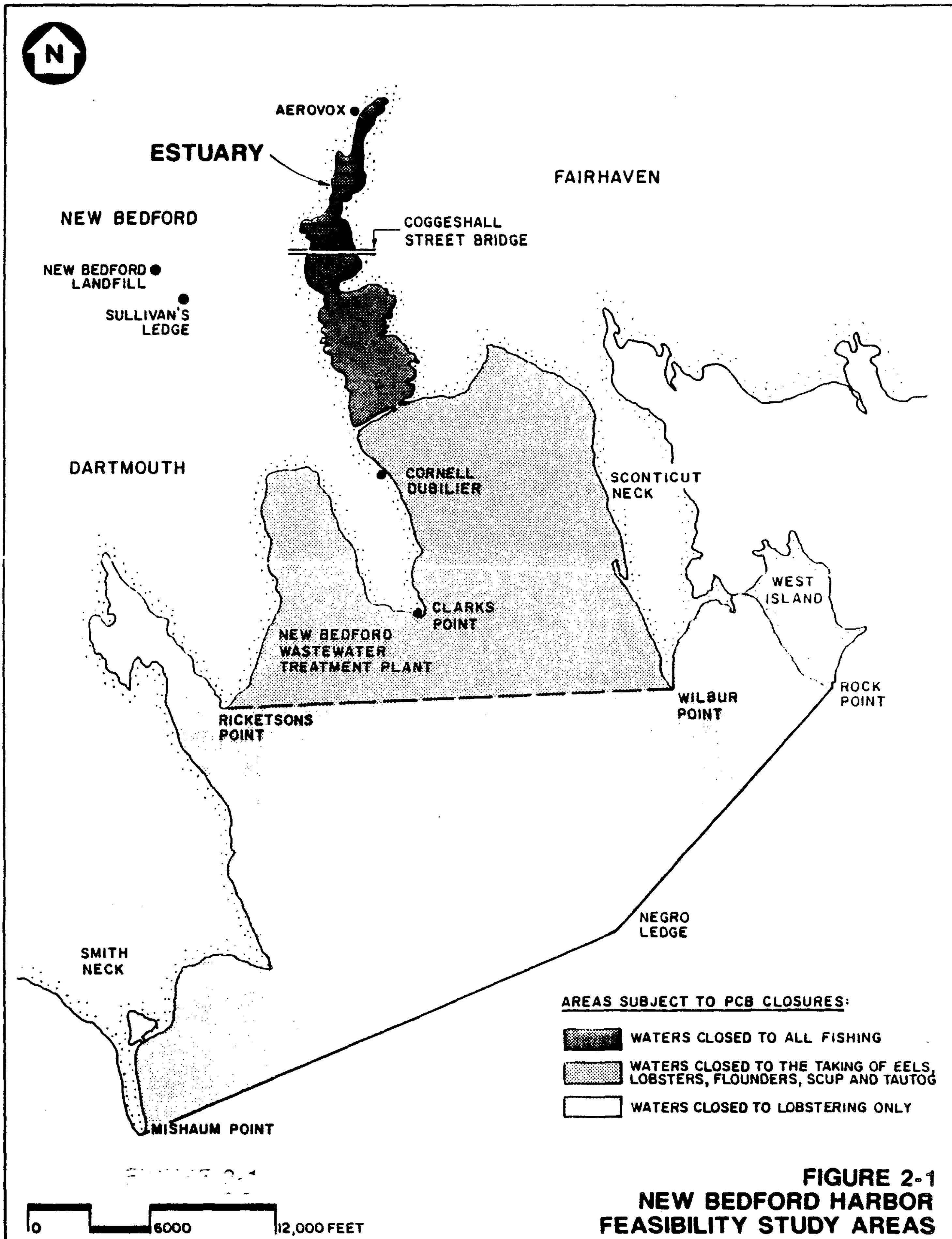


FIGURE 2-1
NEW BEDFORD HARBOR
FEASIBILITY STUDY AREAS

feet for the Acushnet River Estuary with a maximum difference between alternate tides of 1.2 feet. The tidal prism for this area is estimated at 65,644,000 cubic feet for a full 13 hour cycle time. The number of tides necessary for all the water in the Estuary to be changed is approximately 1.4. It is estimated that the Acushnet River has an annual average fresh water discharge of 30 cfs. Dry periods of the year are likely to yield no fresh water flow at all (NUS, 1984).

2.1.2 Hot Spot Area

The Hot Spot area within the Estuary is an area of approximately 3 acres located on the western bank of the Acushnet River directly adjacent to the Aerovox Corporation facility. The water bottom slopes gently from the shoreline towards the center of the river channel. Low tide exposes much of the Hot Spot area as mudflats. Mean low water depths range from -1.6 to 2.2 feet.

2.1.3 Lower Harbor and Bay

The Lower New Bedford Harbor and associated Upper Buzzards Bay area is the largest geographically defined study area. The Lower New Bedford Harbor is considered to be the body of water inside the hurricane barrier and south of the Coggeshall Street Bridge. Its area is approximately 747 acres. Water depths typically range between 6 and 12 feet except adjacent to the federal and state maintained ship channel which is 30 to 35 feet deep. Tide driven currents are usually less than 1 foot per second. Those at the entrance to the hurricane barrier are recorded to be approximately 4 feet per second. Water drains from the harbor into the bay along the water bottom and fills the harbor from the bay in the upper water column (Summerhayes, WHOI, 1977). The portion of Buzzards Bay included within the Harbor/Bay study area is greater than 5,000 acres. It includes the area between Mishaum Point on Smith Neck, to Negro Ledge to Rock Point on West Island. This area is transected by the Fort Phoenix Reach of the New Bedford Harbor ship channel. Water depths in the Bay vary from tidal flats near shore to 35 feet in the channel.

The seawater circulation in this portion of Buzzards Bay is not well documented. A net counter-clockwise flow pattern is, however, most likely. Available physical oceanographic data indicate that the seawater flow out of the harbor follows along the western shore and funnels southerly out of Buzzards Bay (Battelle, 1984).

2.2 PHYSICAL CHARACTERISTICS OF SEDIMENTS

Acushnet River Estuary sediments are comprised largely of fine particles. Grain size analysis has shown that 40 to 80 percent of the sediments in the Estuary pass through a U.S. Standard No. 200

sieve. Sediments in the Hot Spot area are 75 to 80 percent silts and marine clays with 20 to 25 percent of the grains not passing the 200 mesh sieve (sands). Sediment samples taken in the Lower Harbor and Bay area show an average of approximately 60 percent sands increasing in a seaward direction to 90 percent. The greater sand concentrations trend towards the center of the waterways. Dewatering of the sediments in some areas would be necessary for implementing several of the technologies being considered.

Sediments in the Estuary were determined to be comprised of predominantly organic silts with some silty sands. Lower Harbor sediments showed less plasticity with predominantly silty sands being present along with some organic silts.

Organic content determination was done for the estuarine sediments only. Organic content ranged from 2.99 to 22.9 percent with the majority of the measurements falling at approximately 12 percent.

2.3 PCBs AND METALS CONCENTRATIONS

Contaminant levels vary widely throughout the three study areas. PCBs and metals concentrations have been identified in all areas but do not necessarily coincide with one another. Metals of concern identified to date are cadmium, chromium, copper, and lead. PCBs and metals concentrations are generally higher in the Estuary. Both PCBs and metals are found to be concentrated near combined sewer outfalls in all areas.

TABLE 2-1

APPROXIMATE RANGE OF PCB AND METALS CONCENTRATIONS IN SEDIMENT

Area	PCBs	Metals
Estuary	0-5000 ppm	0-7000 ppm
PCBs Hot Spot	8,000-54,000 ppm	0-4000 ppm
Harbor/Bay	0-100 ppm	0-3000 ppm

2.4 OTHER CONTAMINANTS

Additional chemical analyses have been conducted on selected sediment samples from the Upper Estuary and Lower Harbor/Bay. The results, summarized in Table 2-2, indicate the presence of polyaromatic hydrocarbons (PAHs), polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs).

TABLE 2-2
APPROXIMATE RANGE OF PAHs, PCDDs, AND PCDFs
IN SEDIMENT

CONTAMINANT		CONCENTRATION RANGE
PAHs		3.2 - 148 mg/kg
PCDDs:	2,3,7,8-TCDD	4 pg/g
	Other Congeners	17 - 7370 pg/g
PCDFs:	2,3,7,8-TCDF	10 - 1440 pg/g
	Other Congeners	n.d. - 1510 pg/g

Note: PAHs expressed as total PAHs equal to the sum of parent compounds and homologs

The locations of these contaminants do not appear to be correlated with areas of PCB concentrations. Concentrations of PAHs have been found to be less than concentrations of PCBs except for select areas. These areas will be evaluated in the overall risk assessment should they warrant remedial action on the basis of PCB concentrations. Of the PCDDs and PCDFs detected, 2,3,7,8-TCDD and 2,3,7,8-TCDF are toxicologically more important relative to a potential threat to human health and the environment. However, a preliminary risk assessment of these compounds indicates that given the large concentration differences between PCBs and PCDDs, and PCBs and PCDFs, the risk associated with direct contact and/or ingestion of sediments will be driven by the PCBs.

3.0 CRITERIA FOR DETAILED ANALYSIS OF TECHNOLOGIES

The detailed analysis of remedial technologies was conducted in accordance with CERCLA FS guidelines (EPA OERR/OWPE, June 1985), the requirements of the revised National Contingency Plan (NCP) (40 CFR 300.68) effective February 1986, and the Superfund Amendments and Reauthorization Act (SARA) of October 1986.

The criteria used for the detailed analysis of technologies were grouped into three categories: effectiveness, implementation, and cost. Figure 3-1 summarizes the analysis process and the criteria. Table 3-1 presents the factors considered for each criterion and the reference to the appropriate requirement(s)/guidance documents.

The effectiveness of each technology was assessed on the basis of technical reliability and whether or not it would significantly and permanently reduce the toxicity, mobility, or volume of hazardous constituents. Potential impacts to public health and the environment were considered. However, attainment of federal and state ARARs for the protection of public health and the environment will be considered during the detailed analysis of remedial alternatives.

The implementation of a technology at New Bedford Harbor considered factors relating to the technical, institutional, and

TABLE 3-1
CRITERIA FOR DETAILED ANALYSIS OF REMEDIAL [1,2,3]
TECHNOLOGIES AND ALTERNATIVES
NEW BEDFORD HARBOR FS

CATEGORY	CRITERIA	FACTORS TO CONSIDER	REQUIREMENT/GUIDANCE
	- Adverse Effects	- Persistence, toxicity, mobility, and propensity to bioaccumulate hazardous wastes	SARA 121(b)(1)(C)
		- Reversible/irreversible effects to environmentally sensitive areas and resources	CERCLA 6.2.2
		- Potential threat to (human health and) the environment associated with excavation, transportation, and redisposal or containment	SARA 121(b)(1)(G)
		- Methods of mitigation and costs of mitigation of adverse impacts	NCP 300.68(h)(vi), CERCLA 6.2.2.2
		- Extent to which alternative meets or exceeds federal or, if more stringent, state ARARs governing protection of the environment	SARA 121(d)(1), NCP 300.68(h)(iv)
Implementation	Technical Feasibility	- Site- and waste-specific characteristics	CERCLA 3.1.1
	Level of Development	- Bench- and/or pilot-scale results	
		- Previous use in the field	
		- Failure/downtime estimate	
	Support Requirements	- Pre-treatment/post-treatment steps or processes	

TABLE 3-1
CRITERIA FOR DETAILED ANALYSIS OF REMEDIAL TECHNOLOGIES AND ALTERNATIVES[1,2,3]
NEW BEDFORD HARBOR FS

CATEGORY	CRITERIA	FACTORS TO CONSIDER	REQUIREMENT/GUIDANCE
	Availability	- Equipment, capacity, site access, land	
	Installation	- Implementation as a function of studies, design, construction, weather, unknown site, and safety precautions	CERCLA 3.3.2
		- Constructability with respect to site conditions	CERCLA 3.2.1
	Time	- Time to implement	CERCLA 3.3.2
		- Time to achieve beneficial effect	
	Safety	- Short-term and long-term threats to nearby communities and on-site workers	CERCLA 3.4
	Monitoring and Maintenance Requirements	- Frequency/complexity	
		- Labor/material	
	Permitting	- Basic requirements and projected length of time to obtain permits	

TABLE 3-1
CRITERIA FOR DETAILED ANALYSIS OF REMEDIAL TECHNOLOGIES AND ALTERNATIVES[1,2,3]
NEW BEDFORD HARBOR FS
(page 1 of 5)

CATEGORY	CRITERIA	FACTORS TO CONSIDER	REQUIREMENT/GUIDANCE
Effectiveness	Reliability		
	- Performance	- Goals, objectives, and requirements of SWDA	SARA 121(b)(1)(B)
		- Significant and permanent reduction in toxicity, mobility, or volume of hazardous waste; innovative/alternative or resource recovery technologies	SARA 121(b)(1); NCP 300.68(h)(v)
	- Useful Life	- Long-term uncertainties of land disposal	SARA 121(b)(1)(A)
		- Length of time level of effectiveness can be maintained	CERCLA[2] 3.1.2
	Public Health	- Short and long-term potential for adverse health effects from human exposure	SARA 121(b)(1)(D), CERCLA 5.3
		- Potential threat to human health (and the environment) associated with excavation, transportation, and redisposal or containment	SARA 121(b)(1)(G), CERCLA 3.4
		- Extent to which alternative meets or exceeds federal or, if more stringent, state ARARs governing protection of human health	SARA 121(d)(1), NCP 300.68 (h)(iv), CERCLA 5.4
	Environment		
	- Beneficial Effects	- Degree of contaminant isolation/removal from environment and subsequent improvement to surface water, groundwater, air, and soil	CERCLA 6.2.1

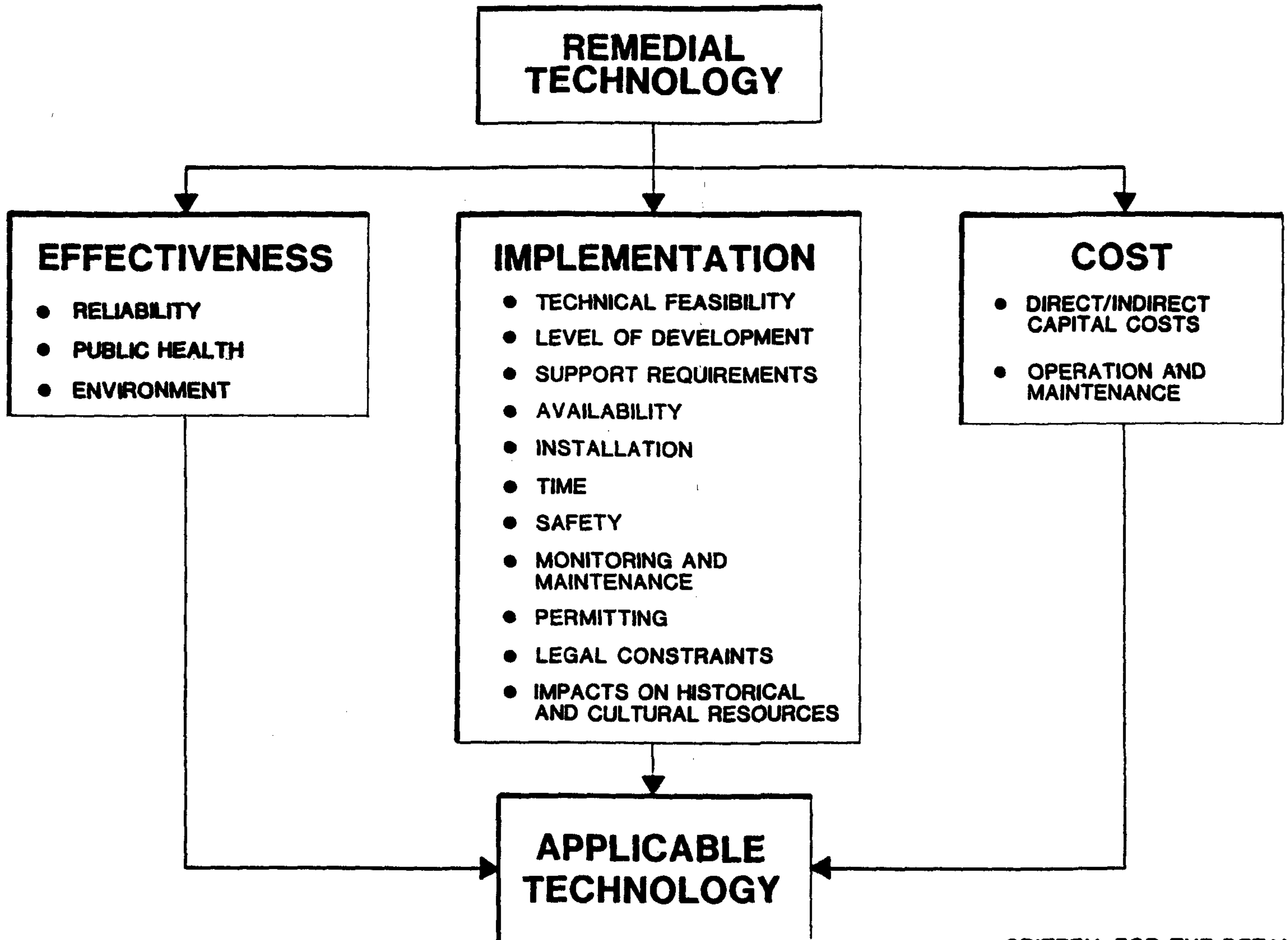


FIGURE 3-1
CRITERIA FOR THE DETAILED ANALYSIS
OF REMEDIAL TECHNOLOGIES
FOR CERCLA FEASIBILITY STUDIES
AS IMPACTED SARA 1986

TABLE 3-1
CRITERIA FOR DETAILED ANALYSIS OF REMEDIAL TECHNOLOGIES AND ALTERNATIVES[1,2,3]
NEW BEDFORD HARBOR FS
(page 4 of 5)

CATEGORY	CRITERIA	FACTORS TO CONSIDER	REQUIREMENT/GUIDANCE
	Legal Constraints	- Siting issues (land rights-of-way, land acquisition, zoning); Opposition from other agencies and citizens' groups	
	Impacts on Historical & Critical Resources	- Potential impacts to recorded/unrecorded archeological/architectural resources	
Costs	Cost Estimation	- Capital Costs:	CERCLA 7.1
		- Direct - Site prep, construction (materials/labor), remedial equipment, buildings & services, disposal costs	
		- Indirect - Engineering, legal/administrative, contingencies	
		- Long-term Operation & Maintenance (O&M) Costs	SARA 121(b)(1), NCP 300.68(h)(ii)
		- Potential costs if remedial action fails	SARA 121(b)(1)
		- Cost accuracy: -30% to +50%	

TABLE 3-1
CRITERIA FOR DETAILED ANALYSIS OF REMEDIAL [1,2,3]
TECHNOLOGIES AND ALTERNATIVES
NEW BEDFORD HARBOR FS

CATEGORY	CRITERIA	FACTORS TO CONSIDER	REQUIREMENT/GUIDANCE
	Present Worth Analysis	- No inflation of costs (OMB Circular A94) - Interest rate = 10% - Performance period = 30 years	CERCLA 7.2
	Sensitivity Analysis	- Design, implementation, operation, interest rate, effective life	CERCLA 7.3

Sources: [1] "Interim Guidance on Superfund Selection of Remedy". EPA OSWER Directive No. 9355.0-19. December 24, 1986

[2] "Guidance on Feasibility Studies under CERCLA" (EPA OERR/OWPE, June 1985)

[3] Superfund Amendments and Reauthorization Act (SARA) of 1986

administrative feasibility of installing, monitoring, and maintaining that technology.

The cost estimates developed for each technology included direct and indirect capital costs, and operation and maintenance expenses. Because final clean-up levels (and hence volume of contaminated sediment) have not yet been determined, the costs have been presented parametrically in this report.

4.0 NON-REMOVAL TECHNOLOGIES

4.1 CAPPING

Capping concepts were selected for a detailed evaluation of their application to the in situ containment of contaminated sediments at New Bedford Harbor. The contaminated harbor areas are separated into three geographical areas for this evaluation: (1) sediments in the Upper Estuary that are contaminated with PCBs at greater than 2,000 ppm (Hot Spot); (2) sediments in the Upper Estuary (north of the Coggeshall Street Bridge) that are contaminated with PCBs at greater than 50 ppm; and (3) sediments in the Lower Bay (south of the Coggeshall Street Bridge) that are contaminated with PCBs at greater than 50 ppm. These geographical areas are consistent with the study areas delineated earlier in the FS process. In addition, areas 1 and 2 are the same areas for which hydraulic control technologies were evaluated in Section 4.2 of this report.

In the following paragraphs, the types of capping materials that are available for containing hazardous wastes are described, and their suitability to the three geographic study areas of the site is addressed. Next, the capping concepts suitable for the three areas are described and a detailed evaluation of capping each area is performed.

4.1.1 Description

Capping waste piles, impoundments, and abandoned uncontrolled hazardous waste sites has been a widely accepted practice in the past. This technology has been used typically as a temporary measure to reduce infiltration of precipitation and subsequent leaching of wastes, or as a final remedial action usually in combination with other technologies.

Capping with natural materials such as clay, sediments or sand and gravel is an in situ (non-removal) approach which has been used in the past. These materials can be applied in a dry or subaqueous environment. Application in a dry (dewatered) situation would typically be through mechanical methods. Subaqueous application could be accomplished using either hydraulic or mechanical methods. The natural materials being considered are all inert materials. Other types of materials which might be used are active natural materials which could react with the contaminants. Examples of such materials which would react with PCBs have not been unequivocally identified and will therefore not receive further consideration in this evaluation. Finally, only sediments, sands, and gravel should be considered for use at the New Bedford Harbor site. Clay should not be considered because: (1) in the Upper Estuary, the low bearing strength of the sediments would not allow for compaction of the clay; (2) clay would not settle quickly in the deeper subaqueous environments;

and (3) placement underwater in a unconsolidated manner would result in high erosion and scouring.

Fabric caps (geotextiles) have been used extensively in offshore construction applications but have not been applied as a containment measure for contaminated marine sediments. This technology could conceivably be applied to stabilize the physical movement of the contaminated sediments either as a permanent or temporary measure and for reinforcement in a multimedia cap. Fabric caps are typically composed of woven or knit synthetic materials and are permeable. Application could be done in either a dry (dewatered) or subaqueous mode. However, the application of geotextiles in the deeper areas of New Bedford Harbor would not be practicable because it would be impossible to place geotextiles over contaminated sediments without resuspending contaminated sediments. As a result, there would not be any added advantage to using geotextiles in the deeper areas. Also, since the materials would have a useful life of about 30 years or less, they would offer no long-term protection to restricting intrusion by burrowing organisms. Geotextile capping materials should only be considered for use in the Upper Estuary shallow areas of the site, as a filtering device or for reinforcement in multimedia cap.

Impermeable synthetic membranes have been used in a wide variety of applications to prevent percolation of precipitation through hazardous waste. Membrane installations in a subaqueous environment would be difficult, with difficulty increasing with the depth of the water. Typically synthetic membranes are used in combination with other capping materials (multimedia). At New Bedford Harbor, a synthetic impermeable membrane could not be applied to deeper sediments because of logistical problems involved with seaming membrane sections and laying the membrane down without resuspending contaminated sediments. The use of subaqueous impermeable membranes in the shallow areas would not be practicable because vents would have to be placed through the membrane to be certain that gas accumulation would not be a problem. Therefore, impermeable membranes will only be considered for use in multimedia caps constructed above the water line.

Multimedia caps are combinations of the above capping schemes. The purpose for combining capping technologies is to compensate for different disadvantages which might occur with "standalone" capping technologies. Multimedia caps will be evaluated for New Bedford Harbor in areas where they would be suitable.

The application of capping materials to the three study areas at New Bedford Harbor would likely proceed as follows:

(1) Hot Spot - Cap with sediments and sands and gravels, or with a multimedia cap, approximately 26.5 acres containing PCBs at >2,000 ppm. Hydraulic controls would be required to protect the structural integrity of the cap during heavy river flows.

Consequently, it is envisioned that the only manner to effectively cap the Hot Spot would be to construct the hydraulic control described in Section 4.2.1 and fill in the protected area with capping materials. The hydraulic control would consist of an 8-foot embankment constructed around the perimeter of the Hot Spot. The soft sediments below the embankment zone would be removed to a depth of 12 feet, and sands would be added in their place to support an embankment with a 2.5:1 slope. The embankment would consist of glacial till or sands and gravel core, a layer of geotextile, and would be covered with rip rap to protect against erosion. The removed clean soft sediment (below 2 feet) would be used for fill material to cap the contaminated sediments on the inside of the embankment. The amount of clean sediments removed from the 2- to 12-foot depth would allow for 3.5 feet of cap over the Hot Spot. A sandy fill material could be placed over the sediments to a depth of 4 feet to act as a drainage layer. This type of cap would not control infiltration, and, although the mobility of PCBs would be reduced, leaching potential would still exist. Alternatively, an impermeable 80-mil HDPE synthetic liner could be placed over the sediments followed by a 1-foot sand drainage layer, and 2 feet of topsoil and vegetation. Surface runoff and gas controls would have to be designed as part of this latter capping scheme.

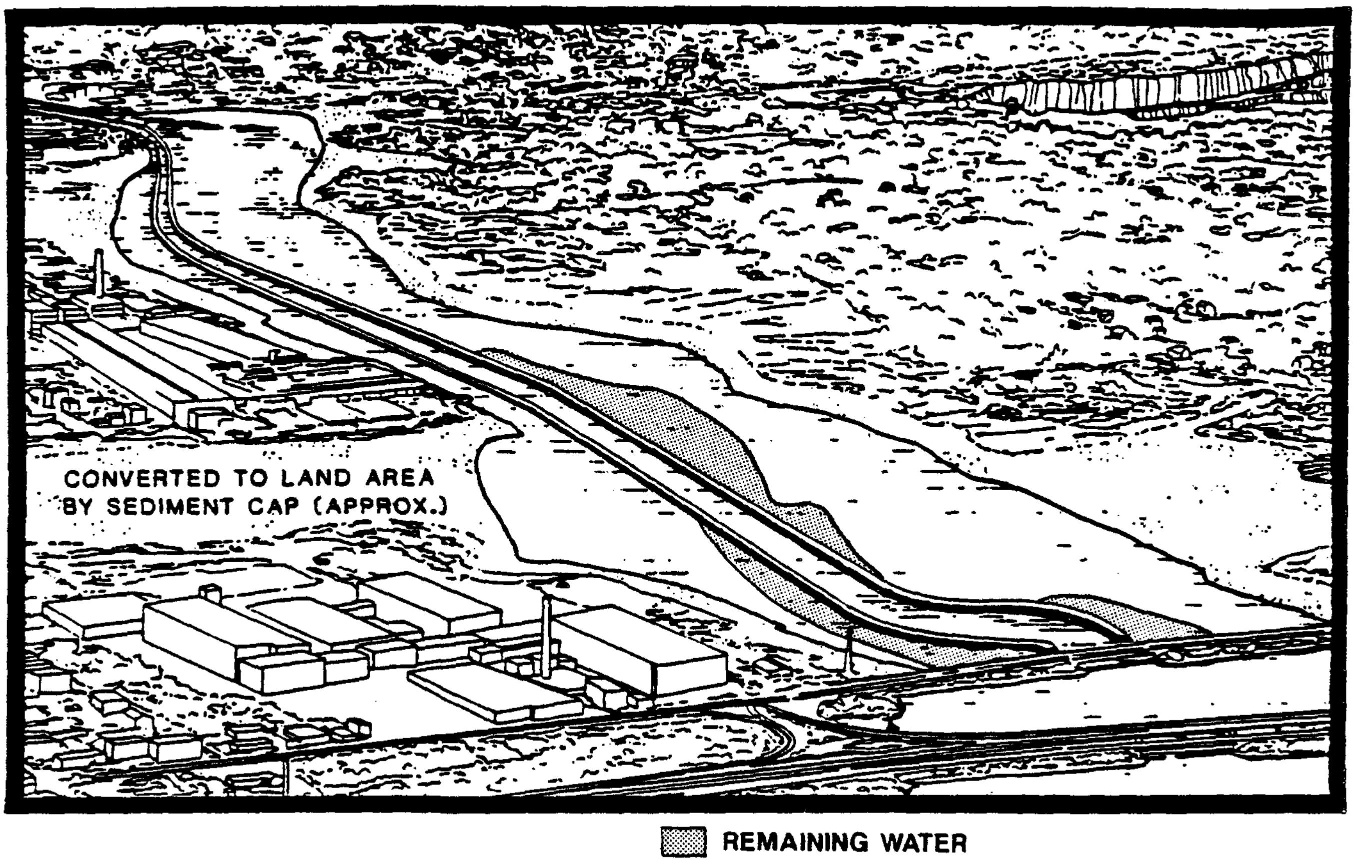
(2) Upper Estuary - Cap all sediments contaminated with PCBs at >50 ppm. The total area to be capped would be about 100 acres or

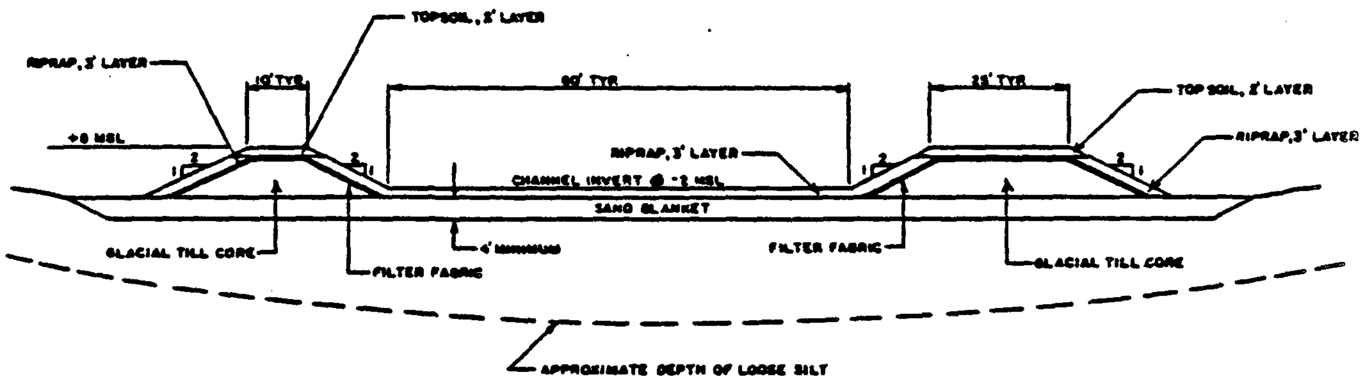
more, and represents more than 65 percent of the entire Upper Estuary (north of Coggeshall Street Bridge). The only manner by which a cap could be placed over this area would be to combine a cap with hydraulic control. This concept was developed in the NUS Draft Feasibility Study (NUS, 1984), and appears as the remedial alternative described in Section 7.2 of the NUS study. The NUS concept, which will be evaluated in this report, consists of a double embankment channel about 80-feet wide running virtually the entire length of the Upper Estuary (Figure 4-1).

The sediments within the channel would be covered with rip rap. The channel would be bordered by two 8-foot high embankments, consisting of a glacial till core, a layer of filter fabric, and a cover of rip rap. The sediments located on both sides of the channel would be covered with clean sediments from Buzzards Bay to a depth of 3 to 4 feet.

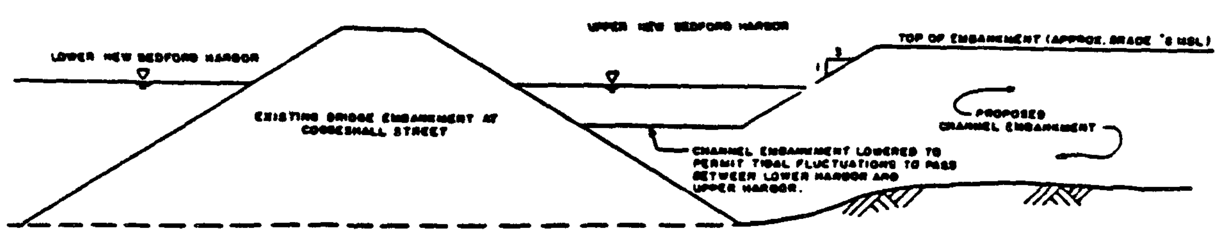
At the low end of the estuary, sufficient space would be provided between the Coggeshall Street Bridge and the end of the channel embankments to allow tidal flows to the Upper Estuary.

(3) Lower Harbor/Bay - Cap the five separate areas in the Lower Harbor/Bay study area where sediments contain PCBs at >50 ppm (Figure 4-2). These areas would be covered with approximately 135 cm (4.5 feet) of clean sediments obtained from Buzzards Bay. The cap depth was determined as follows. Studies conducted by the





TYPICAL CHANNEL CROSS-SECTION

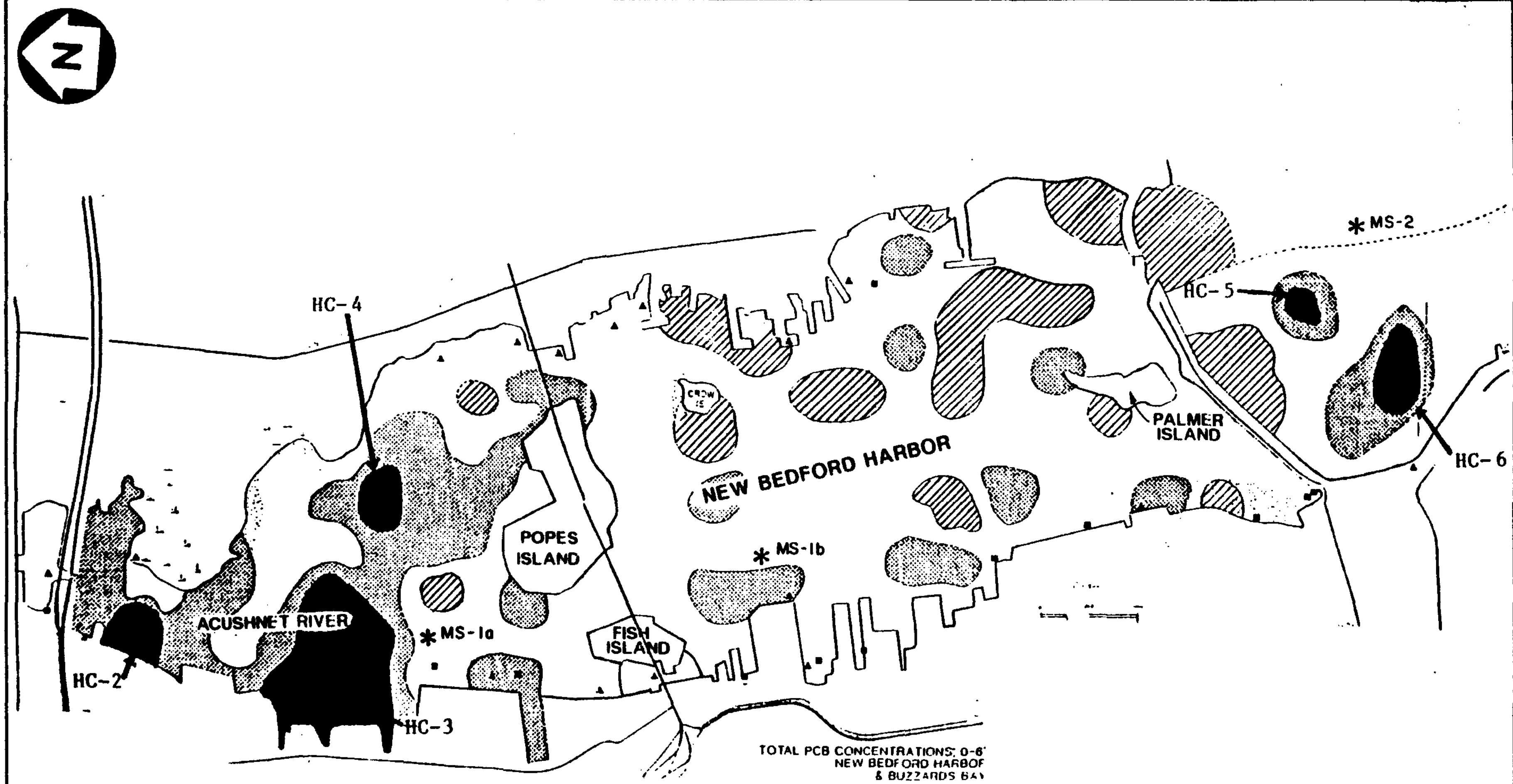


CHANNEL PROFILE NEAR BRIDGE

FIGURE 4-1
ARTIST'S CONCEPTION
AND TYPICAL CROSS-SECTIONS
HYDRAULIC CONTROL ALTERNATIVE
NEW BEDFORD SITE, NEW BEDFORD, MA

NUS CORPORATION
A Halliburton Company

4959-21



LEGEND

HC HYDRAULIC CONTROL/ CAPPING AREAS 2-6

MS MOORING SITES Ia, Ib, 2

APPROXIMATE SCALE
0 1,000 2,000 FEET

VOLUME CALCULATIONS (TOTAL CHARTS 1 & 2)

PCB CONC. (ppm)	AREA (ACRES)	VOLUME (CU. YD.)
< 1	138.72	111,901
1 – 10	666.34	537,511
10 – 50	188.06	151,689
50 – 100	47.08	37,949
>100	4.49	3,623

< 1 ppm
1 - 10 ppm
10 - 50 ppm
50-100 ppm
> 100 ppm

FIGURE 4-2
AREAS BEING CONSIDERED FOR CAPPING/HYDRAULIC CONTROLS LOWER HARBOR AND BAY

4959-21

USACE indicated that a 35-cm cap would prevent diffusion of contaminants into the water column. Research into burrowing organisms present in the harbor indicate that a 100-cm cap would reduce or eliminate bioturbation of contaminated sediments.

The manner by which the sediments would be transported and placed over the contaminated sediments was analyzed. Several scenarios were developed and screened for effectiveness, implementability, and cost considerations. The following scenario was chosen as the most effective and implementable, and is evaluated in detail in the following sections of this report.

A cap material borrow site would be identified outside the Area 3 Fishing Closure Line established by the Massachusetts Department of Public Health. A large hopper dredge would be used to dredge the cap material and transport it to New Bedford Harbor. The cap material would then be hydraulically pumped through a pipeline to a discharge barge in the vicinity of the areas to be capped. The sediment cap would then be put in place with the use of a submerged diffuser system.

4.1.2 Effectiveness

Technical Reliability. All categories of caps will significantly reduce the mobility of the PCBs in the surface sediments. The degree of immobilization of PCBs will be related to the permeability of the synthetic and natural materials and/or the depth of the natural material.

For natural materials it has been hypothesized, based on laboratory studies, that cap materials with higher proportions of clay and silt should be more effective in preventing the movement of PCB and PAH compounds (USACE, 1985). However, it was also observed that if the cap to be placed was thick enough, any of the materials (sand, silt, clay) would be effective in isolating the overlying water column. Therefore, although clays will not be used at New Bedford Harbor, sands or sediments of sufficient thickness would be considered reliable. Geotextiles would, however, allow for some amount of leaching potential due to their permeability.

The useful life of a natural capping scheme would depend primarily on it susceptibility to scouring effects from hydrodynamic forces and burrowing effects of benthic organisms. The susceptibility of natural cover material to scour will be a function of particle size and shape, flow dynamics, and slope. Studies by USACE at the New York Bight Experimental Mud Dump Site indicated that erosion of a fine sand cap under normal conditions of weather, tide, and current was minimal over a sixteen month period (USACE, 1983). Estimates of erosional rates for a fine sand cap were made of 0.3m/18-46 years. USACE also conducted studies at the Central Long Island Sound Dumping Area (CLISDA) at two different locations to evaluate two different capping materials, sand and silt. It was observed that sand caps were more stable. Within a short time after placement, a silt cap lost about 12 percent of the material due to shear stresses produced by the irregular (lumpy) surface topography; however, the silt cap exhibited less erosion over a long period of time. Initial results of studies examining a sand cap in the Duwamish River in Seattle indicate the cap was stable six months after placement (USACE, 1986).

The caps that would be placed over the Hot Spot and Upper Estuary would be protected from scouring and erosion by the embankments constructed around or alongside the caps. In the Lower Harbor, the clean sediments placed over the contaminated sediments just south of the I-195 Bridge would be subjected to scouring because of tidal action through the ship channel at that area. The placement of rip rap over this cap, and any others in the Lower Harbor where there are strong currents, would prevent scouring and erosion.

<u>Public Health</u>. Capping of contaminated sediments would confer public health benefits in two ways:

- o reduction of direct exposure to PCB concentrations in the water column (benefit to swimmers in the outer harbor); and

- reduction in the rate of bioaccumulation in edible fish, shellfish, and birds.

Environment. Capping contaminated sediments in the Hot Spot would have short-term adverse environmental impacts that would be outweighed by the long-term environmental benefits. Capping would eliminate benthic habitats and organisms present in the sediments to be capped; however, the PCBs present in these sediments would not continue to bioaccumulate. This has been demonstrated at other sites (USACE, 1983, 1985, and 1986b).

Capping the entire Upper Estuary would have extreme adverse environmental impacts, as the majority of wetlands area would be irreversibly altered or destroyed. A smaller area of new wetlands would be created in the lower portion of the Upper Estuary, where tidal flows were allowed to spill over the capped areas on each side of the embankments.

In the Lower Harbor/Bay benthic organisms would recolonize the capped area, and these organisms would be exposed only to a minimal amount of PCBs transported from non-capped areas. It is not possible to predict the length of time that would be required for recolonization. It would be expected that if the capping materials were significantly different than the original sediments, then different types of organisms would recolonize the cap than were originally present. In the Upper Estuary and Hot

Spot, most of the capped material would be above the water line. Several years would pass before these areas were vegetated and repopulated by macroinvertebrates and wildlife, unless these processes were stimulated by design as part of the remedial action plan.

4.1.3 Implementation

Technical Feasibility. The Hot Spot and Upper Estuary may be capped without encountering serious technical problems. To cap the Upper Estuary, significant administrative concerns would have to be addressed: (1) gaining site access; and (2) conducting operations throughout the Upper Estuary because of: (a) the high level of commercial development along the western shore, and (b) the large wetlands areas on the eastern shore. In addition, the municipal storm water and combined sewer overflow discharge system would have to be redesigned and rerouted during construction operations.

There are five locations within the Lower Harbor/Bay study area where sediments exhibit PCB concentrations of 50 ppm or more (see Figure 4-2). Sites numbered HC-2, HC-3, and HC-4 are south of the Coggeshall Street Bridge and north of the Route 6 Causeway. Sites HC-5 and HC-6 are approximately 2,500 feet south of the hurricane barrier. The surface area totals 51.5 acres for the five areas.

A 135-centimeter thick-cap over these five locations would require on the order of 370,000 cubic yards of material.

Gradual bottom sediment elevation changes characterize sites HC-4, HC-5, and HC-6. Water depths overlying these areas are on the order of eight to ten feet. These sites are in low vessel traffic areas. It is expected that these three sites may be capped in the manner presented with little difficulty.

Sites HC-2 and HC-3 lie directly adjacent to commercial dock space. Subsequently, vessel traffic is heavier than in the other proposed cap locations and deep water is at a premium. A ship channel passes through the center of both sites, and water depths range from nearshore mudflats at mean low tide to nearly 30 feet at the channel center. Bottom sediment contours are close in these two areas. Water depths can change as much as ten feet over a 50-foot distance. The need to maintain sufficient water depth for commercial and fishing vessel draft is a concern for these two areas. Capping would decrease water depths 4.5 to 5 feet. Depending on tidal fluctuations, certain areas of the cap surface will be exposed to the atmosphere. Difficulty is expected in maintaining cap integrity during placement of the cap material on the slopes of the channel.

Level of Development. Caps and associated hydraulic controls would not require any bench- or pilot-scale studies because these technologies have been successfully applied at numerous locations. The use of natural materials for capping hazardous waste has been a widely used practice. Recently, natural materials have been used as caps for contaminated material disposal in subaqueous environments. This technology has been successfully implemented in Rotterdam in 1981 and Seattle in 1984.

Support Requirements. The municipal storm water and combined sewer overflow system would have to be rerouted prior to initiation of capping operations. This would require lengthy and costly design considerations, and local administrative issues would have to be addressed. A silt curtain would likely be required around the perimeter of the Hot Spot, or north the Coggeshall Street Bridge for capping the Upper Estuary. The NUS Draft FS presents details on the conceptual design of a silt curtain for capping the Upper Estuary.

Other principal support requirements would be administrative in nature. Local government and citizen cooperation would be required before and during construction operations because of site access, wetlands, and waterway use issues that would likely arise. Support requirements for placement of the cap would include equipment and labor necessary to dredge, transport, and deposit the cap materials. It is not anticipated that any pretreatment support will be necessary for any aspect of this operation since the material that is to be handled is considered uncontaminated.

Some post treatment support may be necessary. Proposed cap sites HC-2 and HC-3 may require rip rap be placed on some sloped surfaces to help keep the cap in place and minimize scouring.

Availability. In capping the Hot Spot or Upper Estuary, equipment and material availability would pose no special concerns. As discussed in preceding paragraphs, gaining site access would present problems in capping the Upper Estuary. For the Lower Harbor/Bay area, unlimited natural cover materials should be readily available from subaqueous marine borrow sources in Buzzards Bay and surrounding waters. The borrow site(s) should be outside the limits of the Area 3 Fishing Closure Line established by the Massachusetts Department of Public Health.

There are presently five hopper dredges in the United States with hopper capacities in the range of 5,000-10,000 yd^3 that are direct pump out capable. Scheduling considerations should be taken into account when arranging a dredging project. Barge moorings are readily available locally. A discharge barge with diffuser system may require a four- to six-week construction and delivery period.

Installation. Capping the Hot Spot or the entire Estuary would require costly and lengthy design studies and construction activities because of the complexity of factors that would need to be considered, such as: (1) rerouting storm water and combined sewer overflow discharge; (2) river and tidal flows; (3) site access; (4) geotechnical data; (5) material purchases, transportation, storage facilities; and (6) the size of the areas that need to be capped. No significant technical factors or concerns are expected to affect implementation of capping and associated hydraulic control technologies; administrative and legal concerns would likely present significant obstacles to implementation, and these are discussed in other portions of the Capping section.

Installation of the cap material over the five identified sites in the Lower Harbor/Bay would be accomplished using marine sediments from the borrow area(s) in the vicinity of New Bedford Harbor but not within the limits of the Area 3 Fishing Closure Zone. Preferably the material would be a silty sand, similar to the sediments in the study area. A silty sand would be a free-flowing material and therefore easily dredgable. The silt content would lend cohesiveness to the overall cap and benthic organisms native to the area would be more apt to recolonize in material similar to what is there presently. The material would be dredged and transported by a large trailing hopper dredge. Much of the areas to be capped lie in water depths less than the loaded draft of the hopper dredge. Use of smaller, shallower draft transportation vessels would be comparatively inefficient in terms of both time and cost. The large capacity, deep draft hopper dredge would transit to one of two designated mooring sites. From mooring sites no. MS-1a and MS-1b the proposed cap areas HC-2, HC-3, and

HC-4 may be serviced. Cap areas HC-5 and HC-6 may be reached by the hopper dredge at mooring site MS-2. The mooring sites will be located in water depths sufficient to accommodate the fully loaded dredge. The site will consist of a mooring barge of ample size and stability (200' x 70' x 20') such that the dredge may safely lie alongside while discharge operations are underway. Dredge discharge pipe connection is made to piping arrangements on the mooring barge that are designed to accept the dredge's direct pump out hardware. Hydraulic pipelines would extend from there to the discharge barge located directly over the sediments to be capped. Estimates indicate that the approximate maximum pipeline length needed to install the five caps is 3,300 feet if the loaded dredge draft is 25 feet or less (mooring sites MS-1a and MS-2 are used) and 4,800 feet if the loaded dredge draft is 26 feet or greater (mooring sites MS-1b and MS-2 are used). The pipeline and discharge barge piping and hardware would be of complementary size to that of the dredge discharge pipe size. The discharge barge would be moved over the area of the proposed cap. A small tugboat would then be required for discharge barge support. The discharge barge would be equipped with a submerged diffuser system. The submerged diffuser system was developed by the USACE to reduce the velocity and associated turbulence inherent with subaqueous sediment discharge operations. Turbidity generation may be minimized through the use of this system. Another benefit of the submerged diffuser system is that the cap material may be placed with a higher degree of accuracy than either point dumping or the pump down method of subaqueous cap placement. The diffuser is lowered to one meter above the bottom and raised accordingly as the cap material accumulates. Equations have been developed by the USACE to assist in scheduling the movement of the diffuser head so as to minimize interference with the cap. The discharge barge need not be as heavy and lengthy as the mooring barge. It should, however, be sizeable enough to adequately support its equipment and provide the diffuser with a stable platform from which to be operated in a three foot sea. The discharge barge would be approximately 50' x 20' x 41' in size with a cutout in the hull of about 20' x 10' on one end to facilitate deployment and retrieval of the diffuser. Upon emptying the dredge's hoppers, the connection at the mooring barge would be broken and the dredge would return to the borrow area to restart the operations cycle.

Time. The time required to cap the Hot Spot would vary depending on the slope of the embankments used, and the time required for consolidation of the sands or sediments used as fill in the Hot Spot. The construction of an embankment with 2.5:1 slope around the Hot Spot would require 9 to 12 months. An additional 3 months would be required to cap the sediments within the embankments. An additional 9 to 12 months would be required for the fill material to settle and consolidate prior to placement of the impermeable liner and topsoil. Finally, an additional 3 to 6 months would be required to place the liner and topsoil and seed the cap. The total time required to cap the Hot Spot is estimated at about 2 to 3 years.

The time required to cap the entire Upper Estuary is difficult to estimate, and would require an extensive analysis beyond the scope intended for this report. A reasonable estimate would be that it would require 2 years more than the time for capping the Hot Spot, or a total of about 4 to 5 years.

The approximate time required to cap the five proposed sites in the Lower Harbor/Bay, in the manner described, is one month to 45 days. This estimate was obtained from two operations scenarios using different dredge sizes. Both were figured on a 24-hour work day, a 15 nautical mile round trip transit distance from the borrow area to the hurricane barrier, and an average of 20 percent operational downtime. One scenario involves the use of a hopper dredge with a load capacity of 10,000 cubic yards. This volume is based on the assumption that the grain size of the dredged material is in the range of 0.15 to 0.3 millimeters. This vessel is not self-propelled. It is 510' x 75' x 28' (length x beam x loaded draft). It requires 12 hours to complete one round trip. The other scenario involves a 2,400 cubic yard self-propelled hopper dredge. It is 280' x 50' x 20' and requires six hours to complete one round trip.

The time required to achieve beneficial effect by implementing this technology is immediate. By placing the cap material over the contaminated sediment, the contaminants' mobility will be significantly reduced.

Safety

It is expected that implementing this technology in the manner described for each study area would not create new or enhance existing short- or long-term threats to nearby communities or on-site workers. This is primarily because the material being handled is not considered to be contaminated, and placment of these materials on the contaminated sediments is done in a subaqueous environment.

Monitoring and Maintenance Requirements

For the Hot Spot and Upper Estuary, a monitoring and maintenance program would have to be devised to maintain the integrity of the hydraulic barriers, and ensure that no significant erosion of the cap occurs.

A substantial amount of monitoring would take place during cap installation in the Lower Harbor/Bay. Hydraulic survey information to assist in determining cap area and thickness should be taken continuously. Visual inspection, either by divers or underwater equipment, should also be performed. Water column and biota sampling and analysis may also be performed during and after cap placement.

Post installation monitoring to assess the rate of scouring and settling of the cap material will be necessary particularly in areas where cap placement was on a sloping surface (i.e., cap sites HC-2 and HC-3).

Sites HC-2 and HC-3 are expected to require more maintenance than the Lower Harbor/Bay cap sites. These two sites are more susceptible to erosional problems due to the sloping surfaces they cover.

Monitoring and maintenance schedules would be developed commensurate with the deleterious effect the environment has on each particular cap.

Permitting

Permits need not be secured to implement this technology at a Superfund site. Remedial alternatives must, however, meet both federal and state ARARs. Additionally, both the Clean Water Act and River and Harbors Act will need to be addressed.

Legal Constraints. The significant legal issues that may arise with capping the Hot Spot would probably deal with site access, right-of-way, and adverse environmental impacts on the wetlands on the eastern shore of the Estuary. The same issues would be present, but magnified greatly, with capping the entire Upper Estuary. In addition, the destruction/modification of waterfront property would raise significant opposition from affected landowners.

Opposition to capping the designated areas in the Lower Harbor/Bay may arise from those involved in commercial activity in and around the areas to be remediated. Capping the areas immediately south of the Coggeshall Street Bridge may adversely affect commercial vessel traffic both during and after implementation. The time the capping equipment obstructs vessel traffic is a factor as is the final water depth over the capped area.

Impacts on Historical and Critical Resources. Capping the Hot Spot or entire Upper Estuary would not impact any historical resources. Capping the Upper Estuary would impact current recreational uses of this area. Archeological resources are not known to exist at the New Bedford Harbor site. However, operations would cease if, during the course of operations, archeological, historical, or critical resources were discovered. Operations would not resume until it was deemed safe to do so by the federal, state, and local agencies governing such resources.

4.1.4 Costs

The estimated costs for capping contaminated sediments at New Bedford Harbor are presented for capping the three geographic areas evaluated in the preceding sections.

Hot Spot. The estimated cost for constructing the impermeable cap over the Hot Spot is $9,692,000. This cost was derived by taking the cost estimated for construction of an embankment around the Hot Spot (Section 4.2), and adding the cost for filling the enclosed area with 4 feet of sand and gravel. Additional costs that would be incurred if the depth of the cap had to be increased would be approximately $873,000 per foot of cap.

The costs to construct an impermeable cap would be approximately $10,000,000 to $11,000,000, and would be affected by design considerations dealing with surface runoff and gas controls.

The cost estimates in Section 4.2 for embankment construction assumed excavated sediments would be dumped inside the embankment and capped with sand. Capping costs would be significantly greater if contaminated sediments (approximately 20,000 cubic yards assuming top 2 feet of Hot Spot area) had to be disposed or treated at a RCRA/TSCA - approved facility.

The costs for treating or disposing contaminated sediments are estimated in this report in Section 6.

As described earlier, the construction of a cap over the Hot Spot would have a severe impact on the flow of water through the Upper Estuary, and as a result would adversely impact the wetlands. Measures that would have to be devised to divert water flow around or through the cap without impacting the wetlands would result in a substantial increase in the cost estimates presented earlier.

Upper Estuary. The costs for constructing a double embankment channel and capping the sediments were estimated at $52,300,000, as compared to $24,500,000 in Table 8-1 of the NUS Draft FS. Jordan's estimates for capping and construction of the channel (which accounted for about 85 percent of the costs prior to engineering/contingency/profit) are at least twice those presented in the NUS report. The Jordan estimate is based on the construction of channel embankments with 2.5:1 slopes, whereas the NUS report had embankments with 2:1 slopes. The NUS costs did not consider the need to strengthen bottom sediments prior to embankment construction. Costs could increase further if the embankment slopes were greater. In addition, the NUS report described capping sediments with 3 to 4 feet of material. Jordan's cost estimates for this portion of the job are also about twice the NUS estimate, and would increase substantially with increasing depth. Finally, if sediment strengthening were required for embankment construction, then the costs for disposal or treatment of excavated/dredged contaminated sediments would have to be considered. At the present time, Jordan's estimate for capping the Upper Estuary as described in this section is approximately $52,300,000.

Lower Harbor. Costs for capping the five proposed sites in the Lower Harbor/Bay were developed for both operational scenarios described earlier. A cost of $10.00 to $12.00 per cubic yard of cap material put in place was calculated for both dredge alternatives. This cost includes dredge and crew for a 24-hour-a-day operation, mooring barge requirements, a discharge barge equipped with a submerged diffuser system and crew, floating pipeline to reach all cap sites, hydrographic survey boat with crew, and all associated operation and maintenance costs. Mobilization and demobilization of all equipment involved in either operation from New York City to New Bedford and back to New York City was calculated at $400,000. Total costs for capping these five Lower Harbor/Bay sites with clean marine sands in the manner described are in the range of $4,100,000 to $4,840,000.

4.1.5 Summary

Hot Spot. The use of hydraulic control will be necessary if capping is to be effective and implementable for the Hot Spot. As described in Section 4.2.1, the form of hydraulic control may be earthern embankments covered with geotextile and rip rap. The 26.5-acre cap over the contaminated sediments would be comprised of clean sediments and material taken from the area upon which the embankments were built. Capping the Hot Spot would be effective and technically feasible but would impact the hydrology of the estuary as well as the wetlands. The costs for capping the Hot Spot are estimated at $9.7 million to $11.0 million.

Hydraulic control would also be necessary for capping technologies to be effective and implementable for the Estuary. A double earthern embankment with a geotextile liner and rip rap cover would be constructed to channel the Acushnet River and New Bedford Harbor tidal waters and to provide for dewatering of the remainder of the Estuary. The contaminated sediments on either side of the embankments would be capped with natural inert material. This cap would cover approximately 100 acres.

Lower Harbor. Capping the five proposed sites in the Lower Harbor/Bay would require no hydraulic control. These caps would be placed subaqueously and would consist of clean, natural, inert materials from a borrow area in Buzzards Bay. The total surface area of the five caps would be approximately 51.5 acres, and the costs would be about $4.1 million to $4.9 million.

Inert cap materials have been evaluated. Due to the expected behavior of some of these materials under the capping conditions particular to the three New Bedford study areas, the cap material to be used should be relatively free of fine silts and clays.

4.2 HYDRAULIC CONTROLS

4.2.1 Description

One method to isolate the contaminated sediments from the surface water flow in New Bedford Harbor is to encircle them by means of impermeable earthen embankments or sheet piling. These barriers would be constructed to achieve a maximum permeability of 10^{-7} cm/sec, thereby limiting flow through the embankment or piles.

The barriers would be constructed high enough to prevent overtopping during storms and subsequent flushing of contaminants.

Various areas have been identified within the Estuary and Lower Harbor/Bay that may benefit from the application of hydraulic controls. This technology is best suited for discrete areas of contamination that significantly exceed the concentrations of contaminants in the surrounding environment. Six areas have been identified that may be isolated by hydraulic controls.

An area in the Upper Estuary along the western shore contains PCBs in sediments from 2,000 to >100,000 ppm and covers 26.6 acres. A semi-circular-shaped barrier could be constructed along the western shore.

The remaining Upper Estuary has various degrees of PCB contamination ranging from approximately 50 to 500 ppm. Hydraulic controls for the Estuary are discussed as an alternative under separate cover (NUS, 1984).

The remaining five separate isolated areas of contamination are located in the Lower Harbor/Bay (Figure 4-2). These areas have concentrations in excess of 50 ppm that are otherwise surrounded by low to non-detected quantities of PCBs.

The most northern of the five Lower Harbor contamination areas (HC-2) is a six-acre area located just south of the Route 195 bridge near the western shore. Like the Hot Spot, this area can be contained by a semi-circular-shaped barrier.

The second area being considered for this technology in the Lower Harbor (HC-3) is along side the designated shoreline site #7. The largest of the Lower Harbor/Bay areas, it covers 32.6 acres and can be contained with a 3,400-foot-long barrier tied back to the western shore.

Area HC-4 is located between the shoreline site #11 and Popes Island. Since it is situated off-shore, a 1,800-foot barrier would be required to completely encircle the 4.7-acre area.

An area outside but near the opening of the hurricane barrier has also been identified to contain sediment PCB concentrations in excess of 50 ppm. This 2.1-acre area (HC-5) would require a 1,200-foot embankment to surround it.

The final area that may feasibly be isolated from surface water flow is located west of the previous site, off-shore from East Rodney French Boulevard and Cove Road. This 7.1-acre area (HC-6) would also require embankments or piles around the entire circumference (2,400 feet).

Two different technologies are being considered to isolate specific areas within the Estuary or Harbor/Bay from surface contact: earthen embankments and sheet piling. Construction design for the embankments is highly dependent upon the geotechnical properties of the supporting ground surface (sediments). Geotechnical studies have shown that sediments are very soft and would require embankments with side slopes of approximately 7H:1V (horizontal:vertical) to support the structure. The slopes could be increased to approximately 2.5H:1V if the soft sediments were first removed (approximately 12 feet in the Estuary). Limited geotechnical testing in the Lower Harbor indicates more stable sediments to be present. Thus embankments may possibly be constructed at 5H:1V slopes without sediment removal. The embankments would be constructed of sand and gravel or till. Rip rap would be required on the embankment surface to prevent erosion.

Steel sheet piles may also be utilized in various configurations to isolate contaminated sediment areas from the surface water. The structures are generally filled with earth and gain their strength and stability by interlocking tensile stresses between the sheets. The two types suitable for hydraulic control within the Estuary or harbor are cellular steel sheet piles or double wall steel sheet piles.

A cellular steel cofferdam is a structure formed from a series of interconnected straight web steel pile cells filled with soil, usually sand or sand and gravel. The interconnection provides water tightness and self-stability against the lateral pressures of water and earth. General design guidelines for stable cellular structures founded on firm dense soil strata require a diameter to height ratio of about 0.85.

Double wall sheet pile structures consist of two parallel sheet pile walls tied together with tie rods and walls and filled with soil to create a containment structure or cofferdam. General guidelines for design are the same as for cellular steel cofferdams; a width to height ratio of 0.85.

4.2.2 Effectiveness

Reliability. Permanent use of embankments for containment of sediments and exclusion of surface water will likely require an impermeable lining to prevent the future migration of contaminants. Settlement of the embankment could potentially occur, causing the lining to rupture. Fine sediments will with time, however, clog the interstitial pore spaces and reduce permeability.

The embankments should provide an effective means of confining the area of interest. Non-contaminated sand and gravel material can be salvaged for future use, if further action were taken to treat or remove the contaminated sediments. The embankments can be constructed with conventional earth moving equipment, and can also be constructed in a wet environment.

Disadvantages to using earthen embankments over soft sediments are the necessity for large volumes of sand and/or gravel borrow material which must be obtained from off-site. Due to the soft sediments shallow slopes are required (7:1) which would take up significant space in the Estuary or harbor. This size may in turn impede harbor traffic and water circulation. A high strength geotextile will be required at the base of the embankment. Placement will likely require the use of manual labor which may involve considerable exposure risk to the labor force necessitating health and safety measures to prevent harmful exposure to contaminants. The geotextile will require splicing. Careful construction techniques and quality control will be necessary to minimize the contamination of dike materials. Due to strength and consolidation properties of the soft sediments, the dikes will require staged construction. The staged construction will be necessary in order to allow the sediments to consolidate which in turn will increase the sediment strength properties.

These structures are intended to be temporary. Permanent use of these embankments for containment of contaminated sediments would not be recommended due to long term settlements of required linings and potential continuous maintenance.

The design life of embankments constructed with the sediments removed would increase to 50 to 100 years or more. The design life of embankments used as containment systems for contaminated sediments would be dictated by the effectiveness of the liner system.

Sheet piling may be less permeable than embankments since the earth fill would stress the connections, thereby creating tighter seals. Other advantages include less resuspension of contaminated sediments during construction with sheet pile structures because sheets will act to contain sediments during their removal when used as containment structures. Also, sediment resuspension would not occur as a result of sand and gravel placement. Sheet pile structures would require a narrower cross-sectional profile than earthen embankments which would allow excavation equipment to work closer to the contaminated sediments. The narrower profile would also cause less interference with harbor traffic.

Material needed for filling structures could potentially be obtained by dredging sands from the uncontaminated portions of the harbor. (This would require verification during design and should not be assumed for initial cost estimating). Sheet piling and backfill can be salvaged. A disadvantage of sheet piling is the cost. Sheet pile is expensive and engineered structures are generally more difficult to construct than conventional earthen embankments. Also, soft sediments within the cells would require removal and disposal. Steel will be subject to corrosion and eventual failure. Design life in marine environments is generally 10 to 20 years.

Public Health. The hydraulic barriers could successfully isolate sediments with elevated concentrations of contaminants from the water column. The degree to which this technology will be useful in mitigating contaminant levels throughout the Estuary and harbor will be addressed during the analysis of remedial alternatives. For those sites where the barrier would attach to the shoreline, fences and/or signs would need to be erected to prevent the public from contacting the isolated areas. Capping those areas may also be useful in preventing contact. Commercial and recreational boaters and fisherman would be forced to circumvent these more heavily contaminated areas, which would also reduce the opportunity for direct or indirect (fishing, clamming) contact.

Environment. A potential problem in implementing the hydraulic control option is the impact the barrier would have on the channel/Estuary hydraulics and the harbor boat traffic. This problem is site specific. It would have the greatest impact at the Hot Spot (for hydraulic reasons) and sites 3 and 4 due to hydraulic and traffic considerations. For all three sites the channel flow would need to be diverted around the barriers, potentially causing significant hydrologic impacts. Containment in areas 2 and 3 would also preclude the use of those areas for waterfront use.

4.2.3 Implementation

Installation of Embankment Over Soft Sediments. The specific steps involved in the installation of an embankment over soft sediments are as follows:

1. Placement of geotextile over soft sediments beneath entire width of embankment. Seams of fabric must be sewn or spliced;

2. Follow placement of the geotextile with granular embankment material placed to just above the high tide water surface (dewatering is not necessary for material placement);

3. Continue sequence of geotextile splicing and fill placement until entire first lift of embankment is completed;

4. Place exterior rip rap in sequence with fill placement;

5. Allow sediments beneath the embankment to consolidate. Consolidation time is estimated to be 9 to 12 months. During consolidation process, additional fill placement may be necessary to keep embankments above high tide level;

6. Monitor embankment settlements;

7. Construct embankment to full height after consolidation of sediments has been achieved.

<u>Time</u>. The time required to construct an earthen embankment on the soft sediments will vary according to the length of the embankment and depth of sediments to consolidate. It is estimated that a ±4,000 foot embankment proposed for the Hot Spot area of the Estuary would take 1.5 to 2 years to construct. Acceleration of the consolidation process could be achieved with the use of wick drains.

<u>Monitoring and maintenance</u>. Monitoring of settlements will be required during the initial consolidation phase of the embankment. Continual maintenance is likely in order to accommodate for continual settlement. Side slopes may require periodic dressing due to erosion.

Support requirements. Support requirements for construction are anticipated to be minimal. Contaminated sediments beneath the embankment are likely to be forced into suspension if not removed prior to construction. A silt curtain around the perimeter may be required in order to lessen interaction with the exterior water column.

Availability. Geotextiles and earthen materials required for construction are readily available. Construction techniques required have been demonstrated in the past on similar type soils.

Safety. The most significant risk of exposure to contaminated sediments will occur during construction during the placement and splicing of the geotextile.

Installation of Embankment with Sediment Removed. The construction sequence for these dikes would likely involve the following steps:

1. Install suspended sediment controls;

2. Remove and dispose of contaminated sediments;

3. Remove and dispose of uncontaminated sediments;

4. Follow removal of sediments with placement of granular embankment material in one lift to just above the high tide water surface;

5. Construct embankment to grade above water line in lifts;

6. Continue sequence of sediment removal and fill placement;

7. Place exterior riprap in sequence with fill placement;

8. Dewater interior of containment area and place liner if necessary.

Time. The time required for dike construction will vary with the size of the embankment and the amount of contaminated and uncontaminated sediment to remove and dispose of. Excluding sediment disposal, it is estimated that construction of a ±4,000-foot-long embankment around the Estuary Hot Spot would require 9 to 12 months.

Monitoring and Maintenance. Monitoring for the movement of contaminants through permanent embankments would likely be required. Long term maintenance would consist of dressing the interior and exterior slopes due to erosion.

Support Requirements. Support requirements would consist of containing resuspended sediment during construction and removal. The removal of the sediments will require an evaluation of the appropriate dredging techniques.

Availability. Earthen materials required for construction are readily available. Construction techniques required have been demonstrated in the past on similar type soils and embankments.

Safety. This construction will be performed primarily by machine with relatively little manual labor involved. Therefore, worker exposure to contaminated sediments will be minimal.

Installation of Cellular Sheet Pile. Cellular sheet pile structures would most likely be constructed in the following sequence:

1. Fabricate template for construction of cells;

2. Place all sheets for cell and drive;

3. Remove soft sediments from interior of cell;

4. Backfill cell with dredged sands, if available and suitable, or granular borrow from off-site source;

5. Construct next cell by same process;

6. Link cells together with arches, remove sediments, and backfill;

7. Continue sequence until required length of structure is completed.

Time. Time required will vary directly with contractor capabilities but generally would require 2 to 3 days to construct individual cells.

Monitoring and Maintenance. Monitoring and maintenance would generally not be necessary for temporary structures.

Support Requirements. No unusual support requirements are necessary.

Availability. Numerous contractors are capable of constructing cellular containment structures.

Installation of Double-Walled Sheet Piles. Double-walled sheet piles would most likely be installed in the following sequence:

1. Install template for sheets and sheet piles between tie rods;

2. Excavate soft sediments;

3. Install walers and tie rods;

4. Backfill with sand and gravel;

5. Continue sequence until the barrier is completed.

Time. Time will vary directly with contractor capabilities.

Monitoring and Maintenance. No special monitoring or maintenance is required for these structures.

Support Requirements. No special support requirements are necessary for the construction.

Availability. Technology and materials are readily available.

Safety. There is a potential risk of exposure to construction workers while placing lower ties and braces under water.

4.2.4 Cost

Costs have been developed for the five different hydraulic control scenarios in each of the areas of interest. These costs were developed based on numerous assumptions and are to be considered only preliminary. The areas identified to be contained have been delineated based on, in some areas, only a few sample data points. Thus the areal extent of contamination could be smaller or larger than has been given here. Second, very little geotechnical information is currently available for the majority of the sites in question, so broad assumptions have been made based on the few borings present. This information can have significant cost implications since load-bearing capacities of the sediments will dictate the design criteria of the hydraulic controls. Assumptions used in determining costs include the removal of 12 feet of soft sediment in the Estuary and 5 feet in the Lower Harbor/Bay to sustain an embankment slope of 2.5:1. Without sediment removal, the minimum slope required to sustain a stable embankment would most likely be 7:1 in the Estuary and either 7:1 or 5:1 in the Lower Harbor/Bay when built utilizing geotextile membranes. For sheetpile cofferdam construction, the piles are assumed to be driven approximately 25 feet into the sediment. Costs for material and labor were obtained from vendor quotes and cost estimating tables (1987 Means Publishing Co.).

Table 4-1 identifies the costs of containing the various identified areas of contamination (HC-1 to HC-6). In general, the least expensive option involves removing the soft sediment layer and building a 2.5:1 slope embankment on the uncovered soils. Area HC-1 indicates the least costly option to be the 5:1 slope

TABLE 4-1

SUMMARY OF CONSTRUCTION COSTS FOR HYDRAULIC CONTROLS

Site	Embankment Length (ft)	2.5/1 ($)	Embankment 5/1 ($)	Slope 7/1 ($)	Steel Sheetpile Cellular ($)	Double Wall ($)
HC1	2920	3,561,720	2,829,480	3,678,470	5,909,759	4,322,000
HC2	1490	1,254,407	1,764,160	2,312,480	3,278,000	2,026,000
HC3	3191	2,663,310	3,778,144	4,952,432	7,020,000	4,340,000
HC4	2006	1,684,616	2,375,104	3,113,312	4,413,200	2,728,000
HC5	1484	1,249,727	1,757,056	2,303,168	3,264,800	2,018,000
HC6	2385	2,007,653	2,823,840	3,701,520	5,247,000	3,244,000

embankment over the soft sediments, but this scenario would most likely not be stable enough in this location (Upper Estuary).

In area HC-1 double walled sheetpile cofferdams can be constructed for an additional cost of 20 percent. Since a considerable width of the Estuary is being contained by these hydraulic controls, it would be advantageous to limit, to the extent possible, the size of the barrier so as to not further impede the channel hydraulics. The 2.5:1 slope embankment would have a 140-foot-wide base as compared to the 30-foot-wide sheetpile wall.

The remaining areas (HC-2-HC-6) would also benefit from the reduced size of the sheetpile cofferdams for reason of channel and tidal hydraulics as well as marine traffic. In the Lower Harbor the sheetpile option would cost 60 percent more than the least costly alternative (2.5:1 slope embankment).

4.2.5 Summary

The new SARA guidelines prefer clean-up alternatives that permanently and significantly reduce mobility, toxicity, or volume of the given waste. The hydraulic control technology would, by itself, only reduce the mobility of contaminants, and would not address the toxicity or volume reduction. The permanence of this solution is a function of the permeability of the embankment, and will vary considerably with the choice of construction methods.

Ideally the hydraulic controls would be implemented in conjunction with a suitable in situ treatment technology that stabilizes or detoxifies the confined sediments.

Construction of embankments over soft sediments for hydraulic controls will be dropped from further consideration. Placement of geotextile would be difficult and hazardous to the laborers. Large quantities of material would be required for construction and would require considerable space due to side slopes necessary. Liners used may lose their integrity due to the slow consolidation. Time required for consolidation is also a disadvantage.

Should hydraulic controls be utilized during remediation at the New Bedford Harbor site, a combination of embankments (with sediments removed) and the two types of sheet pile would be best suited for this technology, depending on location.

4.3 IN SITU BIODEGRADATION

4.3.1 Description

In situ biodegradation is a process by which contaminants are degraded by microorganisms without removing the contaminated medium from its source. In situ biodegradation is accomplished by enhancing the biodegradation capabilities of either the indigeneous microbes and/or an exogenous source of microbes. In situ biodegradation has reportedly been used successfully for the treatment of groundwater and soil contaminated with volatile aliphatic and aromatic hydrocarbons and for oily lagoon sludges.

4.3.2 Effectiveness

In situ biodegradation has never been successfully applied to river or harbor sediments. To accomplish in situ biodegradation, a number of factors such as the microbial population, nutrient levels, and physicochemical parameters affecting microbial growth and degradation capacities, have to be controlled. The logistics of controlling these parameters in unconfined sediments make it unlikely that any significant in situ biodegradation of contaminants could be accomplished. In situ PCB biodegradation has not yet been demonstrated in any environment. Although GE researchers are presently conducting in situ PCB biodegradation experiments in soils at the Glens Falls dragstrip in New York, the microbes they are using are incapable of growth in a marine environment.

4.3.3 Implementability

There is much conflicting evidence regarding the occurrence and mechanisms of in situ biodegradation of PCBs; therefore, the full range of factors involved with implementing this technology is unknown. Extensive studies would have to be conducted to identify indigenous or exogenous microbes and their nutrient requirements for enhanced PCB biodegradation. In situ biodegradation would likely take several years to accomplish, based on published reports of laboratory studies dealing with microbial degradation of PCBs. A very extensive monitoring and sampling program would be required to monitor and maintain parameters affecting PCB biodegradation, and ensure quality control and effectiveness.

4.3.4 Costs

It is difficult to estimate the costs associated with in situ biodegradation of PCBs in New Bedford Harbor sediments. It is apparent, however, that construction and implementation costs would probably be comparable to other technologies evaluated in this report, whereas the costs associated with monitoring, sampling, and analysis would likely far exceed those for any other technologies.

4.3.5 Summary

In situ biodegradation should be eliminated from further consideration as a treatment technology for New Bedford Harbor sediments. It has not yet been successfully demonstrated for PCB degradation in any environment, nor for any contaminants in sediments. It is unlikely that it would be successfully accomplished in the complex environment of New Bedford Harbor sediments. The extensive monitoring, sampling, and quality control programs that would be required would likely be impractical and cost prohibitive.

4.4 IN SITU SOLIDIFICATION

4.4.1 Description

Solidification/stabilization techniques are used in the treatment of hazardous wastes to:

- o eliminate or reduce the mobility of the chemicals of concern, by chemical bonding or by trapping the chemicals in the interstitial spaces of the solidified material;

- o eliminate or reduce the toxicity of the chemicals of concern by eliminating present exposure routes and reducing the future exposure potentials; and

- o improve the physical characteristics of the material to facilitate its handling and transportation.

In this section, the in situ stabilization of New Bedford Harbor sediments will be evaluated. Solidification of dredged sediments is examined in Section 6.2 of this report as a separate treatment technology. Section 6.2 presents a discussion of various solidification agents, their characteristics, and potential effectiveness in treating the sediments. This discussion is not repeated here; rather, this section is limited to an evaluation of the application of this technology to the in situ treatment of New Bedford Harbor sediments. To evaluate in situ solidification, bench-scale testing will be used to demonstrate the potential of treating the sediments with a particular solidification agent.

To date, the in situ stabilization of marine sediments has been employed only in Japan. A variety of civil engineering projects in Japanese harbors have utilized a method, alternately termed the deep cement mixing (DCM), deep lime method (DLM), or deep cement continuous mixing (DECOM) method, to solidify and strengthen sediments (Otsuki and Shima, 1984; Takenaka Komuten, Ltd., 1976; and undated product literature). In this method, slurried cement is injected into the sediments and mixed through rotary action utilizing specially-designed drilling equipment. The result is that overlapping or abutting cement columns are created in the sediments. The method has been effective for its intended purposes; however, it has not been used to treat hazardous wastes in sediments.

The DCM method is currently being utilized to treat PCB-contaminated soils at a PRP-lead Superfund site in Florida (E.C. Jordan Co., 1987a). At this site, PCBs had migrated several feet below the soil surface. The method may not be applicable to the New Bedford Harbor site for several reasons. In the sediments, the PCBs are primarily in the upper 2 feet. The available data indicate that significant strengthening of marine sediments, by the DCM method, increases with depth. It is likely, therefore, that with the DCM method, the upper layers of sediments may not interact with the solidification agent. This problem could be overcome by depositing a layer of clean sediments over the contaminated sediments. This would result in substantial added costs. This concept should be considered, however, as part of a multimedia capping alternative. It would require that only about 1 to 2 feet of sediment cover be utilized, versus 4.5 feet for a simple sediment cover system. In Section 3, the use of synthetic materials as part of a cover system for the site is eliminated from further consideration in the FS. The solidified sediments would provide substantial advantages to a simple cover system because of enhanced reduction in mobility of contaminants.

Deep cement chemical mixers as manufactured contain drilling equipment and cement mixing on a single floating vessel with drafts of at least 10 feet. This type of equipment would not be suitable for use at the New Bedford Harbor site, where most of the heavily contaminated sediments are located in shallow areas in the

Upper Estuary, or near the shorelines of the Lower Harbor. In addition, the mixers create cylindrical columns of solidified material. The columns could be overlapped to ensure that all contaminated sediments are solidified, which is being done at the Florida site (E.C. Jordan Co., 1987a). At New Bedford, however, quality control monitoring in a subaqueous environment would pose substantial problems and probably could not be ensured. For this reason, in situ stabilization of New Bedford Harbor sediments would require the use of modified equipment or the development of new injection and mixing equipment which could operate in shallow waters and would mix the cement and sediments in such a manner that quality control would not pose special concerns.

In situ stabilization of contaminated soils and hazardous waste sludge lagoons has been reported by several vendors (E.C. Jordan Co., 1987a, 1987c, 1987d); however, with one exception, those vendors contacted were not aware of the application of the technology to sediments. One vendor reported that in situ stabilization of hazardous sediments has been performed by the Japanese. Research of the Japanese application of this technology is ongoing. The following evaluation of this technology is based on the information presented above.

4.4.2 EFFECTIVENESS

Reliability. The reliability of this technology would be dependent on the nature of the solidification agent chosen. Bench-scale tests would be conducted to determine the best agent suited for stabilizing the PCBs in the sediments. The technology would be considered highly reliable if the solidification agent used could retain its integrity in sediments for many decades, and if it formed covalent bonds with PCBs or transformed the PCBs. A final assessment of reliability will require the results of bench-scale tests on the chosen agent.

Public Health. This technology would yield substantial public health benefits by:

- eliminating direct exposure to PCBs;
- reducing future migration of PCBs; and
- reducing bioaccumulation of PCBs in edible fish, shellfish, and birds.

The contaminants would not be removed from the sediments. Natural disintegration of the solidified sediments, and future activities in the harbor that damaged the integrity of the sediments, could allow PCBs to contact receptors again. Therefore, the long-term public health benefits would be correlated to the properties of the solidification agent, i.e., its durability and whether it transforms or covalently binds PCBs. The results of bench-scale tests would be needed to assess the long-term public health benefits.

Sediments would be suspended and dispersed during the solidification process. Unless measures were taken to mitigate the sediment dispersion, public health risks would be expected to increase above baseline conditions. Dispersion of contaminated sediment could be minimized by the use of a subaqeous shroud surrounding the mixing equipment. Alternatively, a layer of clean sediments could be placed over the contaminated sediments prior to treatment.

Environment. This technology would provide substantial environmental benefits for the same reasons described in the preceding section. In addition, the long-term limitations of this technology to public health protection also apply to environmental protection.

Potential adverse impacts associated with this technology include the following. Contaminated sediments would be suspended and dispersed during the solidification process, leading to additional migration of PCBs. In addition, destruction of habitats for benthic organisms would occur. A substantial decline in the population of benthic organisms and bottom feeders would be expected.

The implementation and effectiveness of this technology might be facilitated by first placing 1 to 2 feet of clean sediments over the sediments to be solidified. This would also reduce the adverse environmental impacts described above by eliminating or reducing suspension and dispersion of contaminated sediments, and by re-creating habitats for the benthic populations. In addition, the overlaid sediments would enhance reduction in mobility of PCBs over the long-term as natural disintegration processes occurred.

4.4.3 Implementation

Technical Feasibility. The technology is available to create and demonstrate suitable solidification agents for the sediments. The technology and resources needed to design operational requirements are available in Japan or the United States. The equipment that would be necessary could be manufactured or constructed by modification of existing equipment. The characteristics of the site would pose special concerns. It would be difficult to bring the necessary equipment over or adjacent to the sediments to be treated because of the shallow water in the upper harbor and along the shorelines, and because most of the land along the western shore (where contamination is greatest) is developed.

Demonstrated Performance. The application of the solidification technology to the in situ treatment of sediments has not been demonstrated in the United States. Its reported application to contaminated sediments in Japan is being researched.

Support Requirements. The implementation of this technology would require that the necessary equipment be brought to the treatment areas via shoreline access routes or from the ship channel. The latter is unlikely because of the shallow water over the contaminated areas, and access routes are limited due to shoreline development. Community support would be required to allow for access to the treatment sites.

As stated previously, there are several advantageous reasons for placing a layer of clean sediments over the contaminated sediments prior to treatment. This would require significant support in the form of dredging, transporting, and depositing the clean sediments.

Availability. The technology and resources required for application of this technology to the New Bedford Harbor site are not readily available throughout the United States Coordination between technical specialists in Japan and project engineers in the United States would likely be required. This link has recently been established by one United States vendor who has entered into a consortium with Japanese construction and equipment manufacturing firms for the purpose of applying solidification technologies to the treatment of hazardous waste sites in the United States (E.C. Jordan, 1987a). They are currently active at a PRP-lead Superfund site in Florida.

Installation. As stated previously, transporting and installing the equipment at the treatment sites would require specific attention to the fact that there is limited access to the affected areas. The most contaminated areas are in shallow waters in the Upper Estuary or along the western shore which is heavily developed.

Time. There is insufficient information available to estimate the time that would be required to implement this technology. Research is ongoing into Japanese efforts at in situ sediment solidification. Best estimates will be developed upon completion of this research.

Safety. The principal safety concern with in situ solidification is that mixing and dispersion of contaminated sediments could enhance the potential of exposure for swimmers in the outer harbor. Therefore, sediment resuspension and dispersion would need to be controlled. The use of television cameras would be safe and may be suitable for monitoring purposes.

Monitoring and Maintenance Requirements. Monitoring of the operations would be required to ensure that quality control objectives are met. This would require advance consideration as to whether divers and/or television cameras should be utilized.

Long-term monitoring for several decades would be required to be certain that PCBs are not diffusing into the water column from treated sediments. In addition, a program to monitor wildlife in and around the harbor would be necessary to determine the effectiveness of the treatment. This program would take several years to be certain that bioaccumulation of PCBs was no longer occurring, or occurring at a substantially lower rate than current baseline conditions.

Maintenance of the solidified sediments is not an applicable issue. If it is discovered that the material is disintegrating or ineffective, then these affected sediments would have to be removed or treated again.

Permitting. Under current statutes (CERCLA as amended), permits need not be obtained for Superfund remedial actions, however, permit requirements must be met. The applicable RCRA, CERCLA, TSCA, and DEQE standards governing PCB-wastes and cleanup of hazardous waste sites would have to be considered here. In addition, specific legal requirements relating to the protection of wetlands, rivers, and harbors would have to be satisfied.

Applicable federal statutes would include the CWA, NEPA, Rivers and Harbors Act, Fish and Wildlife Coordination Act, and the Coastal Zone Management Act. State regulations that would have to be considered include: Coastal Zone Management Program, DEQE-Administration of Waterways License, DEQE-Wetlands Protection, and DEQE Hazardous Waste Regulations.

Legal Constraints. Legal opposition to implementation of in situ solidification might arise from local commerce and the community, over the issue of using private or public lands to gain access and to implement operations at the treatment sites. Additional opposition would arise if the operational requirements included restrictions or limitations on the use of the ship channel. Local environmental groups may oppose the use of this technology at the site because wetlands may be impacted by the operations themselves, as well as by the destruction or impairment of benthic habitats.

Impacts on Historical and Cultural Resources. No impacts on historical resources would be expected by the use of in situ solidification at the site. It is possible, however, that local beaches in the outer harbor would be closed to swimming during operations because of the potential for enhanced exposure to suspended contaminated sediments.

4.4.4. Costs

At present, it is not possible to estimate costs for in situ solidification of contaminated sediments at the New Bedford Harbor site. One vendor quoted a price of $50 to $60 per cubic yard. (E.C. Jordan, 1987a) This is a lower estimate than that derived for solidification of dredged sediments, discussed in Section 6.2. The estimate might be applicable to the outer harbor sediments where necessary equipment could be floated over the areas to be treated. For the Upper Estuary and shallow areas in the Lower Harbor, significant costs would be associated with site access and equipment design, construction, and installation. Further research is required to develop cost estimates that may be applied to specific scenarios for the in situ solidification of sediments at the site.

4.4.5 Summary

In situ solidification should be retained for further consideration as a treatment technology for selected areas of the New Bedford Harbor site.

This technology would reduce the mobility of contaminants in the sediments. Long-term monitoring of the water column and wildlife, and a long-term inspection program, would be required to assure long-term protection of public health and the environment.

Adverse environmental impacts might arise as a result of the destruction of benthic habitats.

Based on available information, the technology could be implemented in areas where site access and installation of equipment would not pose a special concern, such as in very shallow areas of the Upper Estuary (e.g., Hot Spot), or in the deeper areas of the Lower Harbor and outside of the hurricane barrier. It would be impractical to apply this technology to very large and relatively shallow areas of the Lower Harbor, where site access and equipment installation would be hindered by heavy boat traffic, and for shoreline development. An additional constraint in the Lower Harbor would be the difficulty of solidifying the steeply sloping and deeper sediments inside, and bordering, the ship channel. Mitigative measures to eliminate or reduce dispersion of suspended contaminated sediments, and extensive quality control considerations to ensure effectiveness, would be required during implementation.

The effectiveness of the technology could be enhanced, adverse environmental impacts reduced, and implementation facilitated by placing a clean layer of sediments over contaminated sediments prior to implementation.

Further information and research are required to derive cost estimates for this technology.

5.0 REMOVAL TECHNOLOGIES

This section describes the detailed evaluation of the removal technologies retained after the initial screening process. Removal technologies would remove PCBs and metals from the harbor bottom by removing sediment where the contaminants are located. The removal actions discussed include: mechanical dredging, hydraulic dredging, special purpose dredging, and excavation technologies. The detailed evaluation of these technologies is being conducted using effectiveness, implementation, and cost as screening criteria.

5.1 MECHANICAL DREDGING

5.1.1 Description

Clamshell

A clamshell dredge is a conventional dredge readily available throughout the United States. Clamshell dredges are usually barge mounted and transported by tugs. In most cases anchors and spuds are used to position and move the barge during dredging. Clamshell dredges can be ship mounted and self propelled, but these are not as common as the barge mounted clamshells.

Clamshell dredges typically load dredged material into scows or barges that are towed to the disposal site.

The clamshell dredge was retained for detailed screening for the Estuary and Lower Harbor/Bay. Further analysis, however, determined that it is unsuitable for both areas. It is unsuitable for use in the Estuary for three reasons. First, a minimum vessel draft of six feet is required for the clamshell barge and the barges to transport sediment. Only a small portion of the Estuary has water depths of six feet. This portion comprises a channel in the middle of the Estuary that extends halfway up the Estuary. Dredging would be limited to approximately 25 percent of the Estuary.

Second, the Coggeshall Street Bridge only has a eight foot vertical clearance. A clamshell barge could not pass under that bridge into the Estuary but would have to be launched upstream of the bridge. No suitable area currently exists for the launching of a barge, and the construction of a launch area is not warranted because of the limited working area discussed earlier. In addition, the barges transporting the sediment out of the Estuary to the unloading area would not be able to pass under the bridge.

Third, the clamshell is not suitable for use in the Estuary due to the large amount of resuspension that the dredging process creates. The clamshell produces sediment resuspension when the bucket impacts the sediment, is drawn from the sediment, pulled through the water column and then drains above the water as it is being loaded into the barge. In such shallow waters sediment resuspension is also created by the action of the barge and spuds on the bottom sediment. Sediment resuspension in the Estuary is a significant concern since this area has PCB-contaminated sediment an order of magnitude or greater than the sediment in the Lower Harbor/Bay.

The clamshell is unsuitable for the Lower Harbor/Bay because of the sediment resuspension problems discussed earlier. Although contamination in the Lower Harbor/Bay is not as high as that found in the Estuary, over 750,000 cubic yards are estimated to be contaminated with PCBs. Sediment resuspension in the Lower Harbor/Bay needs to be minimized in order to keep the contaminated sediment from further migration into Buzzards Bay. Therefore, the conventional clamshell bucket will be excluded from further consideration in the Lower Harbor/Bay.

Watertight Clamshell

The watertight clamshell bucket was developed to minimize sediment resuspension generated by the conventional clamshell bucket. The buckets can be used on clamshell dredges with no modification required to the dredge. The watertight bucket has tongue-in-groove edges which seal when the bucket is closed. The top is also closed to minimize the loss of dredged material. This technology has been field tested and proven to reduce sediment resuspension when compared to a conventional clamshell bucket.

The watertight clamshell has the same limitations as the conventional clamshell with respect to vessel draft and inability to fit under the Coggeshall Street Bridge. For these reasons, its use in the Estuary is being excluded from further consideration.

The watertight clamshell can not be used in all areas of the Lower Harbor and Bay. The vessel draft of the clamshell barge and the sediment transportation barges preclude its use in water with depths less than six feet. This reduces the area within the Lower Harbor and Bay that can be worked by the watertight clamshell by 30 percent. The use of the watertight clamshell to remove all contaminated sediment within the six foot working depth is not recommended since the clamshell is not effective in removing thin lifts of contaminated sediment as exist in the Lower Harbor and Bay. Overexcavation of two to three feet would be required to ensure contaminant removal. If used in all workable areas of the Lower Harbor/Bay, the amount of sediment to be removed for treatment and/or disposal would be prohibitive.

The use of the watertight clamshell to excavate selected areas of the Lower Harbor/Bay is possible. Sediment with PCB contamination greater than 10 ppm typically occurs in pockets or localized areas. It is feasible that these areas could be excavated with a watertight clamshell. The advantage is that the watertight clamshell could remove the higher concentrations of contaminated sediment with minimum set up time and disturbance to harbor activities. If needed, these localized areas could be surrounded by silt curtains and oil booms to keep the contamination confined to the work area. A station would be required to unload the contaminated sediment from the barges and load it into trucks. Additional environmental controls will be employed around the unloading area to keep any sediment spillage from recontaminating the harbor.

The remainder of the discussion on mechanical dredges will focus on the use of the watertight clamshell in the sediment areas contaminated with PCBs in excess of 10 ppm in the Lower Harbor/Bay.

5.1.2 Effectiveness

Reliability. The watertight clamshell is more reliable in the removal of contaminated sediment than a conventional bucket due to less sediment resuspension and subsequent migration of contaminants. Environmental controls, consisting of silt curtains and oil booms, may be required in order to contain any resuspended sediment which is near the water surface. The effectiveness of environmental controls will be determined by environmental monitoring during the dredge activity.

In order to ensure complete removal of the contaminated sediment, overexcavation will need to occur. The watertight clamshell has a two foot vertical accuracy. Therefore it is difficult for the dredge to remove thin lifts of material. At a minimum, a dredge efficiency factor of 4 is expected for the watertight clamshell. That is, in order to remove six inches of contaminated sediment, a minimum of two feet of sediment will need to be removed. Operationally, this may be difficult to achieve and a total removal depth of three to four feet is expected. The watertight clamshell is reliable in removing the contaminated sediment; however, the total volume of sediment requiring treatment/disposal will increase with respect to other removal technologies.

Public Health. As with the other removal technologies, few long term public health effects are anticipated because the contaminated sediment is permanently removed from the harbor. Samples of the remaining sediment will be analyzed to ensure complete removal of the contaminated sediment. Any areas that still contain PCBs exceeding the target level will be further excavated.

The watertight clamshell will excavate the contaminated sediment and place it in a barge. When the barge is full a tugboat will transport the barge to an unloading station at in-harbor site 7. The sediment will then be rehandled by a shore mounted clamshell. This clamshell will load trucks that will transport the sediment to the disposal/treatment areas.

There are three areas that have the potential for adverse short term public health effects. The first is the potential for increased volatilization of PCBs due to the excavation, transportation, and rehandling of the contaminated sediment. PCBs volatilization is expected to be the greatest during the transportation and rehandling of the contaminated sediment. Water or foam sprays may be required to reduce this volatilization if air monitoring results indicate that PCB emissions are above acceptable levels. Continuous air monitoring is anticipated for all work areas.

The second area that has the potential for adverse public health effects is the increased truck traffic. At a minimum, 11 trucks are anticipated to be needed to remove the sediment from the barges and transport it to the disposal/treatment areas. All trucks will be decontaminated prior to entering public streets. The possibility does exist for these trucks to have accidents either injuring people or contaminating public areas with the PCBs sediment. Truck traffic will need to be monitored and controlled to minimize accidents.

The last area that has the potential for adverse public health effects is the increase in boat/barge activity in the harbor. Harbor activity will increase during dredging as there will be three barges, a tug boat, and the watertight clamshell working in the harbor. Although boating accidents or the release of the contaminated sediments from the barge is not anticipated, the possibility does exist. Dredging activities will be closely monitored to reduce the potential for accidents.

Environment. The dredging of the sediment containing PCBs in excess of 10 ppm will have a beneficial effect on the environment by permanently removing the contamination from the aquatic environment. In addition to removing the sediment, contaminated benthic organisms will also be removed at the same time. This will remove a contaminated link of the food chain. Recolonization of these benthic organisms is expected to occur and will replace this link with a healthy, uncontaminated population.

The watertight clamshell dredge is expected to have a short term adverse effect on the environment due to sediment resuspension during the dredging process. Although the installation of environmental controls (e.g., silt curtains, oil booms) should contain the resuspensed sediment to the work area, a short-term degradation in water quality is expected. Environmental monitoring will be conducted continuously during dredging to provide data that can be used to assess the effect of the operation on the aquatic environment.

5.1.3 Implementation

Technical Feasibility. The technical feasibility of using the watertight clamshell dredge is good. Watertight clamshells have been shown to be effective in the removal of contaminated sediment with less suspension than a conventional clamshell bucket. The areas that are to be dredged with the watertight clamshell will need to be checked prior to dredging to ensure that they are free of rocks, debris, or other material that would prevent improved sealing of the bucket.

Level of Development. The watertight clamshell bucket was developed in Japan for the removal of contaminated sediment. It has been tested in the United States by the USACE and determined to be effective in removing contaminated sediment with less resuspension than a conventional bucket. Bench or pilot scale testing is not anticipated to be required. Downtime of this dredge is estimated to be 20 percent.

Support Requirements. The support requirements for the watertight clamshell dredge are extensive. Environmental controls consisting of silt curtains and oil booms will be required at the dredge and the unloading station to minimize sediment migration. Three barges and a tug boat will be required to transport the excavated sediment to the unloading station. An unloading station consisting of a shore-mounted conventional clamshell will be needed to unload the barges and load the trucks. A truck fleet consisting of a minimum of 11, 20 cubic yard trucks will be needed in order to transport the sediment to the treatment/disposal area. In addition, a decontamination station will be required at the unloading station to decontaminate the trucks prior to leaving the work area. If the Conrail railyard is used as the treatment/disposal area then a truck fleet will not be required as the unloading station is immediately adjacent to this area.

Availability. The current availability of watertight clamshell buckets in the United States is poor (as they have only been used on an experimental basis). Conventional buckets, however, can be modified to watertight buckets. The availability of conventional clamshell buckets is excellent and the fabrication of a watertight bucket is not anticipated to be difficult. Site access for the dredge, barges, and tug boat, and site availability for the unloading station have not been determined. Availability of a tug, barges, and trucks is excellent in the United States. (This information will be determined following the formulation of remedial alternatives.)

Installation. The installation of the watertight clamshell dredge in the Lower Harbor/Bay is not anticipated to be a concern. Some design work and studies will be required prior to installation, but these are expected to be of the same magnitude as for the other removal technologies. Since few watertight clamshell buckets are currently available, some lead time will be required to design and modify a conventional clamshell bucket into a watertight clamshell bucket.

Time. The time required to implement the watertight clamshell is dependent upon the PCB target level chosen for a clean-up standard. If a target level of 100 ppm of PCBs in the sediment is chosen for a clean-up level, then the dredging is estimated to take 1 month. Similarly, >50 ppm will take 2 months and >10 ppm will take 11 months. Mobilization, set-up, and demobilization of the dredging equipment is expected to take approximately one year.

Safety. The short- and long-term safety hazards to the public and workers are the same as those discussed under Public Health. The dredge operators and other on-site workers will be required to use the appropriate safety equipment, and strict adherence to a health and safety plan will be required at all times.

Monitoring and Maintenance Requirements. Environmental monitoring for both air and water quality will be required in both the dredging and unloading areas. This monitoring will document the extent of sediment resuspension, the rate of PCBs volatilization, and the success of the environmental controls. Operational adjustments can be made based on the results of this monitoring to reduce the amount of sediment resuspension and/or PCBs volatilization.

Machinery maintenance is expected to be on an as-needed basis with downtime estimated at 20 percent.

Permitting. No permits are anticipated to be required for this work since all work will take place within the site boundaries. The procedural requirements of several ARARs, however, will need to be followed (e.g., USACE dredge and fill permit).

Legal Constraints. Site access and availability is necessary for the success of this technology. Land ownership and the potential for legal constraints will be determined following the formulation of remedial alternatives.

An increase in truck traffic may occur if upland treatment/disposal areas are chosen. These trucks would transport the contaminated sediment along public streets in New Bedford and neighboring towns. Local community groups may attempt to block the transportation of this contaminated sediment along the public roads. These groups, concerned about the health and safety of their families, could impose legal constraints upon the project which can not be quantified at this time.

Impacts on Historical and Cultural Resources. Currently, there are no known archaeological, historical, or cultural resources located within the New Bedford Harbor site. If any of these resources are uncovered during dredging, all operations will cease until the appropriate state and federal authorities have checked the area and cleared it for future work.

5.1.4 Costs

The volume of contaminated sediment to be removed in the Lower Harbor and Bay was determined by calculating the total volume of sediment containing PCBs in excess of 10 ppm and then reducing this volume to what could be accessed by a vessel with a six foot draft. The costs for removing volumes of sediment by a watertight clamshell dredge were then determined for several PCB target levels (>100 ppm; >50 ppm; >10 ppm). Three different scenarios were evaluated for cost information. In all three scenarios, a three cubic yard watertight clamshell bucket dredges the contaminated sediment, and places the sediment in a barge which is towed to the unloading station located at in-harbor site 7. In the first scenario the dredged spoil is loaded into trucks and transported to a treatment/disposal area located at the New Bedford Municipal Landfill. The second scenario has the trucks driving to a generic off-site disposal area 3 miles from the Lower Harbor area. For the last scenario, treatment/disposal occurs at the adjacent Conrail railyard, and a truck fleet and decontamination station is not required.

The costs are summarized in Table 5-1 and indicate that for all PCB target levels, treatment/disposal at the Conrail railroad is the least expensive, because a truck fleet is not required. This scenario also has an advantage from a public health standpoint because there will be no trucks driving on the public streets. Costs increase with a decrease in PCBs target level because the volume of contaminated sediment increases with the lower target levels. For all three scenarios, the project life is less than one year excluding mobilization and demobilization.

Unit costs approach those of the hydraulic dredges when the larger volumes of sediment are considered. Unit costs for treatment/disposal at the railyard are comparable to hydraulic dredge costs because the truck component is absent.

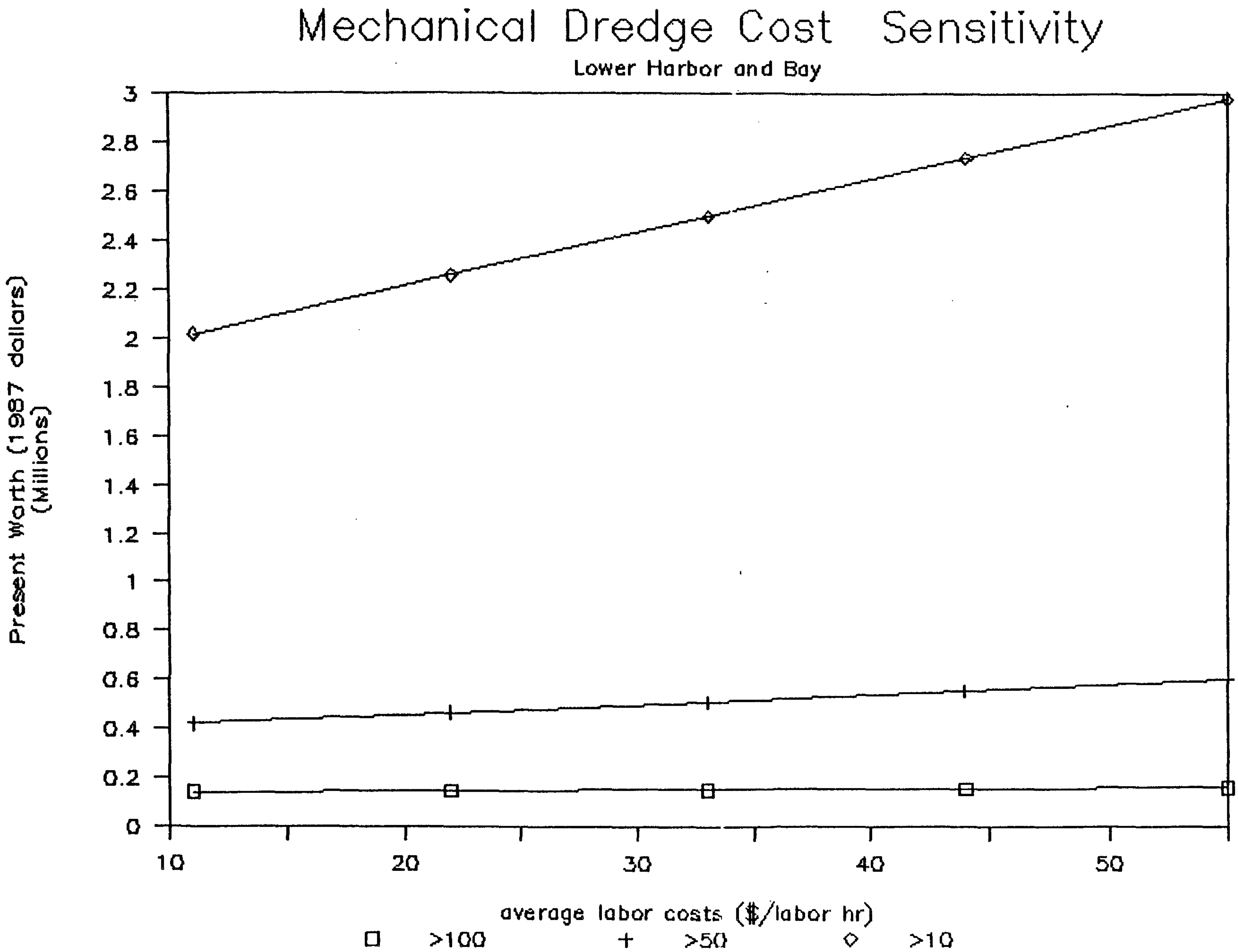
Sensitivity Analysis

Three sensitivity analyses were performed on the watertight clamshell operation. These sensitivities were performed on the scenario of treating/disposing the >100, >50, >10 ppm sediment at the Quarry. The first sensitivity was performed by looking at the effect a change in labor costs has on the project. Figure 5-1 illustrates this effect. Little effect is shown in the >100 ppm

TABLE 5-1
WATERTIGHT CLAMSHELL COSTS - LOWER HARBOR AND BAY

Treatment Site	Landfill	Landfill	Landfill	Off-Site Location	Off-Site Location	Off-Site Location	Railyard	Railyard	Railyard
Bucket Size (yd^3)	3	3	3	3	3	3	3	3	3
PCB Target Level (ppm)	>100	>50	>10	>100	>50	>10	>100	>50	>10
Sediment Volume (yd^3)	1,020	24,460	140,020	1,020	24,460	140,020	1,020	24,460	140,020
Months of Operation	1	2	11	1	2	11	1	2	11
# of Trucks Required	15	15	15	11	11	11	0	0	0
Total Project Cost ($)	173,469	557,935	2,732,788	149,097	467,737	2,258,455	55,093	190,742	908,099
Unit Cost ($/$yd^3$)	170.07	22.81	19.52	146.17	19.12	16.13	54.01	7.80	6.49

Figure 5-1



Mechanical Dredge Cost Sensitivity
Lower Harbor and Bay
Present Worth (1987 dollars)
(Millions)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10
20
30
40
50
average labor costs ($/labor hr)
>100
>50
>10

and >50 ppm target levels since there is limited volume associated with these target levels. The greatest effect occurs in the >10 ppm target level. A doubling of labor costs from $20/hour to $40/hour translates to an increase in present worth project cost of approximately $400,000.

The second sensitivity analysis performed involved a change in interest rate. Since this project has an estimated life of less than one year, a change in interest rate is expected to have a minimal effect, as illustrated in Figure 5-2.

The last sensitivity analysis involved the dredge efficiency factor (see Figure 5-3). The dredge efficiency factor was estimated to be 4 based on a total dredging depth of 2 feet. It may not be operationally practical to limit dredging to this depth based on the weight of the bucket and other operational constraints. Dredge efficiency factors of 6 or 8 are more likely. As Figure 5-3 highlights, a change in efficiency factor has a large impact on cost because more sediment has to be excavated to ensure complete removal. This is most pronounced in the >10 ppm target level where a doubling of the efficiency factor from 4 to 8 increases the project present worth costs by approximately two million dollars.

As a result of these sensitivity analyses, the project costs are more susceptible to an increase in the dredge efficiency factor

Figure 5-2

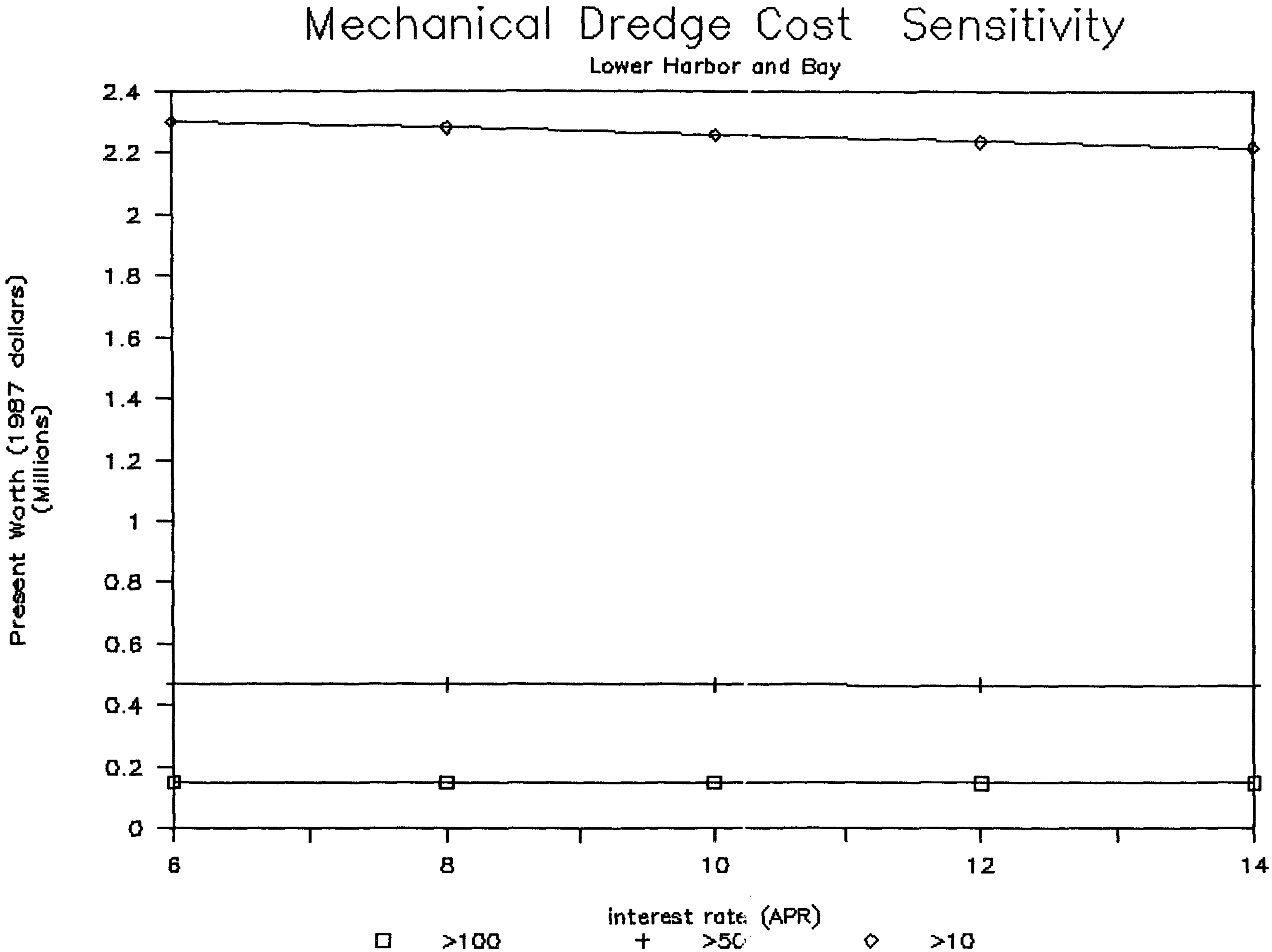
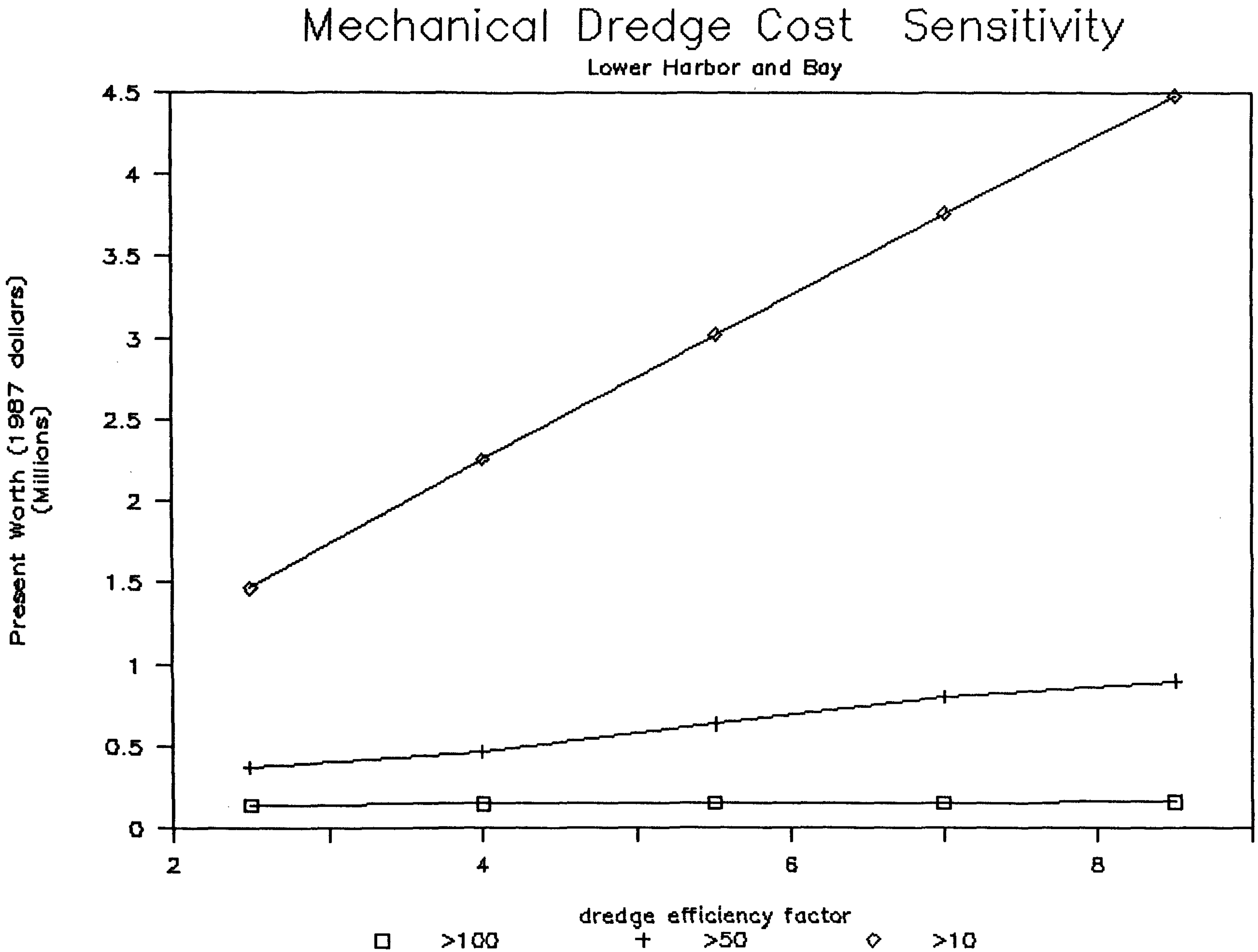

Mechanical Dredge Cost Sensitivity
Lower Harbor and Bay
Present Worth (1987 dollars)
(Millions)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
6
8
10
12
14
interest rate (APR)
>100
>50
>10

Figure 5-3



Mechanical Dredge Cost Sensitivity
Lower Harbor and Bay
Present Worth (1987 dollars) (Millions)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2
4
6
8
dredge efficiency factor
>100
>50
>10

than the other parameters tested. It will be important, therefore, to determine a realistic dredge efficiency factor (overexcavation factor) prior to field implementation in order to obtain an accurate cost estimate. Research or a pilot test may need to be performed prior to full implementation if this technology is chosen as part of a remedial alternative.

5.1.5 Summary

Although the watertight clamshell is a viable removal technology for the Lower Harbor/Bay, it has several disadvantages. The first disadvantage is that it is only effective in localized areas and where water depths exceed six feet. The second disadvantage is the amount of sediment resuspension anticipated from the bucket, barges, tugs, and unloading station. While each of these activities may not contribute significantly to the resuspension, the cumulative effect is expected to be greater than the hydraulic or special purpose dredges. This disadvantage is significant because it does not reduce the contaminant mobility as well as other dredges. The third disadvantage is the vertical accuracy of the dredge. Overexcavation is expected to approach a factor of 6. This increases the volume of sediment removed and associated removal costs.

The watertight clamshell has been removed from further consideration because of these disadvantages. Other removal technologies (e.g., cutterhead) can permanently remove the sediment with fewer disadvantages and at lesser cost than the watertight clamshell.

5.2 HYDRAULIC DREDGING

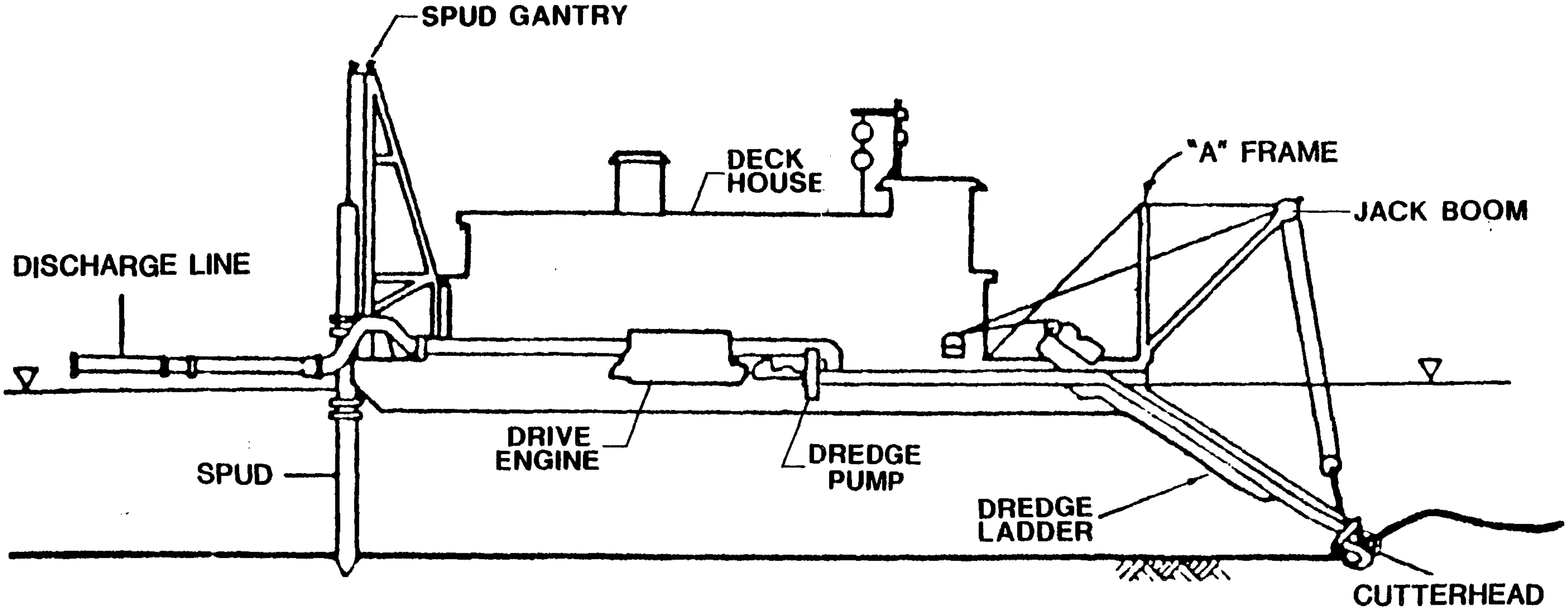
5.2.1 DESCRIPTION

Three hydraulic dredging technologies were retained for detailed evaluation for the removal of contaminated sediments at New Bedford Harbor: cutterhead suction, plain suction, and hopper dredges.

Cutterhead Dredge

The suction cutterhead dredge is the most commonly used dredge in the United States, principally due to its versatile method of operation. The cutterhead is capable of removing all types of material including soft material, compacted deposits, hardpan, and rock.

The suction cutterhead dredge is a barge equipped with a deck house in which the onboard machinery is located. Figure 5-4 shows a profile of the cutterhead dredge. A spud gantry is located at the stern to handle the anchoring spuds and a jack boom is at the



SOURCE: HAND, 1978

FIGURE 5-4
CUTTERHEAD DREDGE

bow to facilitate manipulation of the suction pipe ladder. Raising and lowering the spuds and ladder is accomplished by winch and cable. These may be driven either electrically or hydraulically. By systematically dropping the two spuds alternately and by the timely use of the swing cables, the dredge can be swung laterally and advanced forward for short distances. For long distances the dredge may be towed or pushed. The suction pipe is attached to the ladder which extends from the bow down to the water bottom. A rotating cutter is attached to the end of the suction pipe. The rotating cutter loosens the material which is then sucked through the suction pipe, up the ladder through the dredging pump, and discharged through a pipeline at the stern.

There are two key parts of a suction cutterhead dredge upon which production primarily depends. These are the centrifugal dredging pump and the cutterhead. The centrifugal pump is the heart of the dredging system and is responsible for drawing water and suspended solids from the bottom through the suction pipe up to the dredge and pushing this dredge mixture through the discharge pipe.

Due to the approximately 20 percent solids content of the mixture being pumped, the construction and performance of the centrifugal pump are different than that of a similar pump used in a strictly water application. The severe service required of the dredge pump necessitates that the pump have a generally heavier construction, wide internal clearances to permit passage of a high proportion of solids, and replaceable volute liners and vane tips. This results in a less efficient pump, usually about half as efficient as its water duty counterpart. Generally, the diameters of the suction side and the discharge side pipes are the same. The diameter of the discharge which is the pump's rating is used as the nominal rating of the dredge. The hourly output of a 12-inch suction dredge with a 12-feet-per-second velocity of flow pumping at a 20 percent solids content is 251 cubic yards bank measurement per hour.

Cutterheads have been designed for many sizes of suction dredges and for various applications. Dependent on the characteristics of the material to be removed, the design of the cutterhead will change. Cutterheads used for medium density deposits such as those in the Lower Harbor and upper Buzzards Bay will have smooth blades which are intended to slice and abrade the material to an acceptable size for lifting to and passing through the pump. The rotation of the cutterhead should undercut the sediment to minimize sediment resuspension. Speed of rotation can be varied from approximately five to twenty rotations per minute. Rotation may be reversed to facilitate any necessary unclogging of material. The diameter of the cutterhead varies according to application, but generally is three times that of the suction head. Horsepower applied to the cutterhead is typically 10 percent that of the dredge pump. Regardless of the size, type, and horsepower driving the cutterhead, its speed is adjusted by the nature of the material in which it is working.

A new and innovative hydraulic pumping technology has recently been introduced to the dredging industry. This new pump is called the Eddy Pump and has the capability of replacing the centrifugal pump in dredging applications. The Eddy Pump is based on a design that can handle a higher percentage of solids than does the centrifugal pump. The Eddy Pump's principle of operation differs greatly from that of the centrifugal or vortex pump. It uses hydraulic eddy current principles. The pump creates a synchronized swirling column of fluid in the center of the intake pipe. This tight patterned swirling column agitates the material to be dredged and causes it to swirl upward by reverse flow in the eddy current. This swirling material travels upward near the sides of the intake pipe, into the body of the pump, and out the discharge line.

In the laboratory, the Eddy Pump demonstrated the capability of pumping 80 percent solids. In the field during an actual dredging operation, 65 percent solids were reached for short periods of time. Engineers have built a cutterhead dredge around the 8-inch Eddy Pump. This dredge is presently conducting operations in the United States. The cutterhead dredge employing the use of the Eddy Pump was designed and built using specifications for a dredge with a 14-inch centrifugal pump. The manufacturer claims the Eddy

Pump, with an 8-inch suction line and a 20-inch casing, will outperform any currently manufactured pump with a 14-inch suction line and a 60-inch casing. This Eddy Pump weighs eight times less, and uses less horsepower. The following figures show a comparison between ladder-mounted centrifugal and Eddy dredge pumps:

	Centrifugal	Eddy
Pump Size (intake x discharge diameter in inches)	12 x 14	8 x 8
Production (tons/hour)	508	553
Horsepower (reg. per 100 ft. of head)	263	148

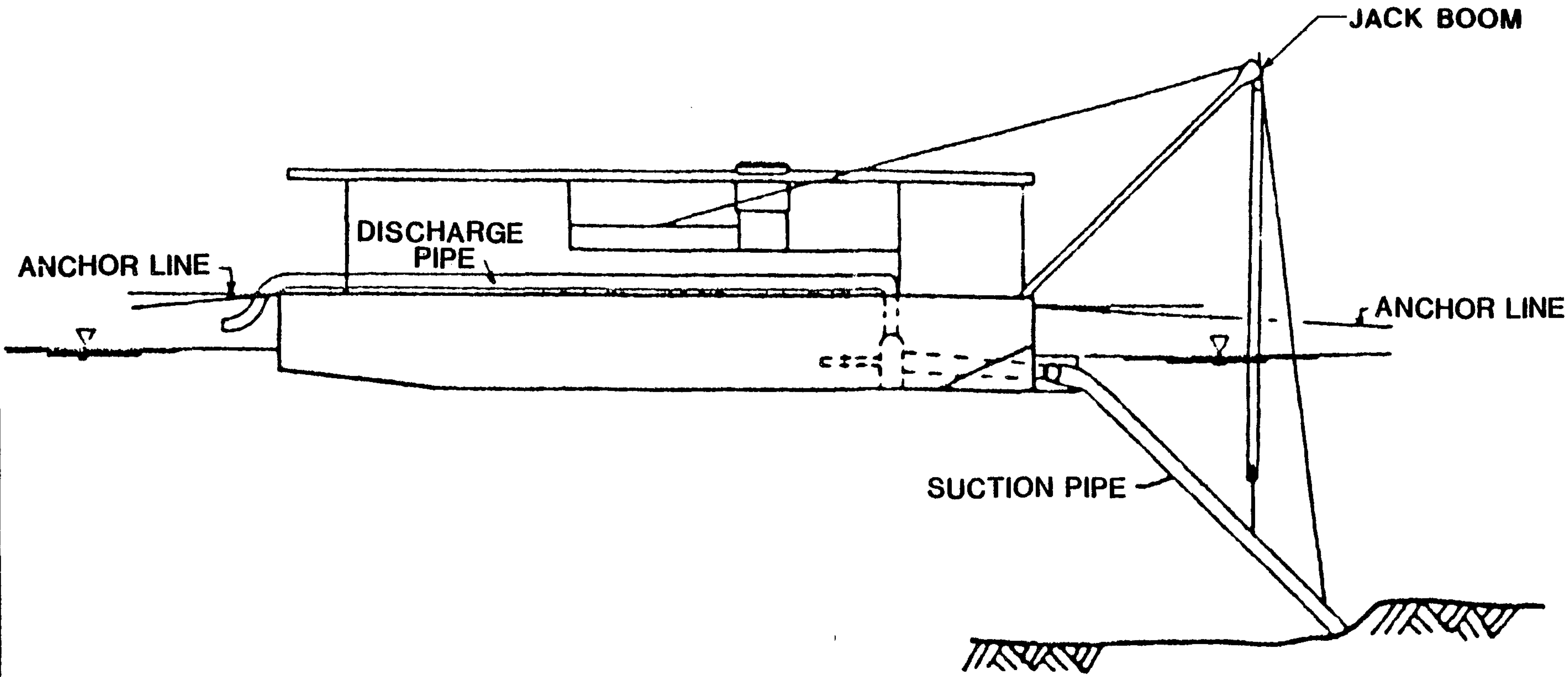
The Eddy Pump has been tested by an independent pump and engineering company. This company has reported that in a dredging application, an 8-inch Eddy pumped hardpack blue clay with production rates similar to that of a 14-inch dredge. They testified that they could not plug the pump with the cutterhead in operation. With the cutterhead operating, the total solids content of the dredged slurry reached 37.9 percent. When the cutter was disengaged and the additional horsepower transferred to the Eddy Pump, the solids content of the slurry increased to 49.5 percent. Production rates achieved were 600 tons per hour with the dredge sized to 14-inch specifications.

Cutterhead Eddy Pump dredges are presently being marketed in the United States. Additional production figures are being compiled presently during dredging projects. Conversations with the engineers designing the Eddy cutterhead dredge concerning the specifics of the New Bedford site lead them to believe the sediments could be pumped at in situ densities without the aid of a cutter.

This new pumping technology should be considered a strong candidate for contaminated sediment removal activities in New Bedford Harbor.

Plain Suction Dredge

Physically, the plain suction dredge is similar to that of the cutterhead. Figure 5-5 shows a profile of a plain suction dredge. A jack boom is at the bow to facilitate vertical control of the ladder to which the suction pipe is attached. The dredge ladder is rigidly attached to the hull at the bow. Unlike the cutterhead, the plain suction uses no spudpoles for positioning or cutter attachment on the suction pipe for material agitation prior to lifting. The workhorse of the dredge is the powerful centrifugal pump which is usually located on deck and is the plain suction's only means of lifting material from the bottom.



SOURCE: HAND, 1978

FIGURE 5-5
PLAIN SUCTION DREDGE

The plain suction dredge operates primarily on the suction generated by the centrifugal dredge pump. A suction pipe is lowered to the surface to be excavated by means of the dredge ladder. The end of the suction pipe through which material is lifted typically has no attachment or means of agitating sediments for the purpose of lifting them other than serrated edges of the head. A powerful pump draws bottom material up through the suction line and discharges through a discharge pipeline to a barge, scow, or disposal site.

The plain suction dredge is typically advanced through the dredging area by means of a cable and winch arrangement. The cable is anchored on land or on the bottom in front and in back of the dredge. The dredge is moved along the line of the cable. The cable is repositioned to provide a new line of travel. This is the only means by which the plain suction dredge may be manipulated laterally.

Hopper Dredge

Hopper dredges are designed to operate in open waters and are best suited to dredging deep harbors and rough water shipping channels. Figure 5-6 shows a profile of a hopper dredge. Rather than a barge, the hopper dredge is normally a large self-propelled vessel ranging between 180 to 400 feet in length and 12 to 30 feet in draft (loaded). The ships are equipped with two propeller and

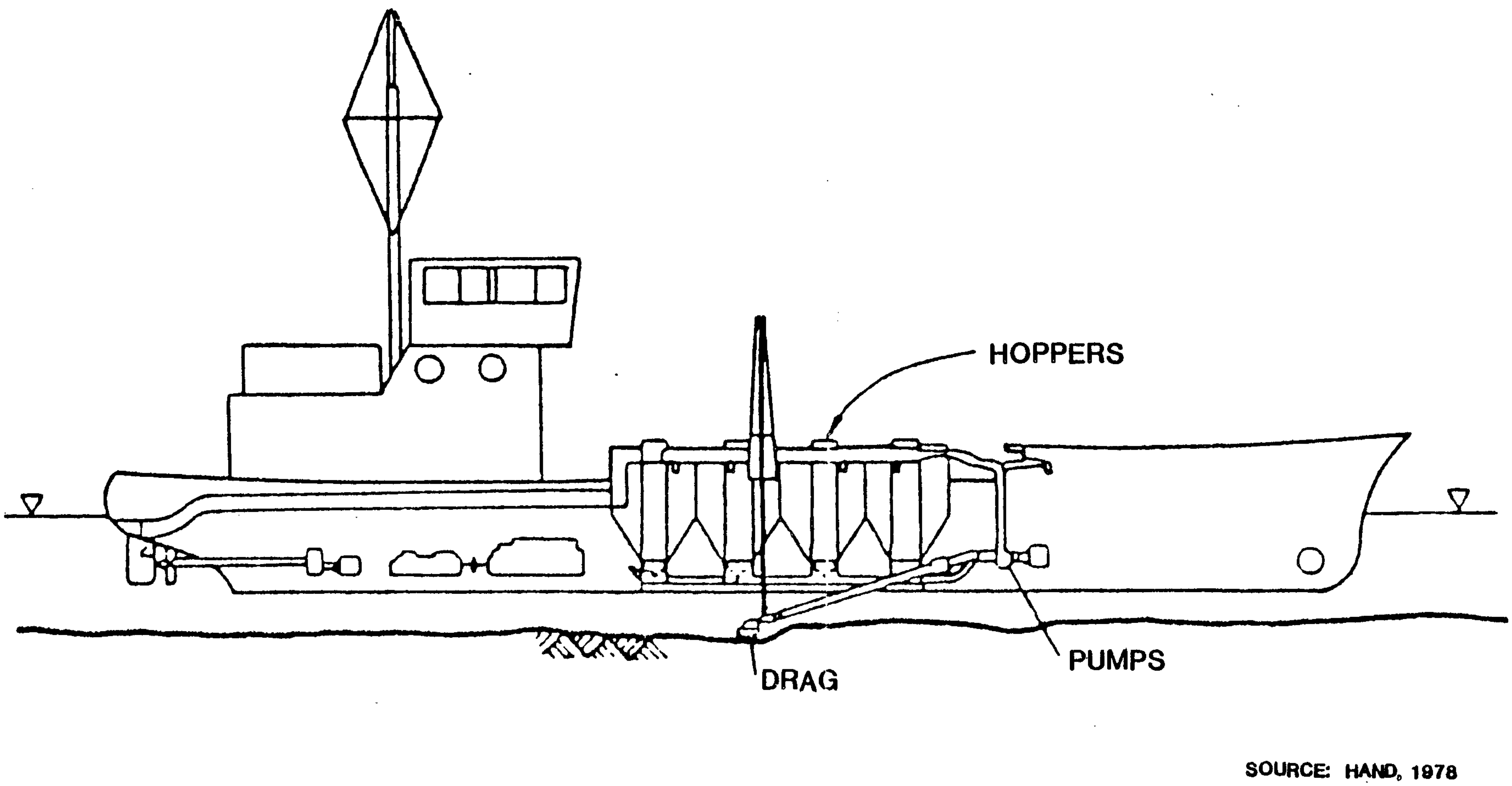


FIGURE 5-6
HOPPER DREDGE

rudder arrangements which provide for positioning and maneuverability required while conducting dredging operations. Material is lifted from the bottom through dredge heads that drag along the bottom (up to approximately 80 feet in depth). This type of hopper dredge is often called a "trailing hopper" since the dredge heads trail behind the direction of the vessel. Each dredge head is attached to a suction pipe hinged on either side of the vessel about midship. The dredge head has no agitation mechanism to aid in dislodging material. A large centrifugal pump provides lift to the material to be dredged. Material transported up the suction pipes is discharged and stored in large hoppers. Hopper capacity can range from approximately 500 cubic yards to 8,500 cubic yards. Water and suspended material that hasn't settled out is usually allowed to overflow the hopper and enter into the surrounding waters, leaving only the heavy coarse grained material to be disposed of. This loading procedure would be unacceptable in the removal of contaminated material. A loaded hopper dredge would cease dredging operations and transit to the unloading area. Most hopper dredges are capable of unloading by opening large bottom doors for open water disposal or by pumping the load through a pipeline to a treatment/disposal facility. Working with contaminated dredged material in most cases would disqualify open water dumping as a disposal alternative.

5.2.2 Effectiveness

Reliability

Cutterhead Dredge

The cutterhead dredge is the most versatile hydraulic dredge used today and is a proven reliable performer. By the nature of its operation, however, the cutterhead does have the potential for causing sediment resuspension. A substantial increase in turbidity has been observed at the cutterhead intake during operations (Raymond, 1983). This would be an area of concern when considering the use of the cutterhead in the removal of sediments contaminated with hazardous waste. In an effort to minimize the adverse effects on ambient water quality, some new dredging techniques for the cutterhead have been identified. These techniques consist of operational controls such as:

- o Monitoring and regulating cutterhead rotation and horizontal swing speeds that will provide for the efficient loosening of material for lifting and so that the amount of material supplied to the suction is not in excess of that which can be lifted by the dredge pump.

- o Regulating the vertical thickness of the dredge cut to minimize the volume of additional dredging required and maximize the removal of contaminated sediments. Layer cutting techniques should be avoided when turbidity is anticipated as a problem.

- o Undercutting sediments which helps minimize turbidity.

- o Electronic positioning to provide more accurate horizontal and vertical dredge head placement and angle.

Structural modifications include:

- o Installing a shielding attachment over the cutterhead to avoid the influx of water and contain the suspended sediment generated by the action of the cutterhead; this attachment should be provided with openings on both lateral sides such that dredging may take place while swinging in either direction.

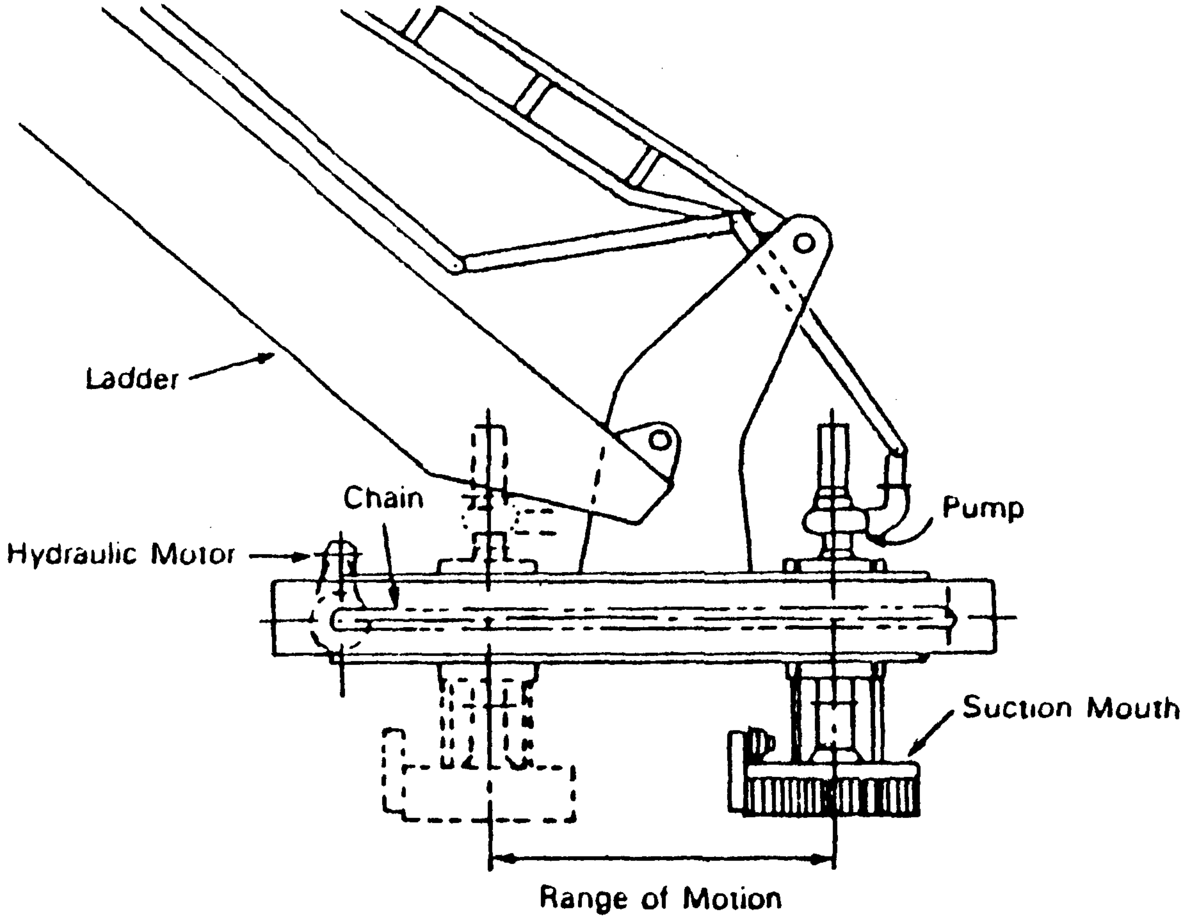
- o Modifying the dredge head and ladder to provide for the optimum dredging angle regardless of dredging depth and waterbottom contour; this modification would make it possible for parallel (not concentric or intersecting arcs) to be dredged (i.e., Drex Head).

The Drex Head was not retained during the initial screening of removal technologies process. Throughout the process, the drex head was treated as an individual technology. It was screened out because it did not exhibit any production or sediment resuspension advantage over conventional methods.

Although the drex head shows little application possibility at New Bedford Harbor as an independent dredging technology, the concept may be applied. A shielded cutterhead mounted on a track that would allow lateral movement of the suction mouth relative to the ladder would be of benefit. This arrangement would allow parallel, rather than intersecting, arcs to be tracked. Dredging accuracy is improved, and a higher solids content of the dredged material will be realized with this tracking pattern. A high solids content translates to a minimization of water in the slurry. When dredging contaminated substances, this is an advantage, considering transportation, handling, and treatment volumes.

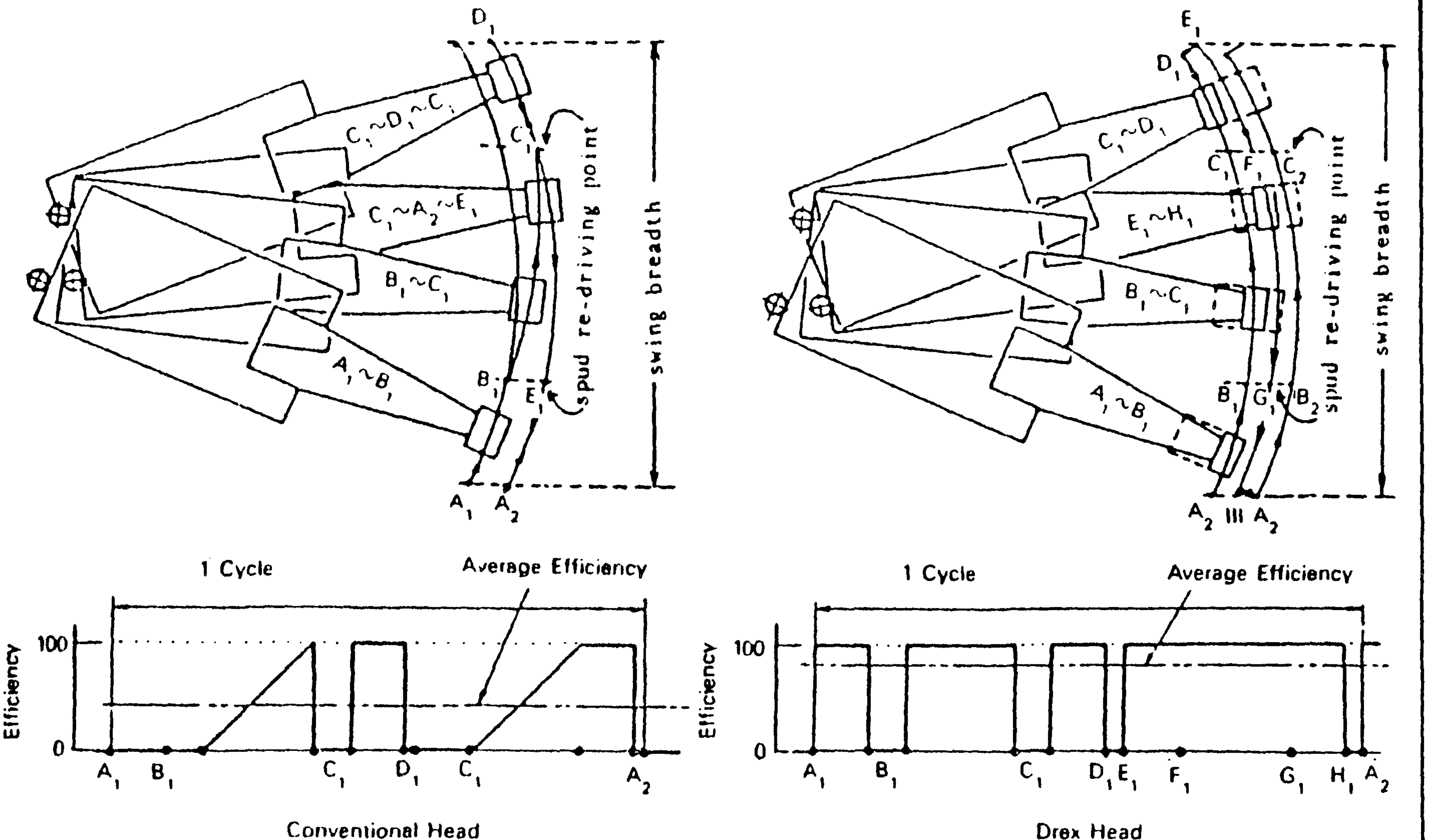
The potential for effective application of the drex head concept exists for the New Bedford Harbor project. Figures 5-7 and 5-8 describe the drex head and show the track and efficiency of it versus a conventional swing-type ladder dredge. Use of the drex head concept should be considered in conjunction with ladder dredge technologies.

It may be necessary to employ these operational controls and modifications to reduce sediment resuspension and subsequent



Source: Noguchi, 1981

FIGURE 5-7
PROFILE OF DREX HEAD



SOURCE: NOGUCHI, 1980

FIGURE 5-8
TRACK AND RESULTING EFFICIENCY OF CONVENTIONAL AND DREX HEADS

contamination migration during operations. For operations involving the removal of contaminated sediments from a waterway in the Netherlands, a conventionally rigged cutterhead suction dredge was modified following the general specifications outlined above and operations were conducted in accordance with the operational controls listed above. According to measurements taken prior to and during operations, suspended solid differences between background levels and levels within 2 to 5 meters of the dredging were approximately 40 mg/liter. Suction cutterhead operations employing these operational controls and modifications could result in reducing the potential for contamination migration during dredging of the hazardous waste found in the sediments of New Bedford Harbor. The use of this removal technology in this fashion may provide an effective means of removing the contaminated sediments in portions of the New Bedford Harbor site.

Plain Suction

Plain suction dredges typically are able to remove large volumes of material (up to 10,000 yd^3/hr) with a solids concentration of approximately 10 to 15 percent solids by weight. The slurry would therefore be comprised of 85 to 90 percent water and would require extensive dewatering prior to treatment, disposal, or overland transportation. Since it employs no method of shearing or abrading material to be lifted, the plain suction dredge would not be effective in removing relatively hard and cohesive materials such as much of those at the New Bedford Harbor site. Its effective use is limited to removing soft, free flowing materials. Additionally, the suction pipe is subject to clogging and damage caused by underwater obstacles. When considering use of the plain suction dredge for removal of contaminated sediments in New Bedford Harbor, it should be recognized that the dredge may experience a substantial amount of downtime due to suction pipe blockage caused by the nature of the bottom sediments and expected amount of underwater debris.

The cable and winch arrangement by which the plain suction dredge is advanced and manipulated makes this dredge an unadvisable choice for operations in rough water.

Hopper Dredge

The hopper dredge is a reliable and effective performer when conducting operations for which it was designed. Because of its unique design and operating method, and due to the complexity of the conditions at the New Bedford Harbor site, advantages and limitations associated with this dredge have been narrowed to only those which would apply to the site.

The advantages of using the hopper dredge technology in the bay portion of the site are:

- safe and effective operations may be conducted in rough open waters;
- no support vessels are required; and
- minimal interference to surrounding marine traffic.

Limitations to conducting contamination sediment removal in the bay portion of the site are:

- insufficient horizontal operating precision (+/- 10' tolerance);
- ineffective lifting hardpacked and consolidated material; and
- relatively high resuspended solids levels caused at dredgehead (on the order of a few grams per liter).

In light of these observations the reliability of the hopper dredge to effectively remove the contaminated sediments of the New Bedford Harbor site is questionable. The limitations of this technology outweigh the advantages when considered in context with the precision needed to remove the in situ consolidated contaminated sediment with little or no sediment resuspension.

Other hydraulic removal technologies being considered would be a more reliable choice.

A comparison of the three hydraulic dredging technologies for reliability in effectively removing contaminated sediments at the New Bedford Harbor site results in the cutterhead being the better choice. The following reasons are given to substantiate this choice:

- proven reliable performance under a wide range of site conditions and sediment characteristics, including those found at the New Bedford site;

- control of sediment resuspension;

- safe and efficient operations under varying sea conditions; and

- vertical and horizontal dredging precision can be controlled to some extent.

Public Health

Cutterhead Dredge

The potential for short- and long-term threats to human health associated with suction cutterhead dredging and the transportation of the dredged material via hydraulic pipeline and/or enclosed barge may exist due to:

- o Contaminant migration due to the sediment resuspension. Measurements taken during the dredging of the first Petroleum Harbor, Rotterdam showed resuspended solid levels 2 to 5 meters from the suction head to be up to a few tens of milligrams per liter above background. (d'Angremond, 1983). Resuspension may also occur when the dredge anchors and spudpoles are located and relocated as the dredge is advanced and maneuvered. Resuspension levels associated with this action have not been documented but are expected to be minimal. Equipment failure or human error at any location along the dredge plant that results in a slurry leak or spill may cause significant resuspension of dredged solids.

  The resuspended contaminants can conceivably enter the food chain by ingestion of the contaminants by fish or migratory waterfowl and subsequent harvesting for human consumption.

- Air volatilization of the contaminants contained in the dredge material may occur while the slurry is being pumped into and out of transportation barges and if leaks occur at the dredge, barge, or along the pipeline. PCBs that have entered the atmosphere may be inhaled by the public.

- Dredge plant operators and workers may experience some increased levels of exposure during clean up, transportation, and delivery operations.

Plain Suction

The potential threat to public health associated with plain suction dredging and subsequent slurry transportation to a treatment/disposal facility may exist because:

- Sediment resuspension and subsequent contaminant migration may occur during periods in which the suction head becomes wholly or partially blocked due to underwater debris. Resuspension levels resulting from a clogged suction head have not been documented but are expected to be above background levels. During periods of normal operation, it is expected that contaminant migration due to sediment resuspension will be minimal, since the plain suction dredge employs no mechanical dislodging device.

The increased contaminant levels in the water column may raise the likelihood for these contaminants to propagate through the aquatic and terrestrial food chains.

- Air volatilization of the contaminants contained in the dredged material may occur while the slurry is being pumped into and out of transport barges and if leaks occur at the dredge, barge, or along the pipeline.

- Dredge plant operators and workers may experience some increased levels of exposure during clean up, transportation, and delivery of the slurry to the treatment/disposal facility.

Hopper Dredge

A potential threat to public health associated with hopper dredging and subsequent dredged sediment transportation to a treatment/disposal facility may exist due to:

- Contaminant migration due to the resuspension of solids in which the contaminants reside may occur. This may occur at the dredge head as a result of the normal operational procedure of dragging the heads over the sediment to be dredged. Suspended solids concentrations may be as high as a few grams per liter near the dredge head. These resuspended contaminants may enter the food chain by ingestion of the contaminants by fish or migrating waterfowl and subsequent harvesting for human consumption.

- Since the hopper dredge stores and transports its own dredge slurry in onboard enclosed hoppers, the potential for air volatilization of the contaminants contained in the dredged material is minimized. This potential is lower with the hopper dredge than with the other hydraulic dredges considered.

- Dredge plant operators and workers may experience some increased levels of exposure during dredging, transportation, and delivery of the slurry to the treatment/disposal facility.

Review of the potential threat to public health associated with the excavation portion of the operation indicates that the cutterhead is less likely to impact public health due to:

- less resuspended solids; and

- control over what has been resuspended such that it can be lifted by the pump and prevented from escaping to the surrounding waters.

The removal technologies being considered are capable of employing three different methods of transporting the dredge slurry to a treatment or disposal facility:

- direct hydraulic pipeline (up to 3 miles in length without booster pumps);

- support vessel load/unload (pump and pipeline both load/unload); and

- self-contained hopper (pump and pipeline in load only).

The self contained method of transporting contaminated dredge slurry, would present the least potential threat to public health from long- or short-term exposure to contaminants.

Environment

The beneficial effects afforded the environment as a result of implementing removal technologies is dependent on the extent to which the contaminanted sediment is removed.

The beneficial effects to the environment as a result of contaminated sediment removal will be seen in the condition of the ecological niches within the New Bedford Harbor environment. Removal of the contaminated sediments will also remove the benthic organisms residing in these sediments. However, recolonization of the remaining sediments is expected to occur. As a result of the contaminated sediment removal, the quality of the overlying water column will improve.

Previous discussion on the amount of resuspension caused by each of the dredges concluded that the cutterhead was more likely to be able to control sediment resuspension generated during the dredging operations.

Slurry transportation methods employed by each of the dredges may vary. Both the cutterhead and plain suction dredges usually discharge via hydraulic pipeline either directly to a treatment/disposal facility on to a barge or scow for ferrying to the facility. The increased handling involved in discharging to a barge or scow and the subsequent removal from the barge or scow to the facility increases the potential for sediment resuspension. It is recommended that handling of the dredged material be minimized and the direct pipeline method be employed whenever possible.

The hopper dredge lifts material through its drag arms and stores this dredged material in onboard sediment tanks. When the tanks are full (no overflow allowed) the vessel ceases operations and transits to the disposal site and pumps the tanks empty. This method of transporting the contaminant slurry is considered more desirable to the hydraulic pipeline method when considering the potential for sediment resuspension.

5.2.3 Implementation

Technical Feasibility

Cutterhead Dredge

An estimated 80 percent of the contaminated sediment in the Lower Harbor and Bay may be efficiently removed using a 12-inch suction cutterhead dredge during periods of calm seas. The remaining 20 percent of the contaminated sediment in the Lower Harbor/Bay could not be efficiently removed by this particular dredge due to insufficient water depth. With the use of the modifications and operational controls previously identified in this report, it is felt that resuspension and contaminant migration caused by the dredging action can be minimized. With hull dimensions of approximately 50 ft. x 20 ft. x 3 ft. the dredge should be relatively maneuverable and able to operate in calm open waters of the Lower Harbor as well as in most of the narrow areas around bridges, docks, and wharves. It is anticipated that seas in excess of a 2-foot wave height would affect the stability of the dredge to an extent that the contaminated sediment would not be effectively and reliably removed. Minimum operating depth will be directed by the draft of the vessel and/or the diameter of the cutterhead. A cutterhead dredge with a draft and cutterhead diameter of approximately 3 feet can operate effectively in a minimum water depth of about 5 feet. The maximum water depth in which the vessel can operate is dependent on ladder length and lift capacity of the pump. A range of 5 to 50 feet is expected for this particular dredge.

A suction cutterhead dredge of this size should provide about 125 horsepower to its 36- to 42-inch diameter cutter. With approximately 450 horsepower supplied to the centrifugal pump, the lift would be enough to draw an average of 250 (150-400) cubic yards of 20 percent solids slurry per hour through a 14-inch diameter suction pipe. The nominal rating of the dredge would be 12, which matches the size of the discharge pipe diameter. This particular dredge has the capacity to remove from three to three and one-half feet of in situ sediments with one pass of the dredge head.

A smaller cutterhead dredge would be selected for contaminated sediment removal in the Estuary area of the New Bedford site. Shallower water depth is the controlling factor over dredge selection. At mean low water, depths range from mudflats along the shoreline and upper end of the Estuary to 16 feet at the channel center near the Coggeshall Street Bridge.

An 8-inch suction cutterhead would be of appropriate size for work in the calm estuarine waters. Typical hull dimensions for such a dredge would be on the order of 35' x 12' x 2' (L x W x D). The minimum working water depth would be approximately 30 inches. Maximum digging depth is dependent on ladder length. A typical length for this dredge would be 20 feet. A greater portion of the Estuary sediments will be accessible for dredging during high tide. It is expected that a dredge such as this may be able to reach 75 percent of the contaminated sediments in the Estuary if operations are conducted in such a manner as to make full use of high tides in shallow areas and low tides in deeper areas.

A suction cutterhead dredge of this size should provide 30 to 35 horsepower to its 24-inch I.D. cutter. With approximately 300 to 350 horsepower supplied to its centrifugal pump, the lift would be sufficient to draw an average of 155 cubic yards (110 to 200) of 20 percent solids slurry through the eight- to ten-inch diameter suction pipe.

It is estimated that 36 inches of contaminated sediment would need to be removed from the Estuary. To accomplish this, two passes of the dredgehead would be necessary.

A feature that is available on some of the smaller cutterhead dredges (8- to 12-inch) is a swinging ladder. The swinging ladder dredge is capable of swinging its cutterhead from side to side without swinging the vessel hull. It can also advance itself without swing cables and a remote anchoring system by manipulating its ladder and spudpoles. If a cutterhead is selected for work in the Estuary, this feature should be considered.

Plain Suction

Approximately 50 percent of the contaminated sediments in the Lower Harbor and Bay may be efficiently removed from the water-bottom using a plain suction dredge. It is unlikely that the remaining sediment could be removed by the plain suction dredge due to: insufficient water depth to provide for vessel draft; insufficient area for maneuverability of dredge; and sediment physical characteristics such that they may not be lifted (hard, cohesive).

A plain suction dredge with approximate hull dimensions similar to the cutterhead discussed would be of optimum size to work in most of the Lower Harbor/Bay areas. It is likely that a dredge with a three foot draft would be able to operate effectively in a minimum of about five feet. Any sediments with less than approximately five feet of water overlying them at low tide would be considered as undredgeable for the plain suction.

Due to the straightline cable and winch arrangement of advancement through the dredging area, the plain suction dredge is manipulated laterally only by the time consuming and cumbersome repositioning of the land and/or waterbottom anchors. This method of operation not only makes operations in rough water unadvisable, but disqualifies the plain suction from working in tight restricted waterways where good maneuverability is needed.

Since the plain suction dredge uses no method of dislodging the material to be dredged from its in situ density, its effectiveness is limited to removing relatively loose free-flowing materials. It is questionable whether the plain suction dredge has the ability to dredge the New Bedford Harbor in situ organic silts and silty sands, particularly at depth.

Hopper Dredge

The hopper dredge has been included in this evaluation for possible sediment removal predominately in the bay area of the New Bedford Harbor site. It would be technically feasible for the hopper dredge to contribute to the overall clean-up effort at New Bedford Harbor only in areas of: sufficient water depth to support vessel load line; open waters where maneuverability is unrestricted; and loose and uncohesive sediments.

Hopper dredges are intended to operate in shipping channels and open water maintenance programs. They are large ocean going vessels with loaded drafts of 12 to 30 feet and lengths of 180 to 400 feet. Onboard navigation and positioning equipment allow operations to be conducted continuously while the dredging vessel travels through the dredging area at a constant speed without restriction. Like the plain suction dredge, the dragheads of the hopper dredge provide no means of dislodging and abrading cohesive sediments. The hopper dredge typically excavates relatively thin (6 to 12 inches) layers of material per pass. Additional traverses over the same area may be required to reach desired removal depth. This method of contaminated sediment dredging reduces removal accuracy and feasibility.

Comparison of the hydraulic dredges concerning the technical feasibility of implementing them at the New Bedford Harbor site identifies the cutterhead dredge as being the more implementable of the three. Review of the operating criteria used to consider each of the technologies' implementability establishes the cutterhead as being the more versatile choice for the site. The cutterhead has the ability to operate in a wide range of waterway conditions and depths. More importantly, it would provide greater reliability at removing the types of sediments expected on site in an efficient manner.

Level of Development

Cutterhead Dredge

The suction cutterhead dredge has a proven record of reliability in the field. It is not expected that the cutterhead should experience any damage during operation in the sediments of the New Bedford site.

Machinery maintenance would take place during evening hours or when tides do not provide for optimum operation. It is expected that downtime due to failure would be minimal, assuming a standard schedule of preventive maintenance is followed. It is anticipated, however, that approximately 20 percent of production time will be lost due to methods of operation such as advancing and turning the dredge and other operational concerns with the slurry discharging procedure. Operational downtime due to weather is to be expected when seas approach a two-foot height in the Lower Harbor/Bay area and one foot in the Estuary.

Plain Suction

The plain suction dredge has been used for decades and is an efficient, reliable machine when conducting operations for which it was designed. Improvements made to centrifugal pump size and horsepower have boosted plain suction dredge output to over 10,000 yd^3 per hour.

It is expected that downtime due to dredge failure may be substantial. The plain suction dredge has no provision for clearing the suction pipe of underwater debris. It is expected that portions of New Bedford Harbor contain a considerable amount of material that may clog the suction pipe orifice. Operational downtime due to weather is to be expected when seas approach two feet.

Hopper Dredge

Hopper dredges have also been in service for decades. Dredging projects involving hopper dredges are usually limited to open water shipping lane maintenance. Hopper dredging techniques have been refined and improved to such an extent that some hoppers are capable of pumping 6,000 cubic yards of material per hour.

When conducting operations, the hopper dredge traverses through the area to be dredged without ceasing operations to reset its dredging or positioning equipment. In this manner production time is maximized and hours of continuous operation is feasible. Once the sediment hoppers have been filled, however, the hopper dredge ceases removal operations and transits to the disposal area for unloading. Rough seas generally pose little hindrance to the hoppers' productivity.

Like the plain suction, the hopper dredge has no means of clearing the suction pipe opening from material too large or awkward to be lifted. It is recognized that some operational downtime would be likely due to this problem should the hopper dredge perform sediment removal operations at the New Bedford Harbor site.

Each of the hydraulic dredges discussed have had considerable effective use in the field. It is expected that the cutterhead dredge would have the greater percentage of productivity versus operational downtime given the particular site conditions at the New Bedford Harbor site.

Support Requirements

Cutterhead and Plain Suction Dredges

Support requirements necessary for the implementation of the suction cutterhead and plain suction dredge in these areas are typical to most dredging operations. These dredges are not usually self propelled and therefore require a tug or tow vessel to move between locations. Once in operation the dredge is advanced and maneuvered by means of self hauled anchors and spudpoles.

The dredged material is discharged by the centrifugal pump through a hydraulic pipeline. This pipeline can either transport the slurry directly to an onshore disposal or treatment site or to a barge or scow first and then transported in bulk to an onshore facility for unloading. Some barges and scows are self propelled; those that are not would require a companion tow vessel. Pontoons are used to support the pipeline over water crossings. A pair of pontoons is usually placed every 19 feet at the connection between pipe lengths. Pipe diameter should match pump discharge size and pontoon size selection will be proportioned to assure pipeline buoyancy and stability.

Support crews and vessels will be necessary for the inspection and maintenance of the hydraulic transport pipeline. This will aid in minimizing the potential for leaks and help pipeline integrity so that slurry is not lost during conveyance.

Hopper Dredge

Due to its method of operation, the hopper dredge requires little support. The hopper dredge is self-propelled and is outfitted with onboard sediment tanks to hold the dredged material. The hopper dredge is capable of dredging, storing, transporting, and unloading without assistance. For contaminated sediment dredging purposes, an offloading hydraulic pipeline would be used for conveyance of the dredged material from the hoppers to the onshore handling facility once the vessel has transported its load from the dredging area to the offloading station.

<u>Availability</u>

Cutterhead Dredge

The suction cutterhead dredge is the most commonly used dredge in the United States. Other than mining operations, over 250 suction cutterhead dredges were available in the United States in 1986 (Wodcon, 1986). Cutterhead dredges with the structural modifications required for hazardous waste clean-up action are not presently available. However, a number of dredge manufacturers do have many dredges which may be modified to suit the necessary structural and operational requirements. The size of dredge required to conduct clean-up operations in the Lower Harbor and portions of Buzzards Bay is small enough to be a portable dredge. A portable dredge may be trucked to the site, assembled on the State Dock in New Bedford and hoisted by a 75-100 ton capacity crane to the water. Access to the portion of the bay or harbor to be dredged may be achieved by towing the vessel to the location. Passage to either side of the hurricane barrier is gained through the 150-foot wide hurricane barrier gate. The Lower Harbor is divided by a two-lane highway which may be crossed only at the swing bridge between Fish and Pope Islands. This bridge opens up providing for two channels, each approximately 94 feet wide.

The cutterhead that may be selected for work in the Estuary would be classified as a portable dredge and is readily available. It would be trucked to the site, assembled, and lifted to the water with a 50-ton crane. Dredge deployment may take place from the state pier on the Lower Harbor or from a location directly adjacent to the Estuary. If the state pier location is to be used, the dredge spudpoles and deckhouse may have to be laid prone on the dredge deck to allow clearance under the Coggeshall Street Bridge, which is approximately 8.7 feet MSL (NUS, 1984).

Plain Suction

Plain suction dredges of varying size and capacity are available throughout the United States and around the world. In 1986, 20 plain suction dredges were in existence in the United States. Another 36 were involved in mining applications in the United States in the same year.

Plain suction dredges are typically towed to the area to be dredged. Some may be portable, in which case they may be trucked to the site and assembled and hoisted to the waters of the harbor in a manner similar to that described for the cutterhead.

Hopper Dredges

Trailing suction hopper dredges of various sizes and capacities are available throughout the world. Twenty-one of these dredges were available in the United States in 1986.

These dredges are self-propelled, ocean going, and provide for their own transportation between project areas. Typical transit speed is 12 to 14 nautical miles per hour compared to 3 knots dredging speed.

Installation

Dredge size is a combination of operational tradeoffs including water depths to be worked, vessel draft, volume to be removed, dredge output capacity, and maneuverability. A suction cutterhead dredge on the order of 35' x 12' x 2' (L x W x D) in size would be appropriate to conduct operations in the Estuary. A suction cutterhead or plain suction dredge in the size range of 50' x 20' x 3' to 70' x 30' x 5' would be large enough for work in Buzzards Bay and Lower New Bedford Harbor during calm weather. A small trailing hopper dredge with a loaded draft of between 12 to 15 feet would be capable of conducting sediment removal operations in approximately 50 to 60 percent of the Lower Harbor/Bay areas. Since the dredgehead of all dredges being considered here is securely fastened to the dredge hull by means of the ladder, a one foot rise in hull elevation caused by waves translates to a one foot differential in dredge head elevation. Therefore, it would be difficult to maintain the dredging precision which is required in removing contaminated sediments in seas, and would significantly affect overall hull elevation. It would be impractical to bring a larger dredge with a deeper draft that would provide for a more stable work platform to the site for work only in rough water periods. Operations would cease when, in the judgment of the dredge crew, sea conditions endanger the safety of the crew or equipment or where they are incapable of controlling the dredge head in a manner that provides for best operational results.

If the removal target level is established at "all detectable levels," then a much more substantial area (an order of magnitude more) will be dredged. It is felt that if such a cleanup level were established a larger dredge capable of operating during rougher sea conditions would be warranted for operations in the Lower Harbor/Bay areas.

Time

A portable suction cutterhead or plain suction dredge of the type described can be assembled and in working condition within 48 hours from time of delivery. Once the hydraulic pipeline connections are in place, production with one or both of these technologies may begin. The non-portable cutterhead and plain suction may be placed in production once towed into position. The hopper dredge needs only to lower its dredging gear and reduce its cruising speed to approximately three knots, as it sails into the dredging area before production begins.

The beneficial effect to the environment as a result of any dredging effort will be immediate.

Safety

An in-depth health and safety program should be implemented prior to dredging and should address potential short- and long-term health impacts for both on-site workers and nearby residents.

Situations occurring in the course of normal daily operations such as leaking slurry pipelines or overflow will be addressed in the safety plan and will have an established, documented, and approved set of procedures to be followed once such a situation arises or the threat of such a situation occurring is apparent.

Delivery of the slurry to the on-shore handling facility via the direct hydraulic pipeline would be recommended as having the least potential for adverse health effects from human exposure. A moderate potential for worker exposure may exist for those instances when it is determined to be impractical to pump via hydraulic pipeline direct to the on-shore facility and a barge or scow is used to ferry the dredged material from the dredge location to the handling facility. The potential for air volatilization of PCBs and worker exposure increases with the number of times the contaminated material is handled. Since some settling and separation of the solids and liquid content of the slurry will occur in the barge or scow, it will be necessary for the dredged material to be reagitated for removal and subsequent transportation from the barge or scow to the on-shore facility.

Proper use of the HASP designated personnel protective equipment will minimize the adverse effects associated with this transportation method.

Sediment resuspension rates generated at the dredge head of the hydraulic dredges considered are not expected to impact nearby communities or on-site workers on a short- or long-term basis. It is anticipated that if contaminated slurry leaks should occur at the dredge, along a transportation pipeline, or during hopper, barge, or scow loading and unloading, it would pose no greater short- or long-term safety threat to nearby communities than what exists prior to the commencement of clean-up actions.

If massive resuspension of dredged material should occur it has been estimated by the USACE that, in general, 97 to 99 percent of the slurry would settle out rapidly to the water bottom. "One to three percent of the discharged slurry will not descend rapidly to the bottom but will remain suspended in the water column in the form of a turbidity plume. Average plume concentrations of several hundred milligrams per liter decrease rapidly with distance downstream from the discharge point and laterally away from the plume centerline due to settling and horizontal dispersion" (Bernard, USACE, 1978). It is expected that the water quality in the vicinity of a massive slurry spill will be adversely affected on a short term basis only.

Monitoring and Maintenance Requirements

Monitoring and maintenance required for dredging operations would include: monitoring of suspended solids generation at the suction intake, monitoring of the dredged material transport pipeline integrity (if used), and maintenance of the applicable dredge plant components (dredge, barges, work boats, pipeline, and pontoons).

For the purpose of monitoring resuspension levels at the dredge head, a turbidimeter may be mounted in the immediate vicinity of the dredging action so that resuspension of solids as a result of dredging may be monitored in real time. Position of the meter should be such that only those solids resuspended by the dredge head and not lifted by the suction pipe are measured. This monitoring may be performed and recorded on a continual basis.

For each mile of pipeline to be maintained in the hydraulic conveyance of the dredged material, one work crew should be responsible for monitoring the integrity of the floating and shore pipeline. A typical pipeline monitoring crew might consist of two men in a small U.S. Coast Guard-approved shallow draft boat equipped with an outboard motor and fuel tank capacity for a full work day's continuous operation. Portable VHF radios may be included so that communications are possible among all respects of the operating dredge plant. The monitoring crews may be equipped to remedy situations requiring minor repair or replacement such that operations need not be shut down for repairs. Separate pipeline construction and maintenance barges are advisable so that if a problem or the potential for a problem arises, the maintenance barge may be dispatched directly to the area in need of repair. In this manner, use of time is optimized.

Scheduled maintenance to the dredge itself may be accomplished during the evening hours while operations have ceased for the day. A preventive maintenance schedule will minimize the potential for unscheduled repairs and lost production time.

Permitting

Permits should not be required to conduct dredging operations as described. Some ARARs, however, will either apply or be used as guidance during remedial alternative design and implementation.

Legal Constraints

It is not expected that opposition to removal efforts such as those previously described will exist. Permission from the state will need to be obtained for the use of the New Bedford State Pier for the deployment and retrieval of the dredging plant and its use as a staging area and decontamination corridor throughout the life of the project, if use of the facility is included in the remedial alternative design.

Impacts on Historical and Critical Resources

Archeological resources are not known to exist at the New Bedford Harbor site. However, operations shall cease if during the course of operations any archeological, historical, or critical resources are discovered or if the potential for such resources to be uncovered is apparent. Operations will not resume until such time as it is deemed safe to do so by the federal, state, and local agencies governing such resources.

5.2.4 Costs

Of the hydraulic dredge technologies discussed, only the cutterhead will be evaluated for costs. The cutterhead is the strongest sediment removal candidate in this category. No benefit would be gained from generating cost scenarios for the other hydraulic dredging technologies.

Costs for operating three different suction cutterhead dredges were developed for the Lower Harbor and Bay area. Three different spoils pumping scenarios were developed for each dredge. These scenarios involved hydraulic pipeline transportation to the:

- o Generic off-site disposal area 10 miles from the Lower Harbor;

- o New Bedford in-harbor disposal site No. 7; or

- o New Bedford in-harbor disposal site No. 10.

These locations were chosen because they are probable disposal/treatment sites. They were evaluated so that a range of costs could be established.

Since a specific PCB clean-up target level has not yet been established, costs were generated for five different levels. Volumes of sediment to be dredged by the cutterhead dredge were calculated for those sediments with overlying water depths of ten feet MSL. It was determined that for the removal of PCBs to target levels >100 ppm, >50 ppm, and >10 ppm, a sediment removal target depth of six inches would be used. For PCB target levels of >1 ppm and >0 ppm, a sediment removal target depth of 18 inches was selected. These removal depths are general guidelines. Some specific instances exist where shallower or deeper depths are warranted.

The costs do not necessarily represent final dredging costs. Final dredging costs will be projected as remedial alternatives are developed and analyzed.

Cutterhead with 14-Inch Centrifugal Pump

Tables 5-2, 5-3 and 5-4 summarize the results of the cost analyses for the cutterhead dredge equipped with a 14-inch centrifugal pump.

Overall dredging and pumping costs were less with the in-harbor disposal scenarios compared to generic off-site disposal area, primarily due to shorter pumping distances. Dredging relatively small volumes with this large dredge is demonstrated as not being cost-effective. Present worth analysis of dredge rental versus dredge purchase was not performed due to the short operation time of the project and the relatively high purchase price of the dredge.

To ascertain which factors have the most impact on dredging costs, sensitivity analyses were performed for pumping rates, labor costs, and interest rates. All sensitivity analyses were performed based on data from the generic off-site disposal alternative.

Figure 5-9 shows the effect a change in pumping rate has upon project costs. The figure clearly shows a cost increase with a decrease in PCB target levels due to the additional volume of sediment to be removed with each subsequent target level. A slight increase in costs is also noted with a drop in pumping

TABLE 5-2
CUTTERHEAD RENTAL COSTS
14-INCH CENTRIFUGAL PUMP
GENERIC OFF-SITE DISPOSAL AREA

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
*SEDIMENT TO BE REMOVED (YD^3)	895	10,045	70,145	1,148,835	1,348,335
MONTHS OF OPERATION	1	1	1	9	10
PRESENT WORTH COSTS (USD)	320,760	558,214	736,401	3,114,386	3,514,397
**UNIT COST (USD/YD^3)	358.39	55.57	10.50	2.71	2.61

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

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TABLE 5-3
CUTTERHEAD RENTAL COSTS
14-INCH CENTRIFUGAL PUMP
IN-HARBOR DISPOSAL SITE NO. 7

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
*SEDIMENT TO BE REMOVED (YD^3)	895	10,045	70,145	1,148,835	1,348,335
MONTHS OF OPERATION	1	1	1	9	10
PRESENT WORTH COSTS (USD)	99,294	293,655	376,196	1,529,213	1,722,549
**UNIT COST (USD/YD^3)	110.94	29.23	5.36	1.33	1.28

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

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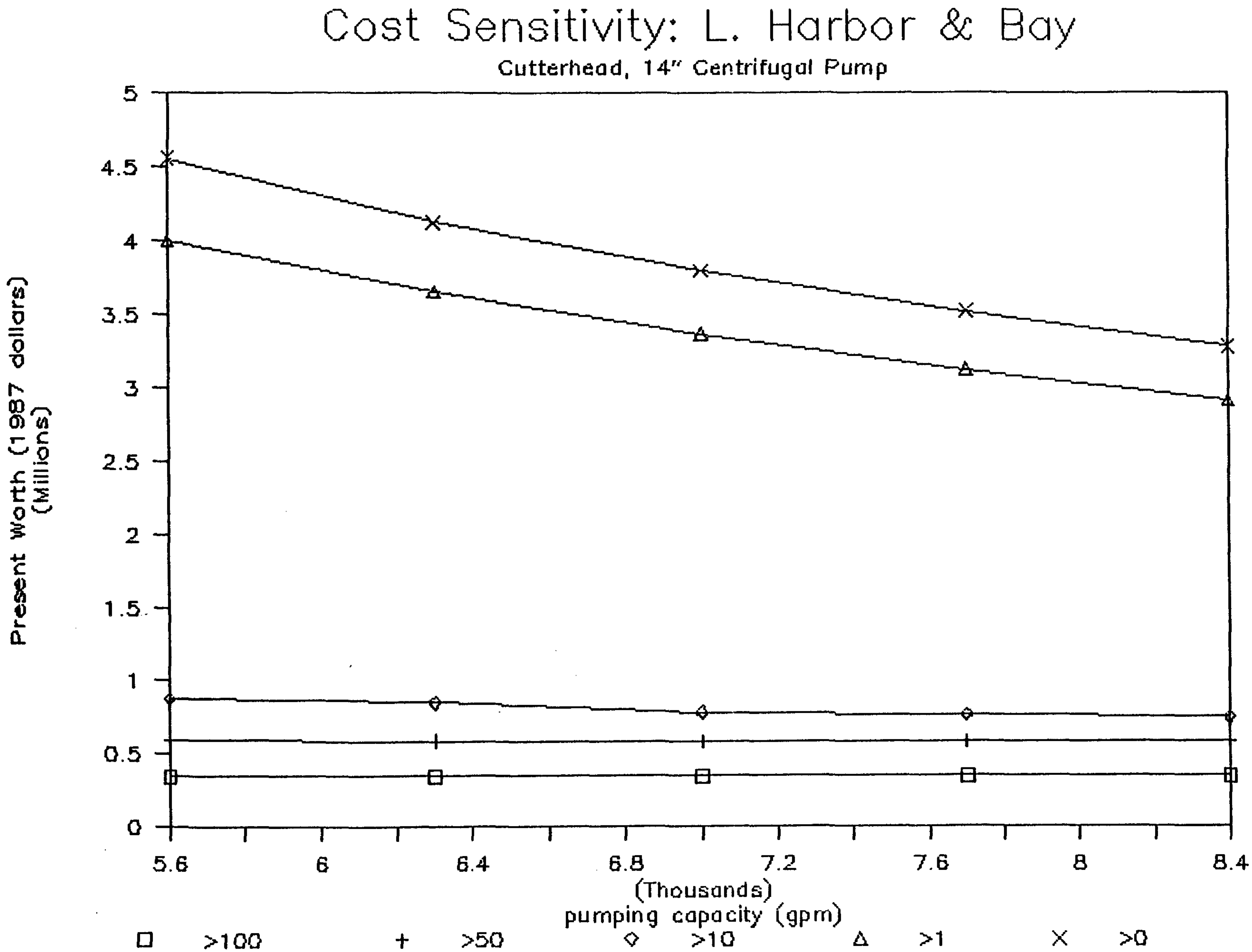
TABLE 5-4
CUTTERHEAD RENTAL COSTS
14-INCH CENTRIFUGAL PUMP
IN-HARBOR DISPOSAL SITE NO. 10

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
*SEDIMENT TO BE REMOVED (YD^3)	895	10,045	70,145	1,148,835	1,348,335
MONTHS OF OPERATION	1	1	1	9	10
PRESENT WORTH COSTS (USD)	242,418	302,560	377,394	1,447,199	1,621,515
**UNIT COST (USD/YD^3)	270.86	30.12	5.38	1.26	1.20

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

Figure 5-9



Cost Sensitivity: L. Harbor & Bay
Cutterhead, 14" Centrifugal Pump
Present Worth (1987 dollars)
(Millions)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
5.6
6
6.4
6.8
7.2
7.6
8
8.4
(Thousands)
pumping capacity (gpm)
>100
>50
>10
>1
>0

rates at the higher target levels. This phenomenon is primarily due to the increased volumes associated with the lower clean-up levels.

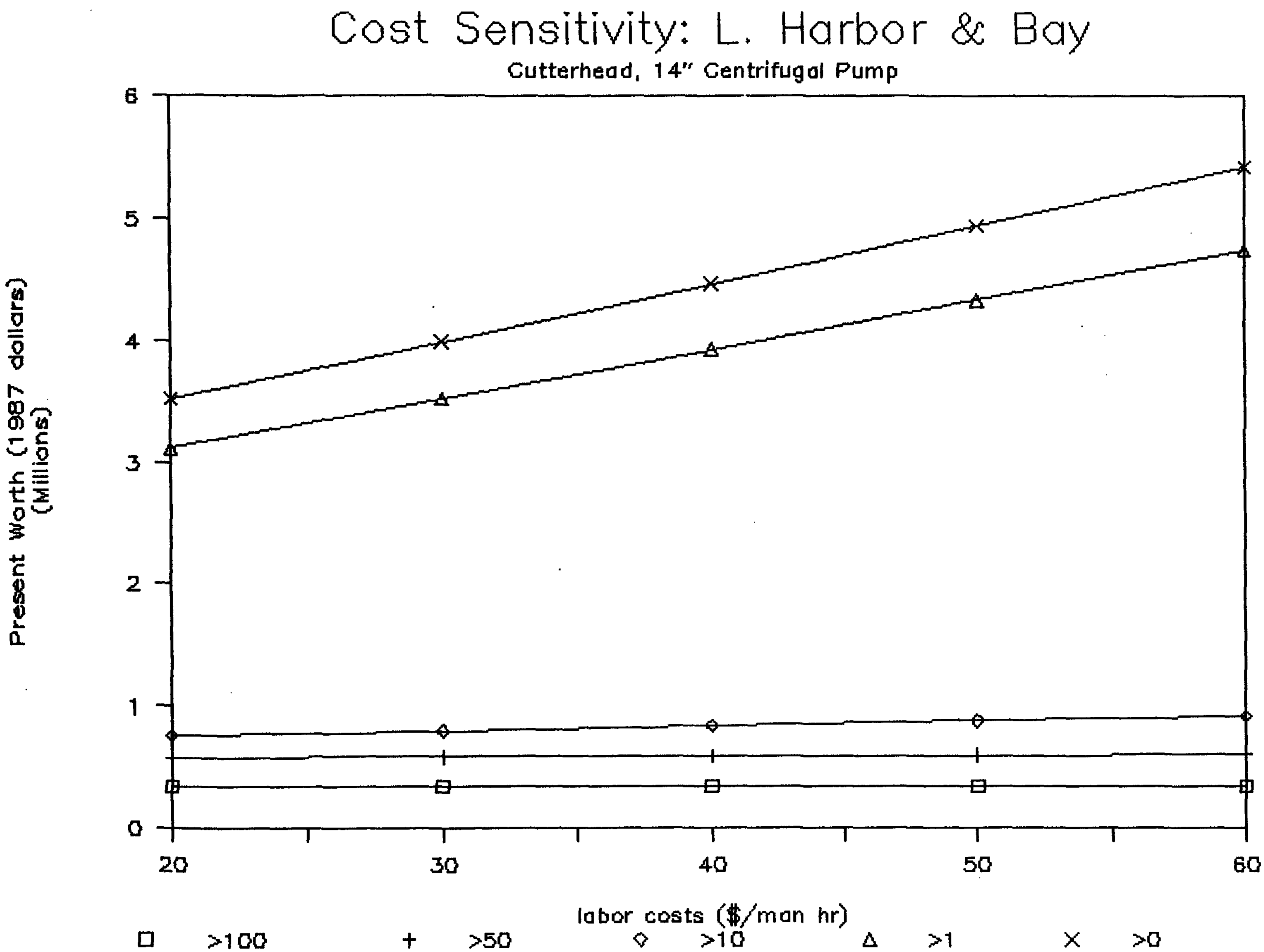
The effect of labor costs on overall operation costs is represented in Figure 5-10. Generally, as labor costs increase overall costs will follow suit. The relative increases are more predominant at the lower PCB target levels. This can be directly attributed to the increased sediment volumes associated with these lower levels. This is particularly obvious at the >1 and >0 ppm levels.

Interest rates have little effect on the overall dredging costs, as illustrated in Figure 5-11. A slight increase in cost can be seen at the lowest target levels. The reason for this overall minimal effect is the relatively short duration of the project compared to the low volatility of the value of money over that period of time.

Cutterhead, 12-Inch Centrifugal

Tables 5-5, 5-6, and 5-7 summarize the results of the cost analyses for the cutterhead dredge equipped with a 12-inch centrifugal pump.

Figure 5-10



Cost Sensitivity: L. Harbor & Bay
Cutterhead, 14" Centrifugal Pump
Present Worth (1987 dollars) (Millions)
0
1
2
3
4
5
6
20
30
40
50
60
labor costs ($/man hr)
>100
>50
>10
>1
>0

Figure 5-11

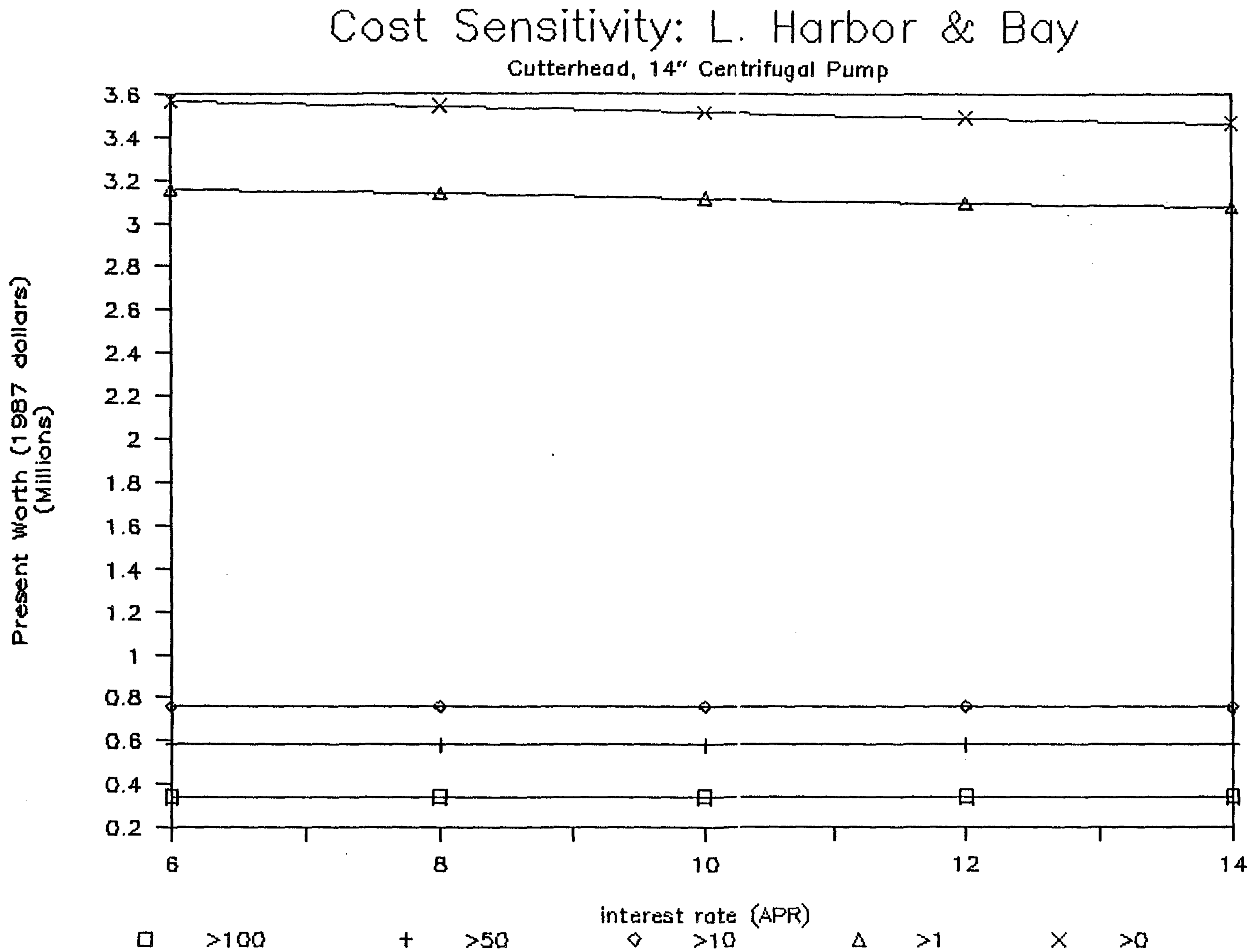

Cost Sensitivity: L. Harbor & Bay
Cutterhead, 14" Centrifugal Pump
Present Worth (1987 dollars)
(Millions)
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
6
8
10
12
14
interest rate (APR)
>100
>50
>10
>1
>0

TABLE 5-5
CUTTERHEAD RENTAL COSTS
12-INCH CENTRIFUGAL PUMP
GENERIC OFF-SITE DISPOSAL AREA

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
*SEDIMENT TO BE REMOVED (YD^3)	895	10,045	70,145	1,148,835	1,348,335
MONTHS OF OPERATION	1	1	2	11	13
PRESENT WORTH COSTS (USD)	256,394	457,910	689,841	3,158,023	3,598,733
**UNIT COST (USD/YD^3)	286.47	45.58	9.83	2.75	2.67

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

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TABLE 5-6
CUTTERHEAD RENTAL COSTS
12-INCH CENTRIFUGAL PUMP
IN-HARBOR DISPOSAL SITE NO. 7

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
*SEDIMENT TO BE REMOVED (YD^3)	895	10,045	70,145	1,148,835	1,348,335
MONTHS OF OPERATION	1	1	2	11	13
PRESENT WORTH COSTS (USD)	75,165	235,074	347,113	1,702,960	1,953,649
**UNIT COST (USD/YD^3)	83.98	23.40	4.95	1.48	1.45

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

TABLE 5-7
CUTTERHEAD RENTAL COSTS
12-INCH CENTRIFUGAL PUMP
IN-HARBOR DISPOSAL SITE NO. 10

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
*SEDIMENT TO BE REMOVED (YD^3)	895	10,045	70,145	1,148,835	1,348,335
MONTHS OF OPERATION	1	1	2	11	13
PRESENT WORTH COSTS (USD)	192,387	248,058	383,097	1,636,081	1,871,260
**UNIT COST (USD/YD^3)	214.96	24.69	5.46	1.42	1.39

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

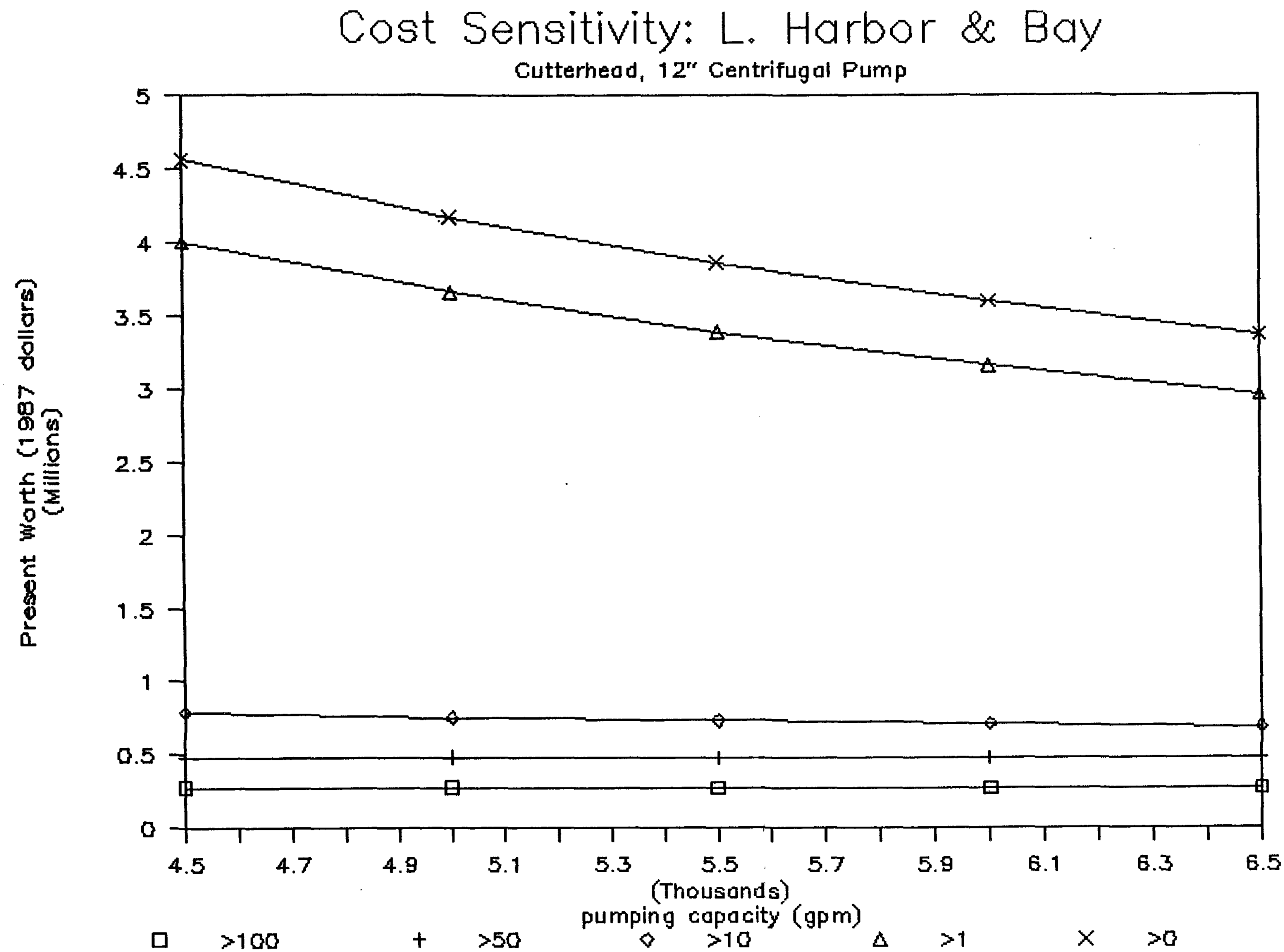
Overall dredging and pumping costs are less when making use of the in-harbor disposal site No. 7. This is primarily because it is the more centrally located of the three disposal sites being addressed in this evaluation. Cost-effectiveness increases with decreasing contaminant clean-up target levels (i.e., increased volumes to be dredged). Present worth analysis of dredge rental versus dredge purchase was not presented, since the short operation time of the project and the relatively high purchase price of the dredge eliminates purchase of the dredge as a cost-effective option.

Sensitivity analyses were run on those factors that were expected to have a significant impact on overall removal operation costs. These analyses were performed using data from the generic off-site disposal scenario. Analyses are run for changes in pumping rates, labor costs, and interest rates.

Figure 5-12 shows the effect of fluctuations in dredge pumping rates. At higher PCB clean-up target levels, the change in pump capacities correlates to only slight increases in project costs. At the lower PCB clean-up target levels (i.e., those involving significantly more volumes) the cost increases are more dramatic.

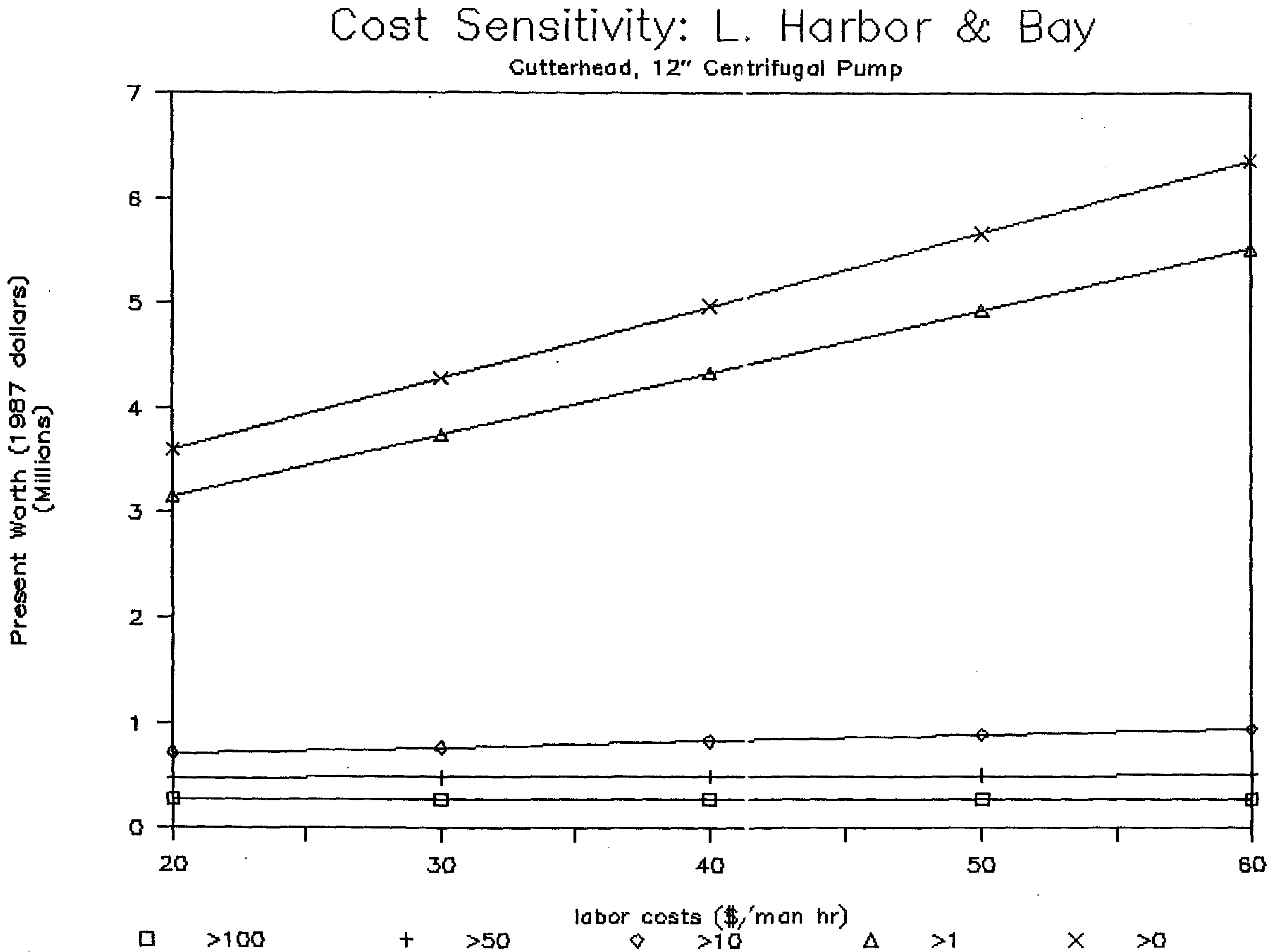
The effect changes in labor costs has on overall costs is represented in Figure 5-13. The only significant increase to overall project costs as a result of increases to labor costs can

Figure 5-12



Cost Sensitivity: L. Harbor & Bay
Cutterhead, 12" Centrifugal Pump
Present Worth (1987 dollars)
(Millions)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
4.5
4.7
4.9
5.1
5.3
5.5
5.7
5.9
6.1
6.3
6.5
(Thousands)
pumping capacity (gpm)
>100
>50
>10
>1
>0

Figure 5-13



Cost Sensitivity: L. Harbor & Bay
Cutterhead, 12" Centrifugal Pump
Present Worth (1987 dollars)
(Millions)
7
6
5
4
3
2
1
0
20
30
40
50
60
labor costs ($/man hr)
>100
>50
>10
>1
>0

be seen at the lower PCB clean-up target levels (i.e., >1 ppm, >0 ppm).

Interest rate changes and their effect on operation costs are shown as Figure 5-14. The present worth of dredging for each target level decreases with an increase in the interest rate. This relationship is to be expected; however, little actual difference can be seen. This is attributable to the relatively short duration time of the project and that the value of money does not change greatly over short periods of time.

Cutterhead, 8-Inch Eddy

Tables 5-8, 5-9, and 5-10 summarize the results of the cost analyses for the cutterhead dredge equipped with an 8-inch Eddy pump.

Cost per cubic yard of in situ material removed (unit cost) is substantially lower for the Eddy pump even though this pump is 33 and 42 percent smaller than the two other comparison pumps. This is due to the large difference in percent solids the Eddy pump is able to pump. Calculations were performed using 13.8 percent solids for the two centrifugal pumps and 50 percent (in situ density) for the Eddy pump. The figure used for the centrifugal pumps is an average expected performance number generated by the USACE for suction cutterhead dredges equipped with centrifugal

Figure 5-14

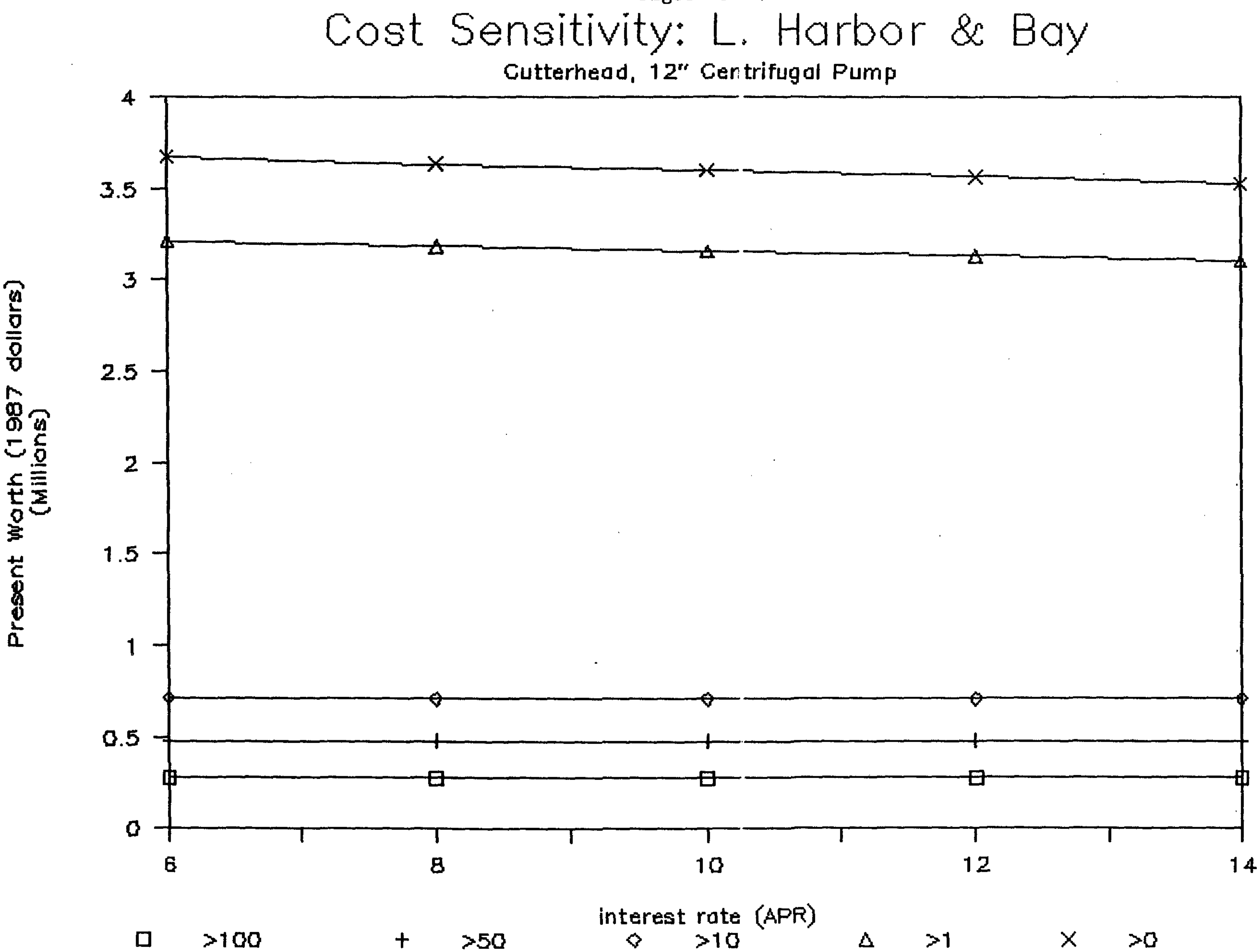

Cost Sensitivity: L. Harbor & Bay
Cutterhead, 12" Centrifugal Pump
Present Worth (1987 dollars) (Millions)
4
3.5
3
2.5
2
1.5
1
0.5
0
6
8
10
12
14
interest rate (APR)
>100
>50
>10
>1
>0

TABLE 5-8
CUTTERHEAD RENTAL COSTS
8-INCH EDDY PUMP
GENERIC OFF-SITE DISPOSAL AREA

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
*SEDIMENT TO BE REMOVED (YD^3)	895	10,045	70,145	1,148,835	1,348,335
MONTHS OF OPERATION	1	1	1	5	6
PRESENT WORTH COSTS (USD)	204,160	347,888	502,328	2,566,374	2,941,604
**UNIT COST (USD/YD^3)	228.11	34.63	7.16	2.23	2.18

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

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TABLE 5-9
CUTTERHEAD RENTAL COSTS
8-INCH EDDY PUMP
IN-HARBOR DISPOSAL SITE NO. 7

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
*SEDIMENT TO BE REMOVED (YD^3)	895	10,045	70,145	1,148,835	1,348,335
MONTHS OF OPERATION	1	1	1	5	6
PRESENT WORTH COSTS (USD)	75,075	189,510	242,269	1,212,979	1,395,080
**UNIT COST (USD/YD^3)	83.88	18.87	3.45	1.06	1.03

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

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0017.0.0

TABLE 5-10
CUTTERHEAD RENTAL COSTS
8-INCH EDDY PUMP
IN-HARBOR DISPOSAL SITE NO. 10

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
*SEDIMENT TO BE REMOVED (YD^3)	895	10,045	70,145	1,148,835	1,348,335
MONTHS OF OPERATION	1	1	1	5	6
PRESENT WORTH COSTS (USD)	158,646	198,697	276,081	1,165,417	1,336,489
**UNIT COST (USD/YD^3)	177.26	19.78	3.94	1.02	.99

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

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0018.0.0

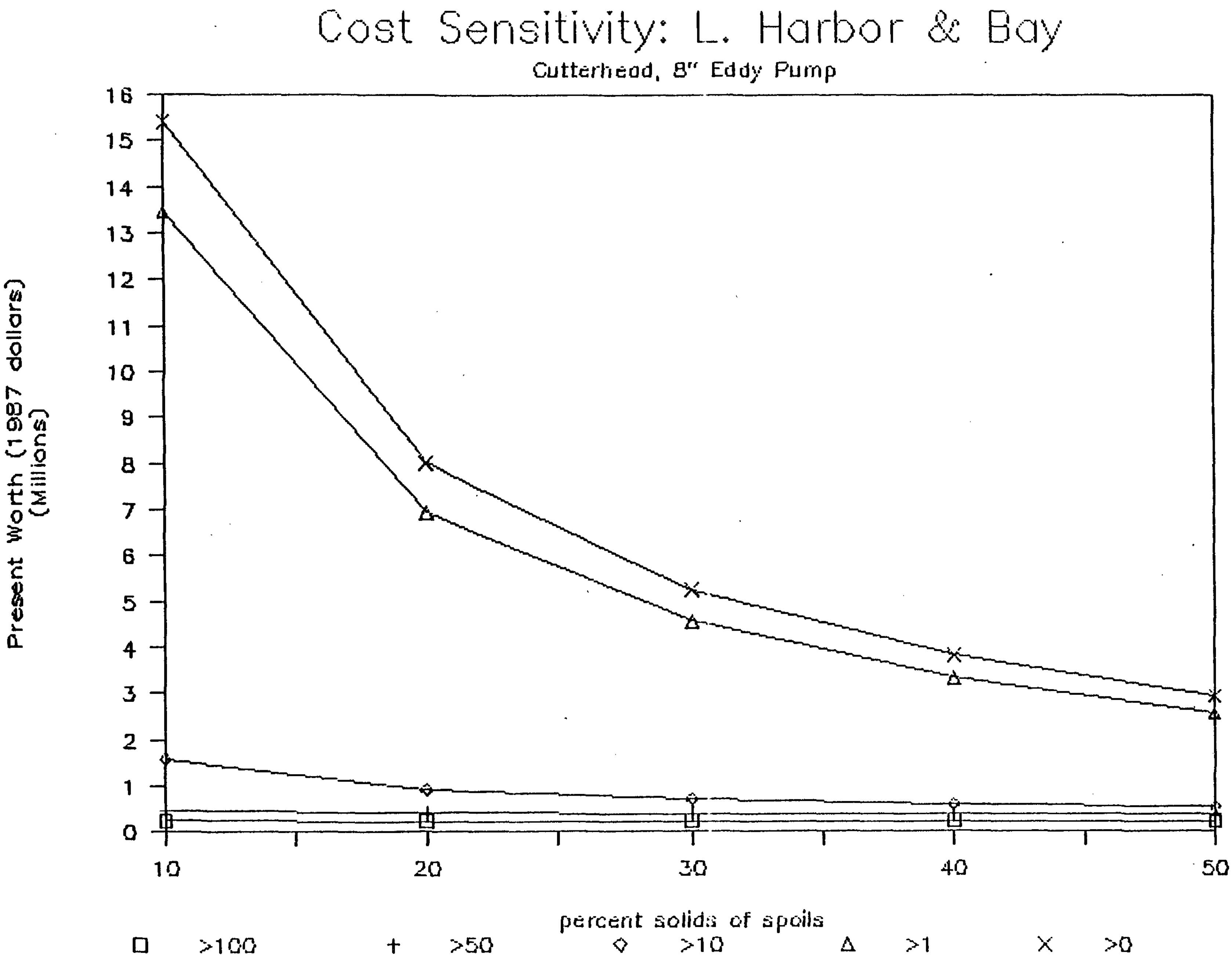
pumps. Tests have shown the Eddy pump to be able to pump up to 65 percent solids. The in situ percent solids of the sediment is approximately 50 percent; therefore, the 50 percent figure was used in calculations.

The in-harbor disposal sites show smaller present worth and unit costs. This is due to substantially less piping costs associated with them because of the smaller distances involved. A present worth analysis of dredge rental versus purchase is not presented. Purchase costs far outweigh rental costs due to the relatively short duration of the project and the high initial costs involved with dredge purchase.

To ascertain those variables that have the most impact on dredging costs, sensitivity analyses were performed for percent solids dredged, pumping rates, labor costs, and interest rates.

Figure 5-15 shows the effect a change in percent solids dredged would have on the present worth costs. This analysis was performed for this particular dredge and not the previous two centrifugal pump dredges because the Eddy pump is capable of pumping at such a higher percent solids content. This percent is expected to fluctuate from the in situ percentage (50 percent) due to localized changes in sediment density and when dredge operation procedures are not optimized. Figure 5-15 presents the costs savings a higher percent solids content provides. This is

Figure 5-15



Cost Sensitivity: L. Harbor & Bay
Cutterhead, 8" Eddy Pump
Present Worth (1987 dollars)
(Millions)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
percent solids of spoils
>100
>50
>10
>1
>0

particularly noticeable at the lower PCB clean-up target levels where substantially more sediment volumes are involved.

The effect pumping capacity, labor costs, and interest rates have on present worth cost is shown in Figures 5-16, 5-17, and 5-18, respectively. The relative effect of changes to these factors on present worth costs is similar to those seen for the previous two dredges analyzed. Discussions on these topics will therefore not be repeated in this section. One should, however, note the lower cost scales involved with the Eddy pump.

5.2.5 Summary

A phased evaluation of technologies has been used to screen potential contaminated sediment removal technologies for the New Bedford Harbor site. Detailed analysis of the three hydraulic dredging technologies that passed the initial screening step has been completed. The detailed evaluation procedure has resulted in the elimination of two of the technologies, the plain suction and the hopper dredges, as potential remedial action alternatives. The remaining technology, the cutterhead suction dredge, is considered to possess the strongest qualifications of the hydraulic dredge technologies evaluated for sediment removal application at the New Bedford Harbor site. It is recommended that its use be limited to areas with ten feet of overlying water

Figure 5-16

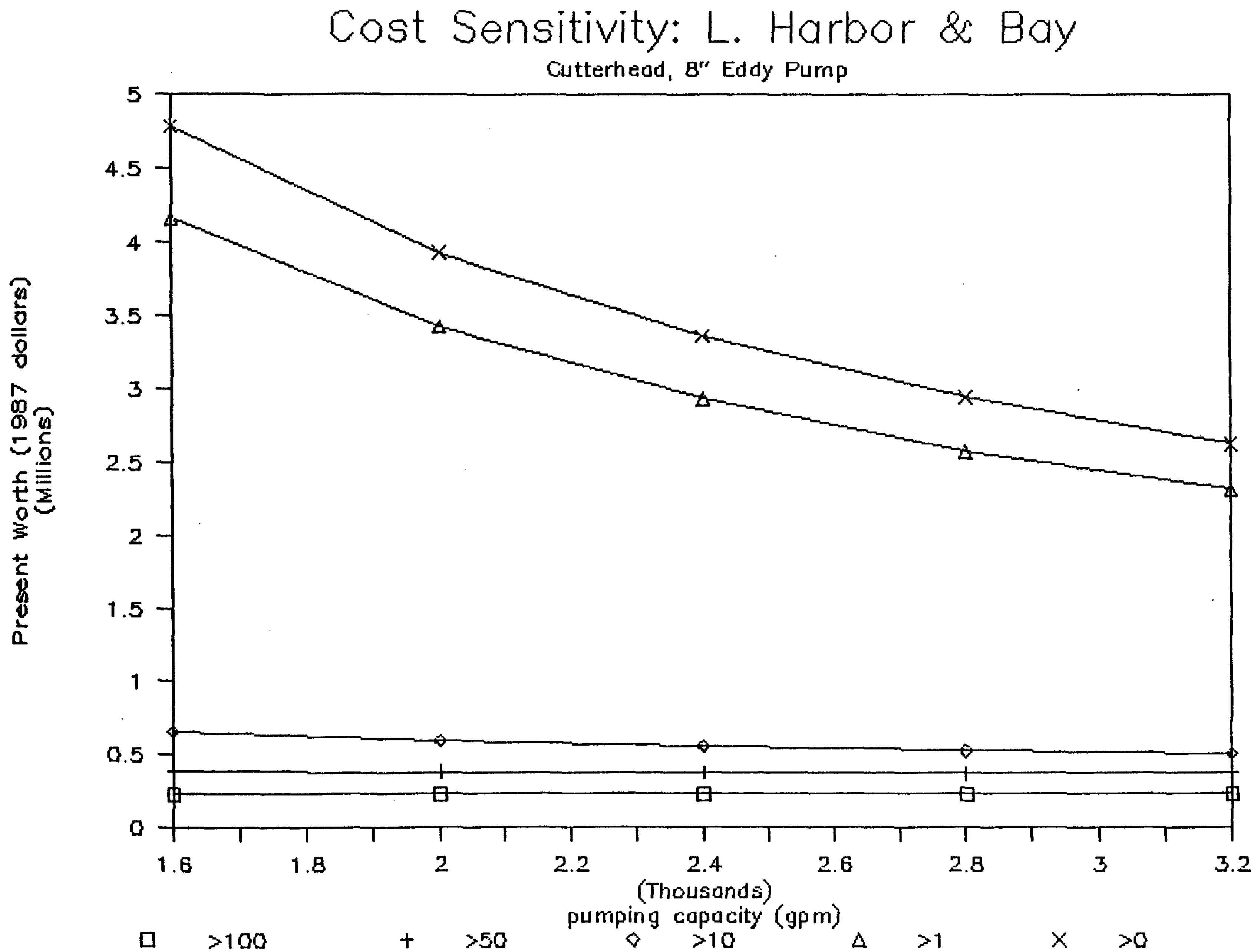

Cost Sensitivity: L. Harbor & Bay
Cutterhead, 8" Eddy Pump
Present Worth (1987 dollars)
(Millions)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
(Thousands)
pumping capacity (gpm)
>100
>50
>10
>1
>0

Figure 5-17

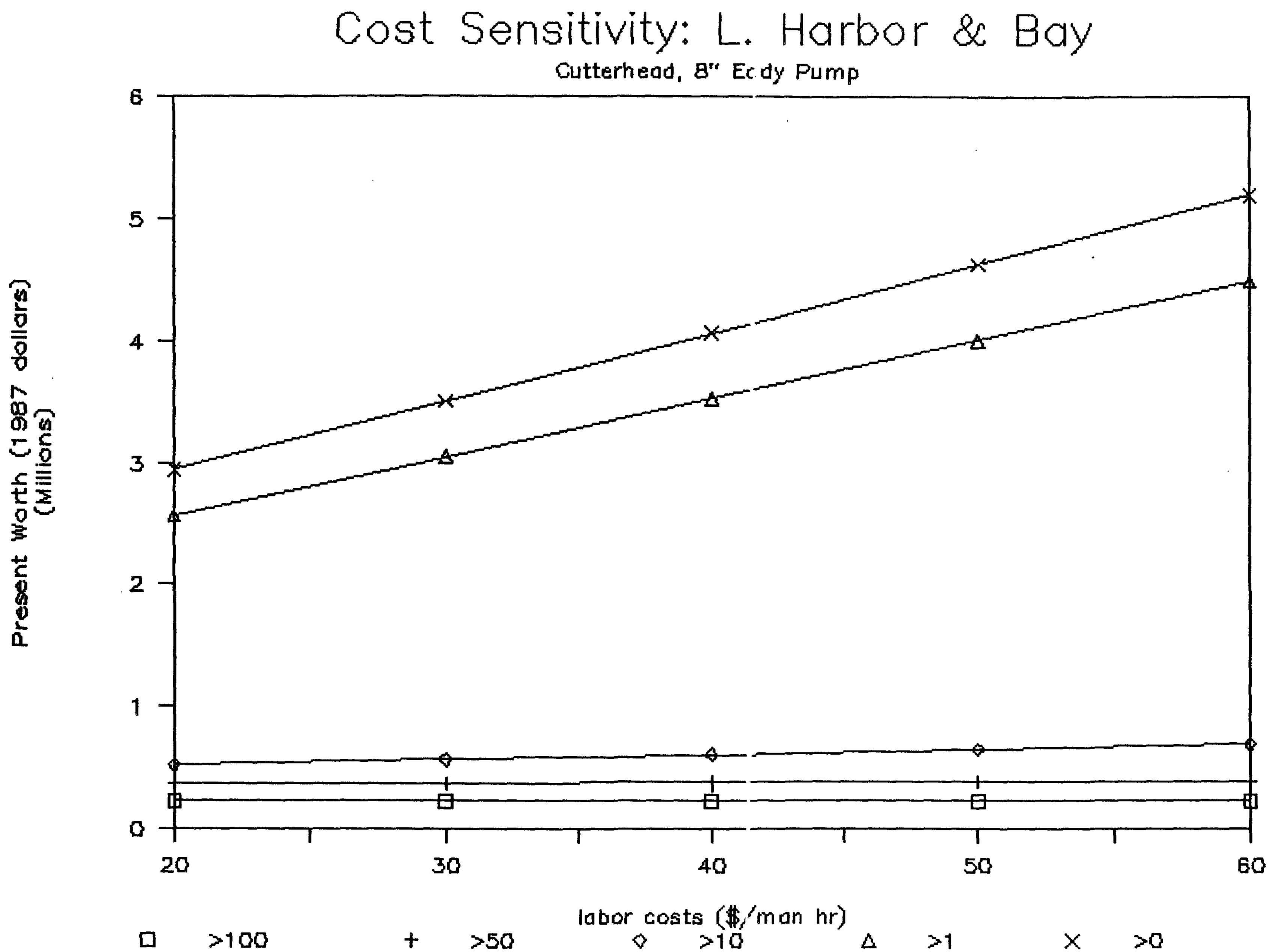
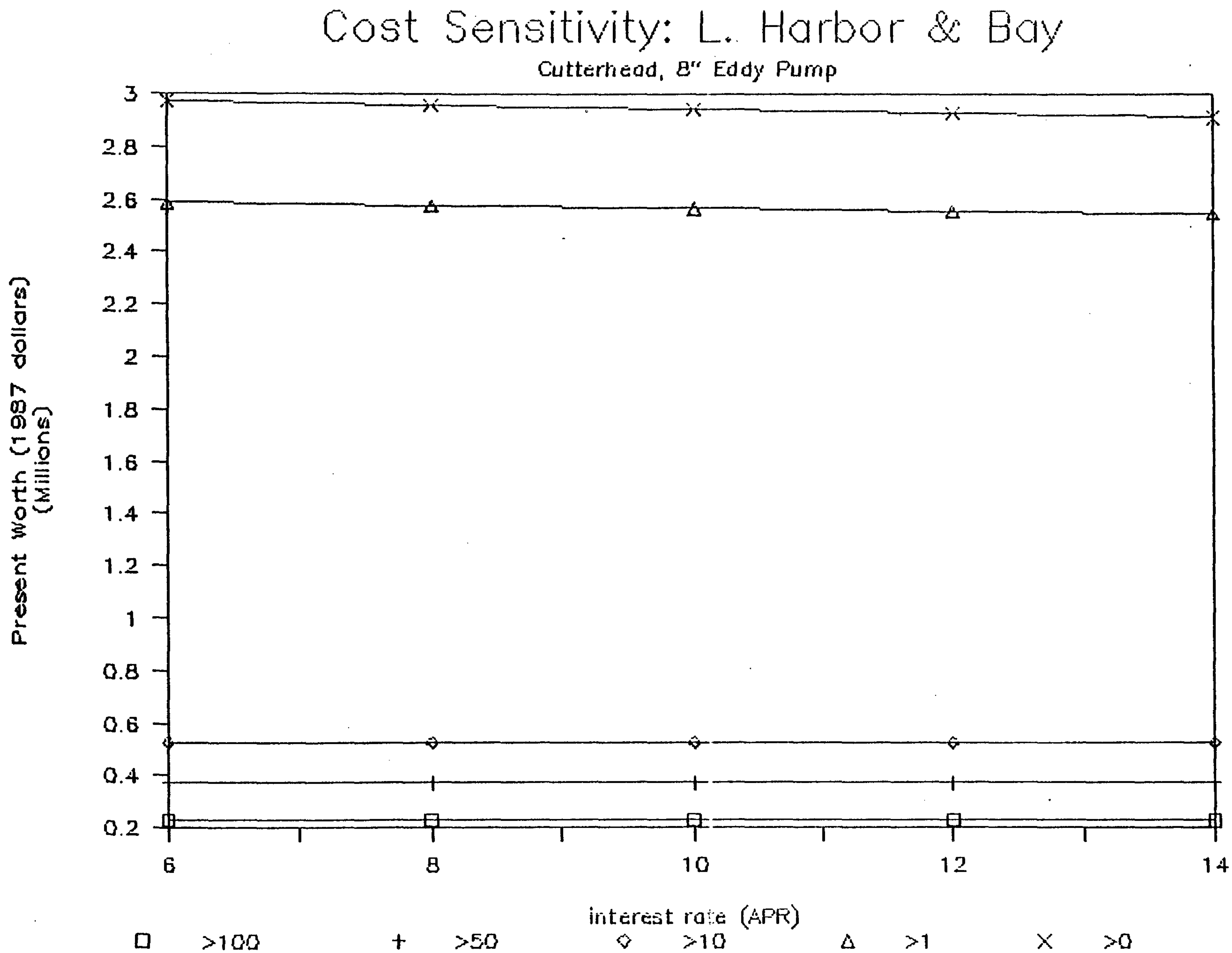

Cost Sensitivity: L. Harbor & Bay
Cutterhead, 8" Eddy Pump
Present Worth (1987 dollars)
(Millions)
0
1
2
3
4
5
6
20
30
40
50
60
labor costs ($/man hr)
>100
>50
>10
>1
>0

Figure 5-18


Cost Sensitivity: L. Harbor & Bay
Cutterhead, 8" Eddy Pump
Present Worth (1987 dollars) (Millions)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
6
8
10
12
14
interest rate (APR)
>100
>50
>10
>1
>0

(MSL) within the Lower Harbor and Bay portion of the New Bedford Harbor site.

It is also recommended that the dredge be constructed with the following specifications:

- overall hull dimensions of approximately 70' x 30' x 5';
- ladder length approximately 45' - 50';
- 36-inch to 42-inch basket cutterhead;
- eight- to ten-inch Eddy dredge pump;
- ten- to twelve-inch discharge pipeline;
- shielding attachments over and around the cutterhead as described in Section 5.2.2;
- modification to the dredgehead and ladder to provide for parallel dredging arcs and optimum dredging angle;
- turbidimeter and TV camera mounted in the vicinity of the dredgehead for "real time" monitoring.

Additionally, operational controls such as the following should be adhered to in an effort to minimize any adverse effects as a result of dredging:

- Monitoring and regulating cutterhead rotation and horizontal swing to speeds that will provide for the efficient loosening of material supplied to the suction is not in excess of that which can be lifted by the dredge pump.

- Regulating the vertical thickness of the dredge cut to minimize the volume of additional dredging required and maximize the removal of contaminated sediments. Layer cutting techniques should be avoided.

- Undercutting sediments to assist in the minimization of turbidity generation.

- Electronic positioning to provide more accurate horizontal and vertical dredge head placement and angle.

Suction cutterhead operations employing these operational controls and modifications could result in reducing the potential for contamination migration during dredging of the hazardous waste found in the sediment of New Bedford Harbor. The use of this removal technology in this fashion may provide a permanent remedy to the contaminated sediment problem in portions of the Lower Harbor and Bay.

5.3 SPECIAL PURPOSE DREDGES

5.3.1 Description

In response to the growing concern over adverse environmental effects associated with conventional dredging techniques, and due to more challenging dredging projects involving the removal of toxic substances, a number of special purpose dredging technologies have recently been developed. These include: special dredgeheads or modifications to conventional hydraulic dredges, scaled down versions employing conventional dredging methods, and the use of compressed air as a materials dislodging and lifting agent.

Six special purpose dredge technologies were retained for detailed evaluation for the removal of contaminated sediments at New Bedford Harbor. These technologies will be carried through the detailed screening as special purpose dredges and will be evaluated and discussed under one of the following sub-headings:

- o Modified Suction
  - Clean-up
  - Refresher
- o Pneumatic
  - Airlift
  - Pneuma
  - Oozer
- o Portable Suction
  - Mudcat

Modified Suction

Two modified suction special purpose dredges passed the initial screening process; the "clean-up" and the "refresher." Modified suction dredges are based on conventional hydraulic suction dredge design. Modifications were incorporated to enhance solids concentrations and to minimize sediment resuspension potentials. Both dredges have been developed by Japanese Companies for the explicit purpose of contaminated sediment removal.

Clean-up Dredge

In the early 1970s TOA Harbor Works of Tokyo, Japan developed the "clean-up" system specifically for the purpose of dredging what TOA has termed as "polluted ooze." Design criteria for the clean-up were high solids concentrations and low turbidity.

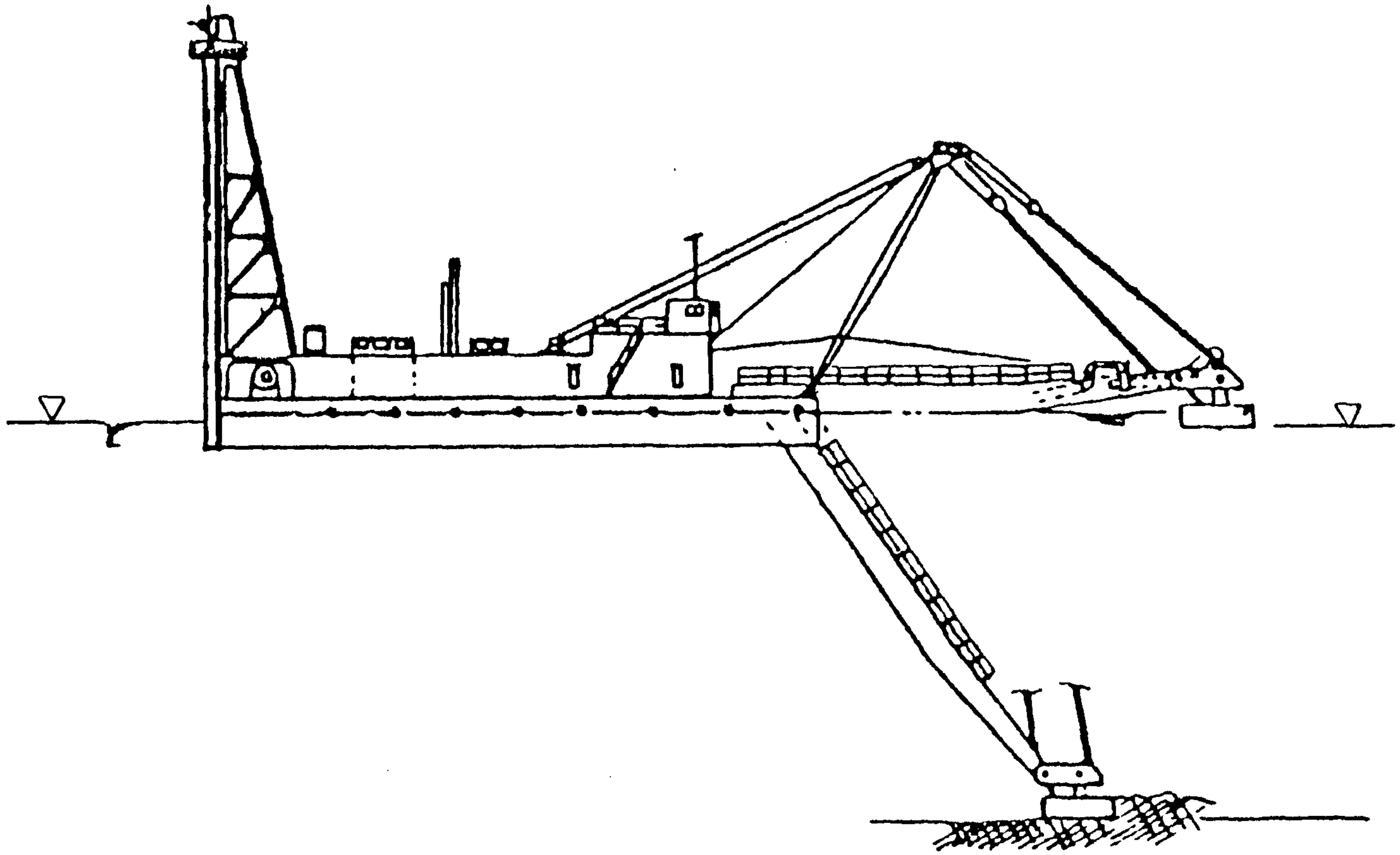
The clean-up dredge is a barge-mounted suction pipe dredge with a modified dredgehead. Figure 5-19 shows a profile of the clean-up dredge. The centrifugal pump is mounted on the end of the suction pipe ladder. The clean-up dredge is not self-propelled and is maneuvered through the dredging area by means of anchors, winches, and spuds. There are five clean-up dredges in existence today. Hull dimensions range from 70' x 26' x 3' (length x breadth x loaded draft) to 140' x 44' x 6'; minimum and maximum dredging depths range from 5 to 75 feet depending on dredge selected. TOA Harbor Works' literature describes the clean-up dredge as a "cutterless type dredge specially designed for ooze dredging, equipped with the unique device of the suction head which offers the following advantages:

- o To suck as much ooze as possible in their original sediment condition, so as to avoid inflow of extra water at the time of dredging.

- o To efficiently convey the sucked ooze into the pump in uniform density.

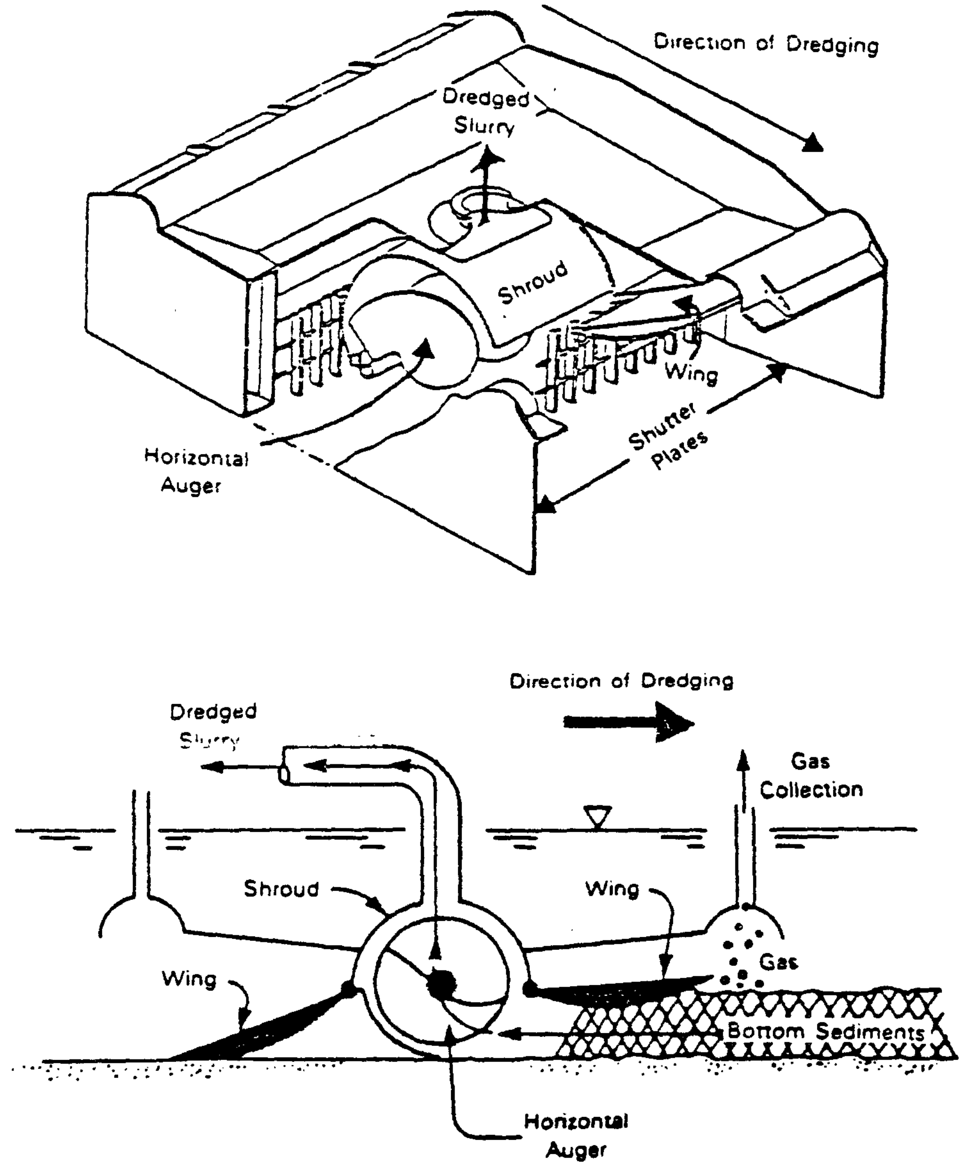
- o To secure constant, definite positions of suction head against surface of the ooze." (TOA, 1987)

The unique dredgehead design, shown in Figure 5-20 has been described as a shielded auger that collects and guides material to



SOURCE: SATO, 1976

FIGURE 5-19
CLEANUP DREDGE



Schematic

FIGURE 5-20
SECTION AND SCHEMATIC OF CLEANUP DREDGE HEAD

the suction pipe. In reality the auger acts more as a mixing device and is designed to supply the suction pipe with a constant volume of material at a uniform density. This apparatus is not intended to act as a cutterhead. Its ability to scour and abrade hard in situ material is questionable. A moveable wing precedes the auger as it swings through its dredging arc and rides up over and covers the sediment prior to it being collected by the auger. Gas released from the material as a result of the disturbance caused by the dredging action is trapped under a shroud, vented to the vessel, and collected in onboard tanks.

Additional equipment includes transducers mounted on both sides of the dredge head. These provide elevation information to the operator. Cameras provide an underwater close up view of the dredge head and vicinity. This is primarily used to give an indication of suspended solids generated but may also be used to locate underwater obstacles, debris, and other hazards to dredging.

The dredge head is also equipped with a horizontal controlling device. This enables the operator to maintain the suction equipment in an optimum position relative to the water bottom. This provides for maximizing production regardless of the sea bed contours and depth. The dredge operator is also provided with information on the condition of the sediments in front of the dredge head and in the mixing apparatus within the dredge head.

Flow rates of the slurry through the suction and discharge pipes can also be monitored.

Refresher Dredge

Penta-Ocean Construction Company of Tokyo, Japan has developed and operated refresher dredges in Japan since 1976. From their conception of the refresher dredge, Penta-Ocean Construction's goal was an environmental one: "to remove sediments containing toxic substances, oily or organic materials so as to improve the quality of the overlying water." (Penta-Ocean, 1987) To improve the quality of the water this removal must be accomplished without the generation of suspended sediment particles. To meet this objective the "refresher anti-pollution system" was developed to minimize turbidity while completely removing sediments.

Design of the refresher was based on that of the conventional cutterhead suction dredge. The modifications to the dredge head which differentiate the refresher from the conventional cutterhead include:

- o A helical-shaped cutterhead with the reducing spiral at the front end;

- The cutterhead completely concealed by a cover which has an adjustable shutter so that swing direction is changeable without leaking suspended sediments;

- Emergency check valves to prevent backflow of the slurry located at both the suction and discharge side of the pump;

- A gas-collecting apparatus installed in the dredge head to collect gas released from the sediments and deliver it to the suction pipe; and

- Dredge head position control capabilities such that regardless of water depth or contour, the dredge head may always be parallel to the water bottom.

Figure 5-21 shows the details of the refresher dredge head. Additional monitoring equipment associated with the refresher dredging system involve:

- closed circuit television camera mounted on the dredge head;

- turbidimeter; and

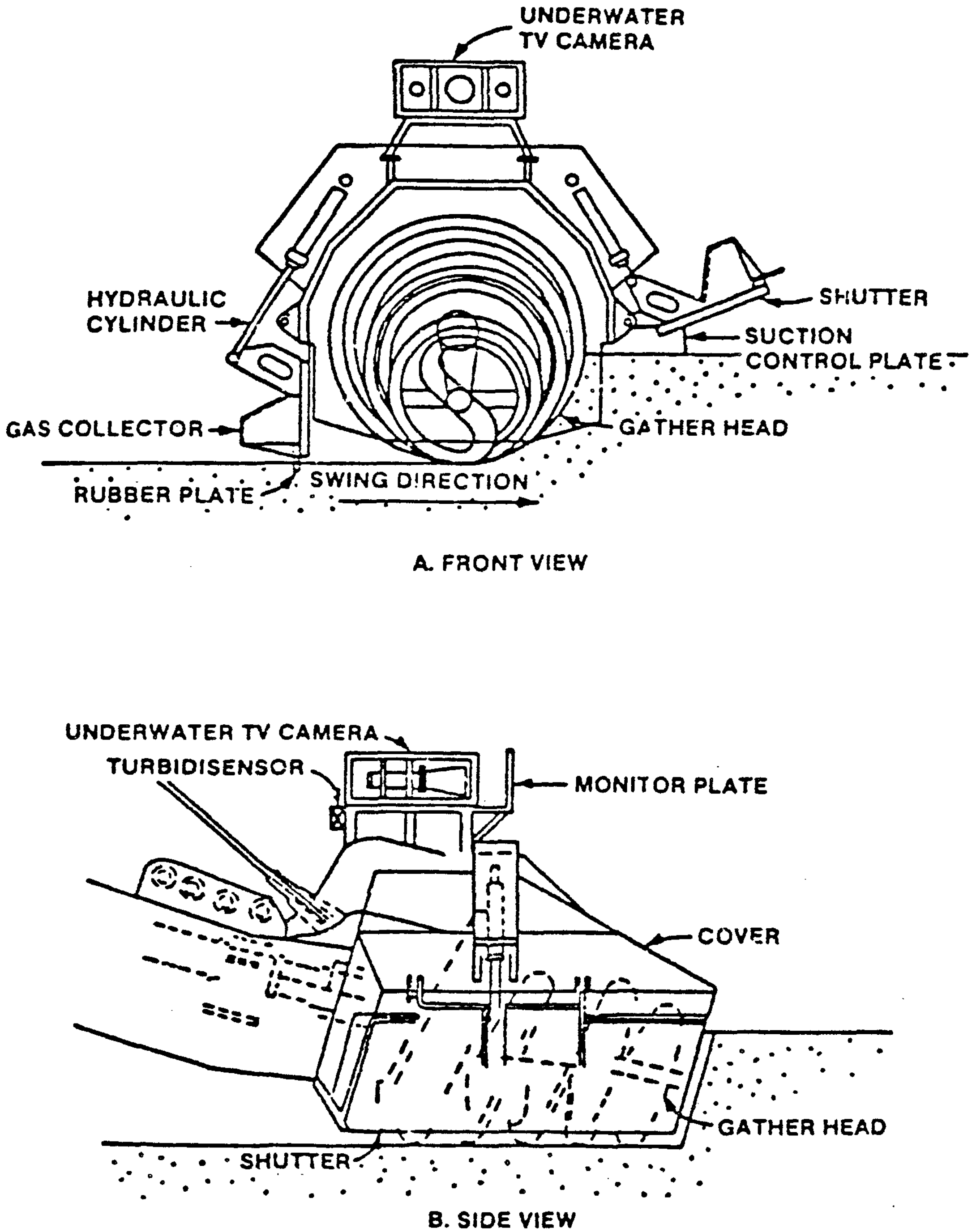


FIGURE 5-21
REFRESHER SYSTEM

- transducers on both lateral sides of the dredge head to provide for before and after dredging water depths.

The refresher dredge is a barge-mounted suction pipe dredge with a modified cutterhead. Figure 5-22 shows a profile of the refresher dredge. A centrifugal pump is mounted at the ladder head and a booster centrifugal pump is located in line on deck. The refresher is not self propelled and is maneuvered through the dredging area by means of anchors, winches, and spuds. There are three refresher dredges in existence today. The larger and smaller have hull dimensions of 176' x 46' x 9' (length & breadth x loaded draft) and 56' x 21' x 4.5'. Minimum and maximum dredging depths range from approximately 5' to 65'.

Pneumatic Dredges

Three special purpose pneumatic dredges were retained for detailed evaluation. Pneumatic dredges are a unique type of hydraulic dredge. With these dredges, compressed air and/or hydrostatic pressure are employed to lift waterbottom materials from their natural state along the conveyance pipeline. The three technologies included in this discussion are: the airlift dredge, the pneuma pump dredge, and the oozer pump dredge.

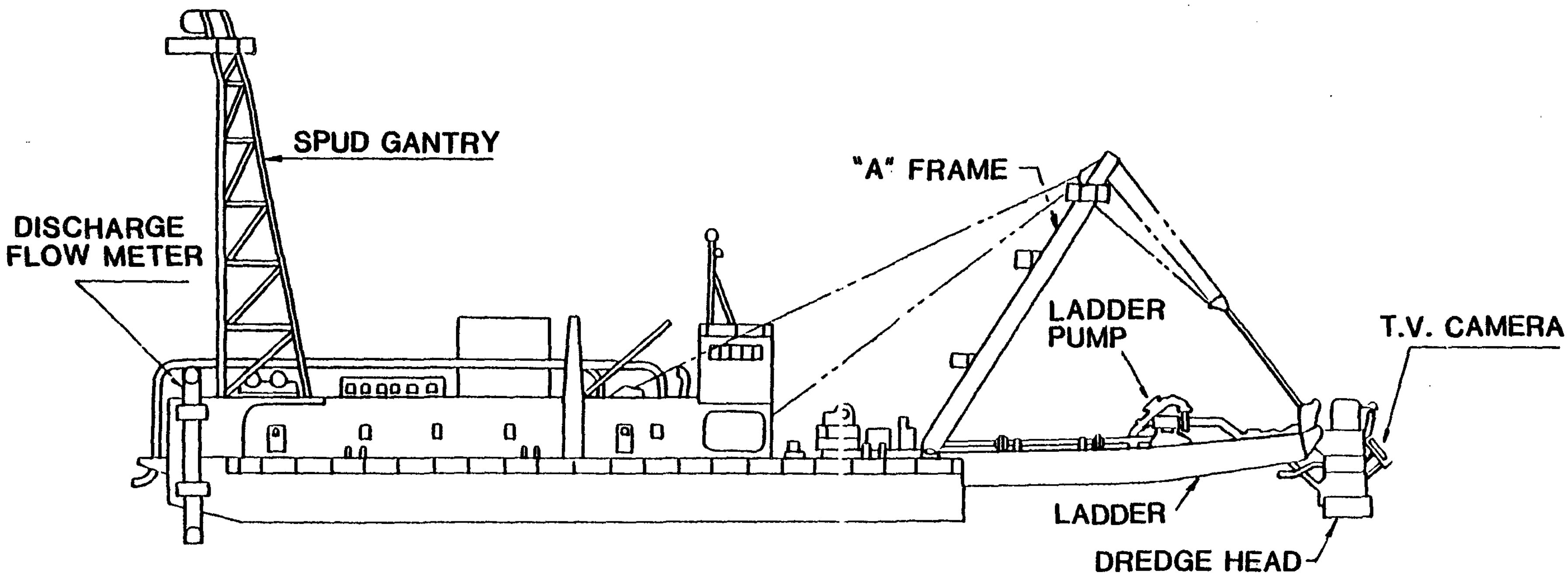


FIGURE 5-22
REFRESHER DREDGE

Airlift Dredge

Airlift dredge operations may be supported by a single barge or by a series of modular units mounted on pontoons. The dredge unit, complete with associated air, water, and discharge lines, is usually deployed and retrieved by a barge or pontoon mounted crane. The dredge is lowered to the bottom and is in direct contact with the sediments to be dredged. The principle of operation is that compressed air, supplied by barge mounted compressors, is pumped down to the low end of the conveying pipe. This air pressure must be greater than the hydrostatic pressure at that particular depth. The compressed air is released inside the conveyance pipe near the low end. The air expands and rises in a pressure equalization reaction. This causes water and sediment in the vicinity to be lifted upwards with the air currents. Figure 5-23 shows a profile of an airlift dredge. An increase in applied air pressure will result in a flow rate increase and thus a higher dredging capacity. Water jet, vibrating or rotating head attachments may be used to mechanically assist in dislodging and suspending cohesive solids.

Pneuma Pump Dredge

The pneuma pump dredging system was developed by the Italian firm S.I.R.S.I. in 1971. It was the first dredging system to employ compressed air as a means of lifting and conveying sediment. The

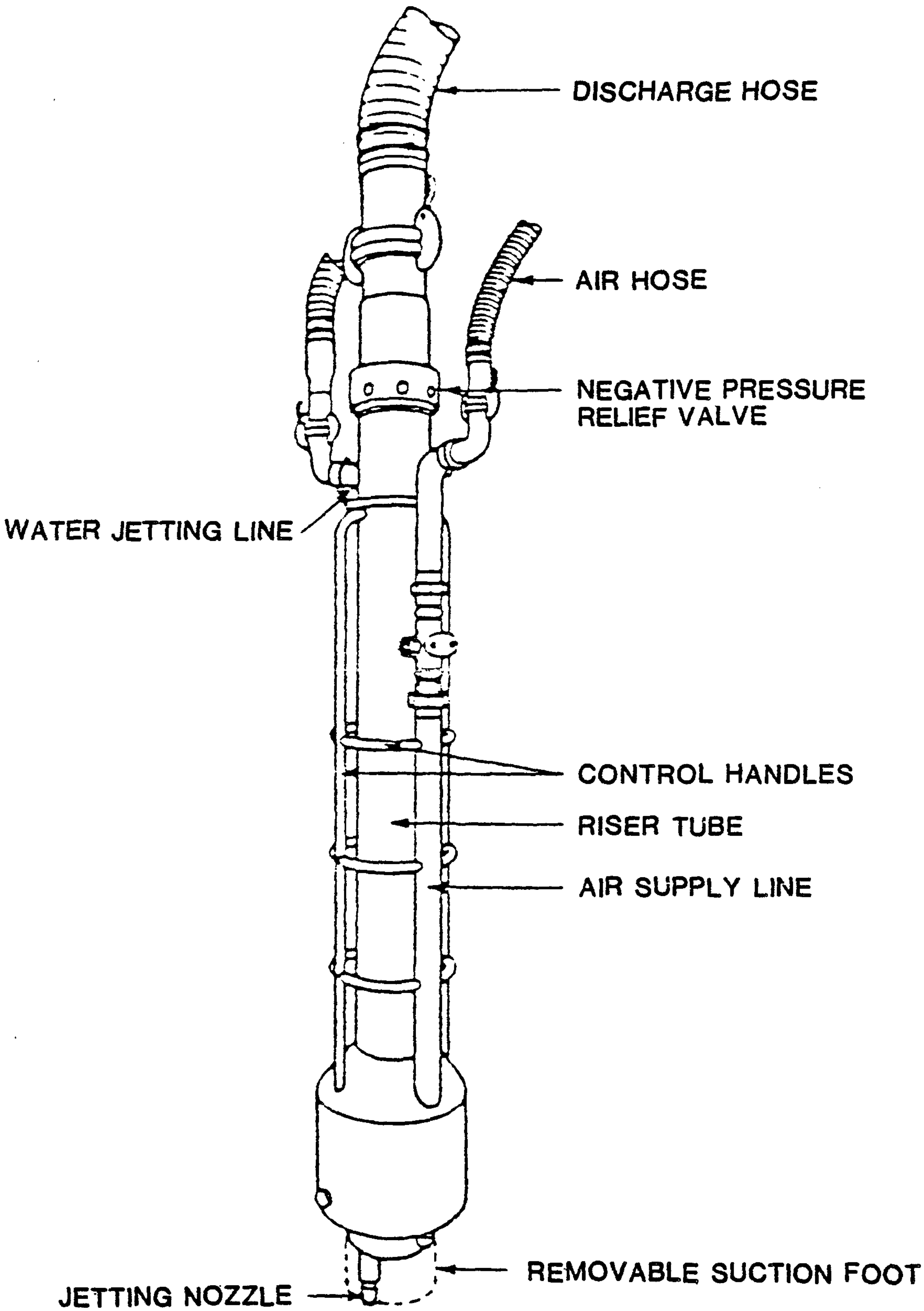


FIGURE 5-23
AIRLIFT DREDGE

system may be either vessel or dock mounted. Figures 5-24 and 5-25 show a profile of a pneuma pump dredge and its operating pump cycle. The pump is submerged during operation and is placed in direct contact with the sediments to be dredged. The system consists of three cylinders each with an inlet and outlet port and valve, a distributor, a discharge line, and a compressor. The distributor controls the pressurization and venting of each of the three cylinders in sequence. The operation cycle for the system is as follows:

- The pump body is lowered to the bottom.

- Water is allowed to fill the cylinder through the inlet valve.

- Compressed air is forced into the cylinder which closes the inlet valve and displaces the water through the discharge line.

- The cylinder, filled with compressed air, is released via the distributor to the atmosphere.

- Head difference between the atmospheric pressure in the cylinder and the pressure at the inlet point forces sediment into the tank.

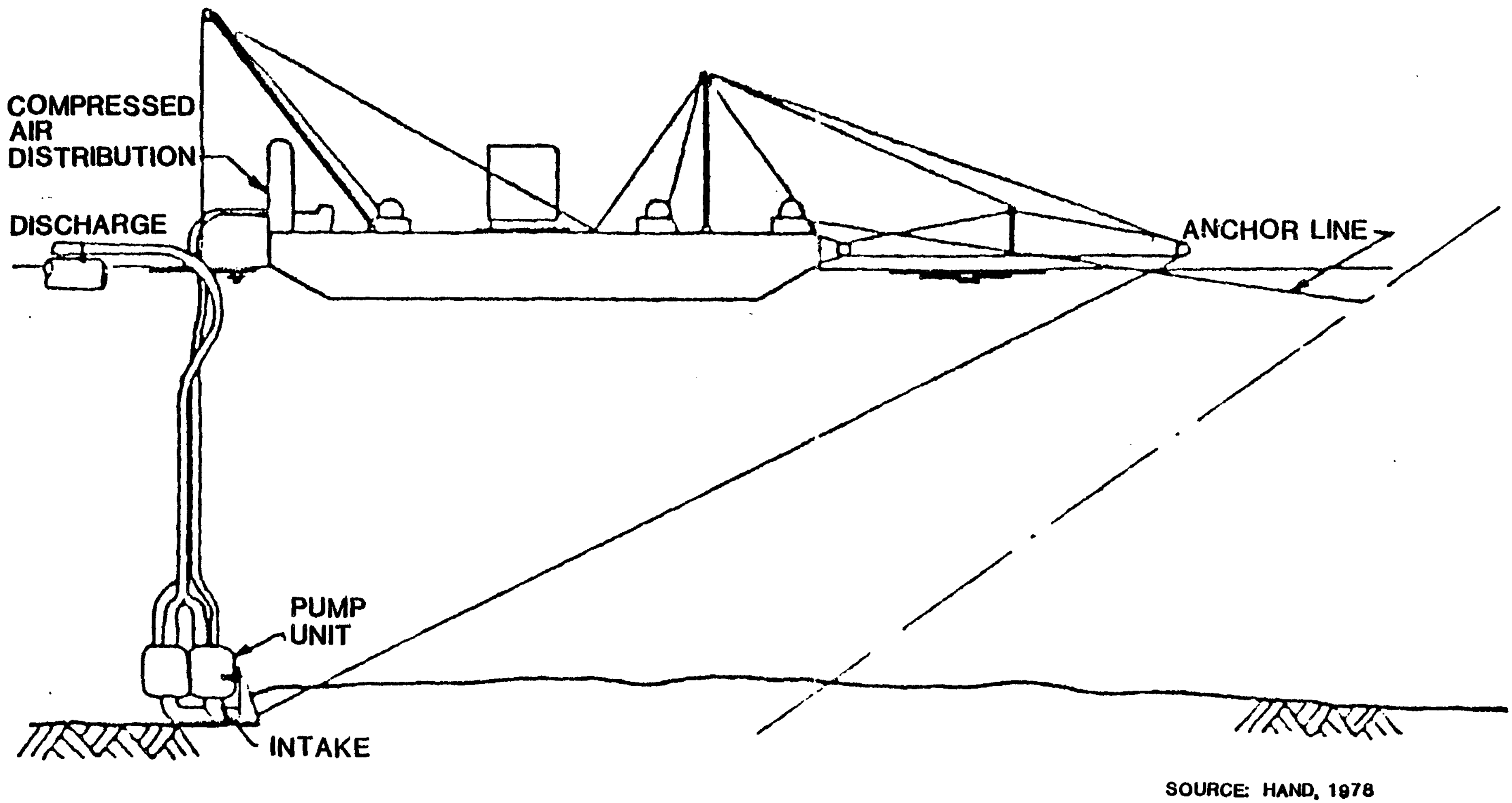


FIGURE 5-24
PNEUMA DREDGE

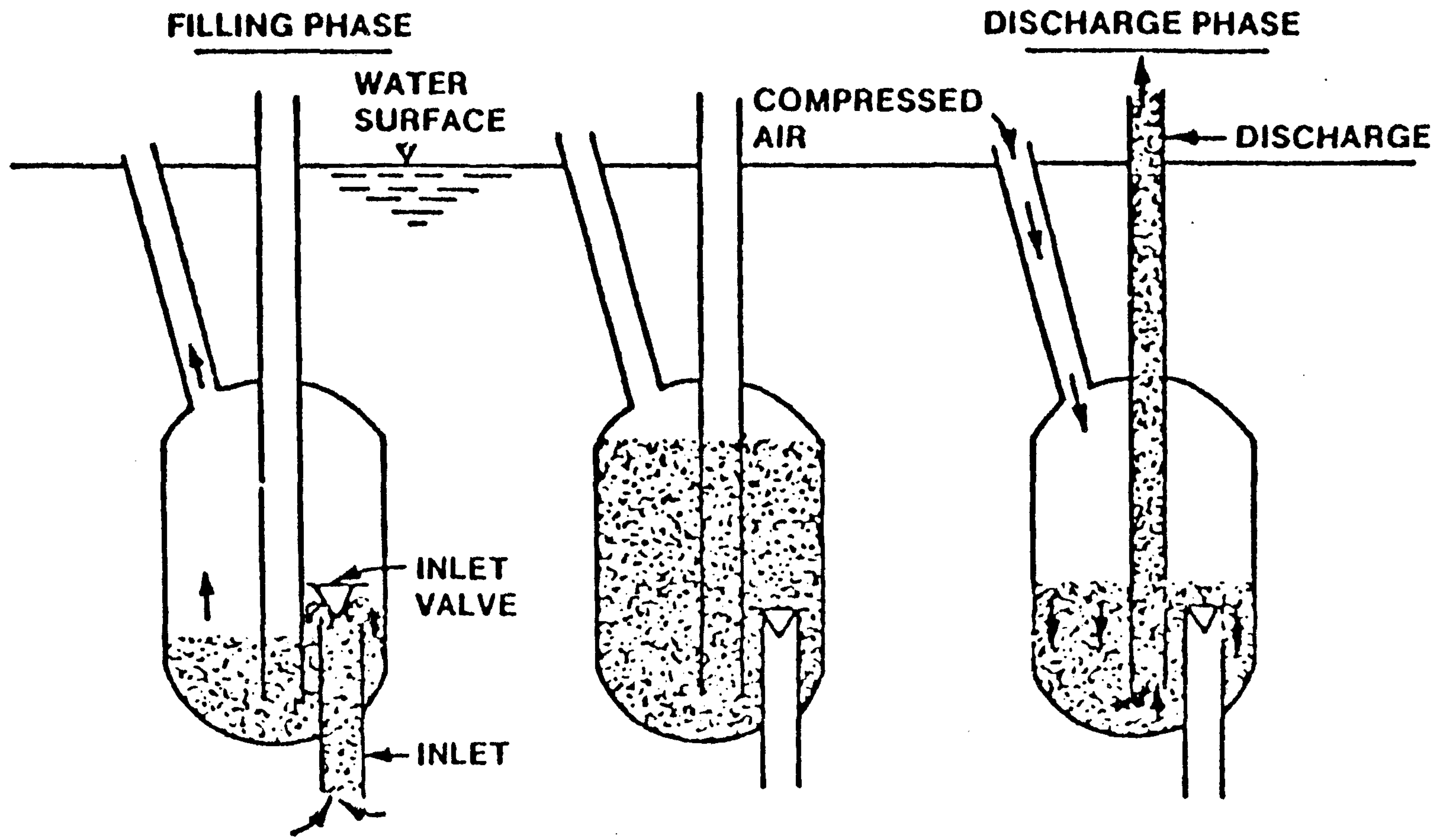

FILLING PHASE
WATER SURFACE
COMPRESSED AIR
DISCHARGE PHASE
DISCHARGE
INLET VALVE
INLET

FIGURE 5-25

- o Compressed air delivered via the distributor closes the inlet port and forces the sediment in the cylinder through the discharge line.

This procedure is repeated for each of the three tanks in sequence such that a continous discharge is maintained.

Dredging capabilities at shallower water depths may be improved with the addition of a vacuum step. The vacuum is applied during the cylinder filling stage. It will allow dredging in water depths one meter less than possible before the addition of the step.

Oozer Pump Dredge

Toyo Construction Company of Tokyo, Japan developed the Oozer pump dredge system in 1974. The design and operation of the Oozer pump system is similar to the pneuma. Figures 5-26 and 5-27 show a profile of the Oozer pump dredge and its operation cycle. Differences do exist in construction and method of operation. The Oozer pumps uses two cylinders instead of three; applies a vacuum to the cylinder filling stage; is ladder mounted and is a swing-type dredge; and may be equipped with special suction and cutterheads.

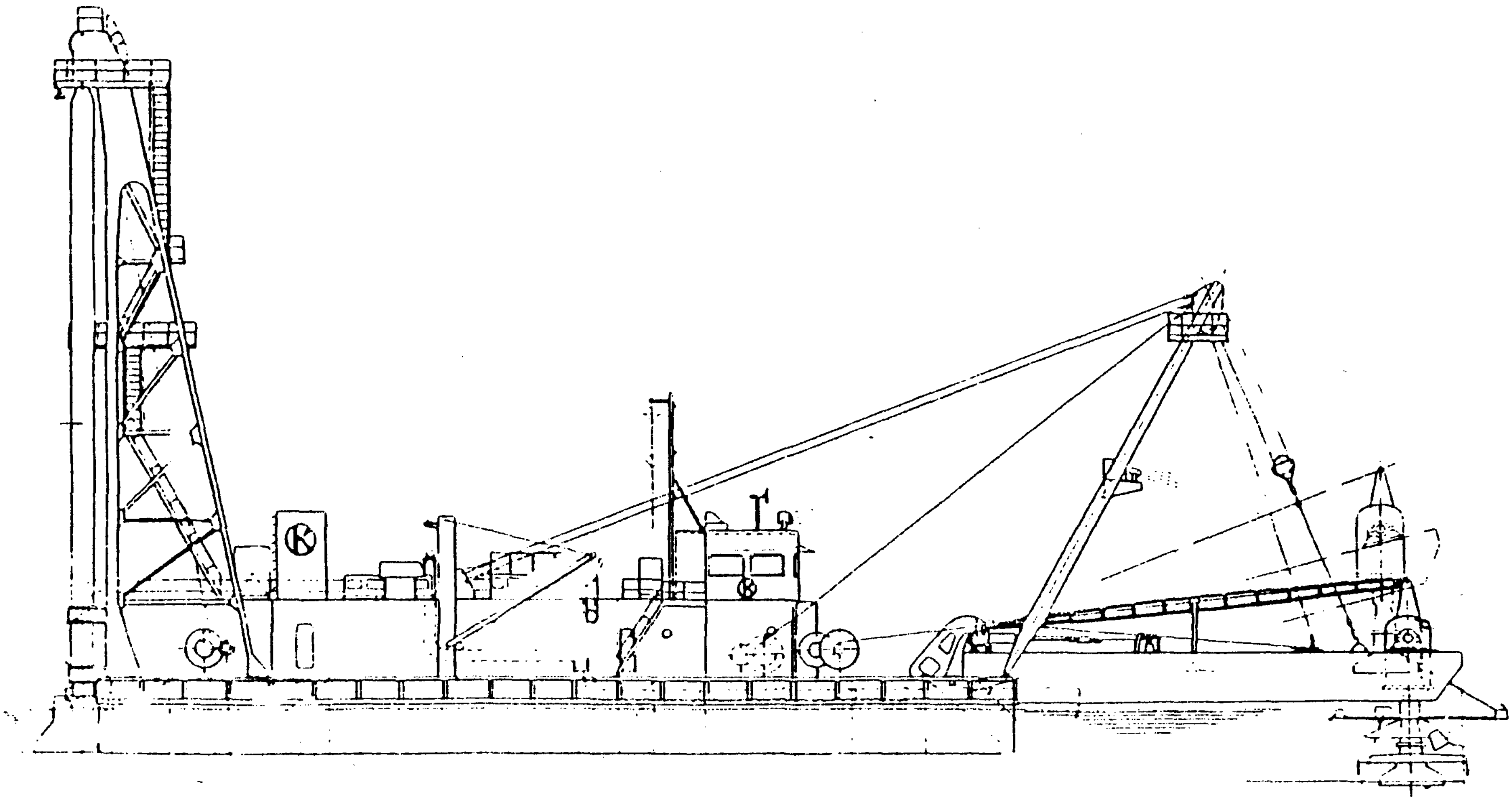
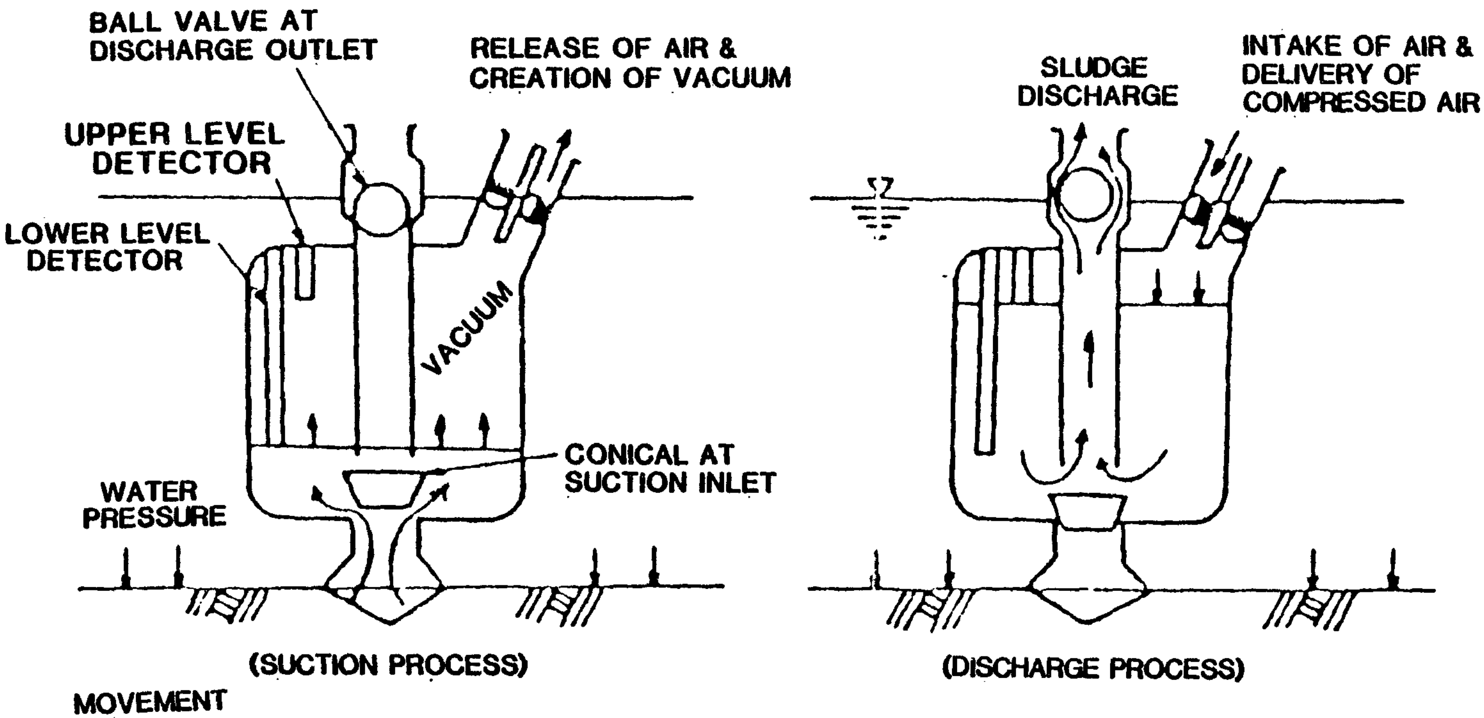


FIGURE 5-26
OOZER PUMP DREDGE



SOURCE: NISHI, 1978

FIGURE 5-27
SCHEMATIC OF OOZER PUMP OPERATION

Additionally, high frequency transducers and underwater television cameras monitor dredging elevation and conditions around the dredge head such as resuspension levels.

The Oozer dredge was developed to operate in the extremely polluted harbors of Japan. High solids concentrations and prevention of resuspension during dredging were the primary design criteria.

Portable Suction

One special purpose portable suction dredge technology was retained for detailed evaluation. This portable suction dredge has, as an original design criteria, the ability to be truly portable; i.e., the unit may be assembled and dismantled easily and quickly so that it may be air freighted or trucked to and from the project site. This point differs from those conventional dredging technologies discussed earlier which were labeled portable. Those dredges for the most part are redesigned versions of their larger predecessors. They are usually shipped to the project site for final and permanent assembly. The design criteria of this portable suction dredge, however, was based on the conventional hydraulic dredges but intended to be truly portable.

MUDCAT Dredge

The MUDCAT dredge is a small hydraulic dredge equipped with a horizontal auger. Figure 5-28 shows a profile of the MUDCAT dredge. This dredge is designed to remove mulch, weeds, sand, municipal, and industrial waste sludge. The horizontal auger is equipped with cutter knives and a spiral auger that cuts the sediment and moves it towards the center of the dredge where it is removed by the pump suction. The slurry mixture of solids and liquid is transported through a pipeline to a disposal facility where the suspended solids settle out.

The MUDCAT dredge is portable and can be used in areas where operating depths are less than 15 feet and shallow vessel drafts are required. The MUDCAT was retained in the initial screening of technologies for use in the shallow areas of all three New Bedford Harbor study areas.

5.3.2 Effectiveness

Reliability - Modified Suction

Clean-up Dredge

From 1973 to 1981, 45 projects were reported to have been completed by clean-up dredges with a total production of

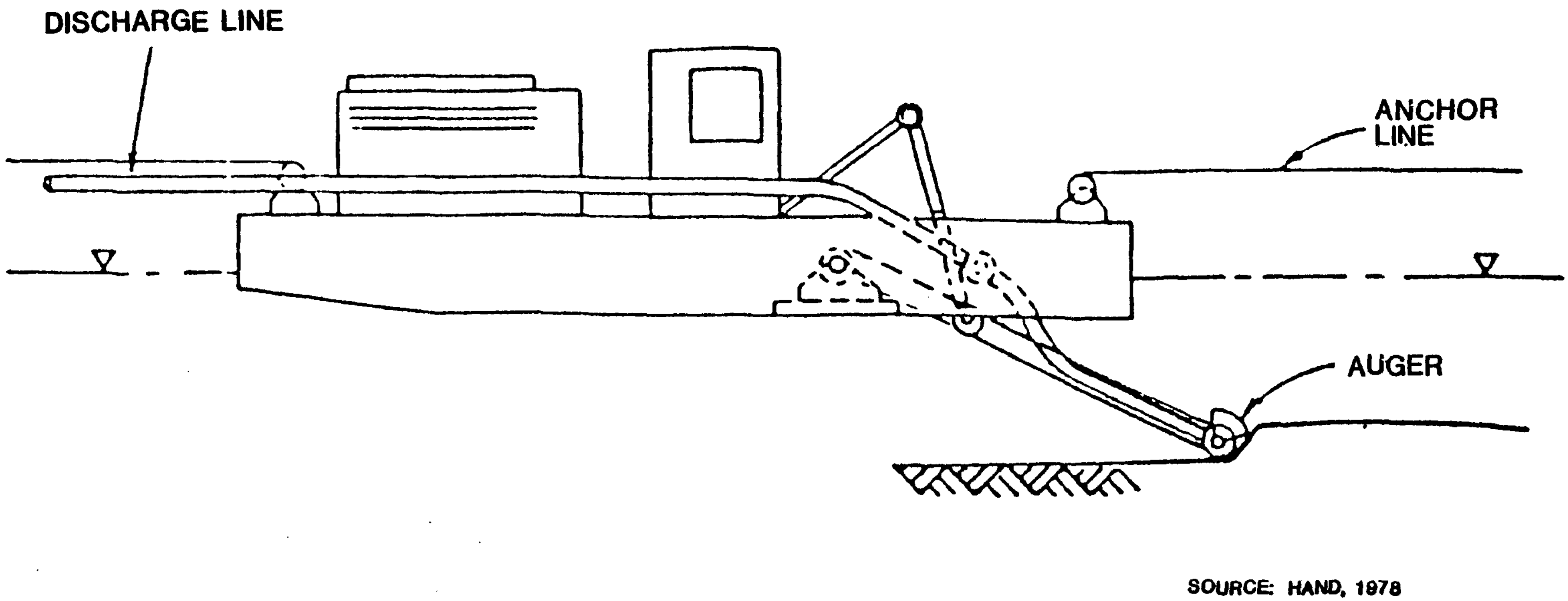


FIGURE 5-28
MUDCAT DREDGE

approximately two million cubic meters of silt, clay, and organic sludges. The clean-up system is a proven reliable performer for removal of the material for which it was developed.

The physical characteristics of the material described by TOA Harbor Works are:

- o Grain Size: less than silt and clay

- o Stiffness: N value ≈ 0

- o Percent Water: > 150 - 200 percent

Sediments exhibiting characteristics other than these may not be handled effectively by the clean-up. "If the ooze to be dredged exceeds a limit of the above conditions, the dredging efficiency may be possibly decreased depending on the extent of the discrepancy" (TOA Harbor Works).

The clean-up system was designed, tested, and developed specifically for ooze dredging. This special purpose dredger sucks the ooze from the soft sediment bed. It was not designed nor tested on a wide range of sediments with physical characteristics differing from those listed above. It is questionable that the clean-up dredge will be able to remove the contaminated sediments of New Bedford Harbor with any degree of effectiveness.

The New Bedford Harbor sediments are dissimilar to those for which the clean-up was designed. It is not expected that the mixing apparatus with turning screw would provide sufficient abrading force to properly dislodge the New Bedford Harbor sediments for lifting by the centrifugal pump.

Refresher Dredge

Four projects involved refresher dredges from 1976 to 1982, all in Japanese waters. Production totals were on the order of 325,000 cubic meters. The physical properties of the dredged materials ranged over a wide variety of specific gravities, grain size distribution, and percent water content:

- Specific Gravity: 2.58 - 2.80
- Grain Size: Gravel - Clay
- Percent Water: 146 - 230 percent

The refresher dredge, like the conventional cutterhead, seems to be a reliable performer over a wide range of sediment characteristics. The range of sediments for which dredging performance information is available does encompass the range of in situ sediments residing in the lower New Bedford Harbor and upper Buzzards Bay areas.

Pneumatic Dredges

Airlift Dredge

In order for the airlift dredge to operate effectively and reliably, the following operation requirements are necessary:

- Small compressed air bubbles must be released in a uniform pattern around the circumference of the conveyance pipe.
- A rotating cutter attachment must be included to assist in suspending solids prior to lifting.
- For maximizing suspension of fine materials, water jets may be attached to the rotating head.

The simple operational method employed by the airlift dredge provides for almost limitless application. An increase in operating air pressure translates to an increase in dredge lift capability. Varying the air pressure, coupled with the use of rotating head attachments, enables a wide range of sediment types to be reliably dredged by the airlift. Sand and gravel may be lifted successfully from unlimited depths. Hard pan clays and firm solid layers may be reliably suspended with the use of a rotary cutting adapter. A maximum dredging depth of 300 feet has been reached. Theoretically, deeper depths may be reached with increased air pressure. Specific minimum depth requirements vary according to the physical characteristics of the material to be dredged. It is questionable if sand and materials with a relatively high specific capacity can be lifted at shallow depths, since hydrostatic head plays an important part in the method of operation.

Percent solids in the dredged slurry associated with the airlift are on the order of a 1:3 ratio (one part solids to three parts water). However, 50 percent solids have been attained under ideal conditions. Unit production rates of approximately 400 cubic yards/hour are typical.

It is felt that the airlift may be an effective reliable performer at the New Bedford Harbor site for:

- o small localized areas not requiring a high production continuous dredging operation; and

- o removal of sand and/or coarse grained materials in a 5 to 10 feet minimum water depth.

Pneuma Pump Dredge

From 1974 to 1982 the Japanese Pneuma pump dredge "Shunkai" removed approximately 2.5 million cubic yards of sediment from areas in the Aji, Kizu, and Shirinashi Rivers. The average solids concentration was approximately 57 percent throughout these projects. As a result of measurements taken during these dredging projects, a correlation may be drawn between water depth and solids concentration: the deeper the water at the dredge location, the higher the solids concentration due to the increased thrust provided by the increased hydrostatic pressure.

In 1976, the USACE used the Pneuma pump to remove PCB-contaminated sediments in the Duwamish Waterway. A total of 9.5 million gallons of slurry was pumped by the Pneuma in 30 days (USEPA, 1977).

In 1978, the USACE conducted a series of performance tests on a Pneuma pump model 600/100 (USACE, 1984). These tests were conducted at three locations on sediments exhibiting different characteristics. Pumping performance and turbidity generation were evaluated for sand and fine-grained material.

From the USACE test, the following general conclusions were drawn:

- o Fine-grained materials may be removed at in situ density;
- o Sand could be removed only in water depths greater than 2.5 meters;
- o A high density discharge could be maintained for periods of 15 minutes or less;
- o Power efficiencies compared to a centrifugal dredge pump were less than 20 percent;
- o Some turbidity generation occurs, but relative increases are not excessive.

Based on the past performance of the Pneuma pump, the Pneuma may have some reliable application at the New Bedford Harbor site. Effective application would be limited to:

- o areas containing sediments that are fine-grained and free flowing. If sand is to be dredged the overlying water must be at least 2.5 meters in depth; and

- areas that are relatively small in surface area since high discharge rates cannot be maintained over expansive areas.

Oozer Pump Dredge

The Oozer pump dredge was built specifically for the removal of polluted sediments. The dredge can effectively remove sediments from their in situ state with a minimum of sediment resuspension and discharges them at a relatively high density.

Since its construction in 1974, the Oozer dredge "Taian Sea" has removed approximately one million cubic meters of contaminated silt and sandy silts on 13 projects (4/1974 - 3/1984). All the service of the "Taian Sea" has taken place in Japan on sediments containing natural undisturbed moisture contents from 50 to 800 percent with an average of 240 percent (sediment moisture content is the ratio of the weight of water over the weight of dry sediment). Toyo claims a sediments:solids ratio of 30 percent: 70 percent is typical for the Oozer dredge "Taian Sea." Suspended solids levels measured during one dredging operation were within ambient concentrations of less than 6 mg/ℓ.

Portable Suction

MUDCAT Dredge

The MUDCAT dredge is a fairly reliable dredge used in the removal of contaminated sediment. Several studies have been completed by the EPA and the USACE which underscore the ability of the MUDCAT dredge to remove contaminated sediment with minimum resuspension. These studies were described earlier in the report, "Initial Screening of Removal Technologies" (E.C. Jordan, April 1987).

Public Health - Modified Suction

Clean-up Dredge

The potential for short- and long-term threats to human health associated with the dredging and transportation of contaminated sediments using the clean-up dredge exists in three forms: indirect ingestion of the contaminants through bioaccumulation, inhalation of the volatilized contaminants, and dermal exposure to contaminants by workers.

Contaminant migration due to the resuspension of solids in which the contaminants reside may occur:

- at the anchors and spudpoles as a result of the positioning and repositioning of the vessel through the operating area;

- at any point along the dredge plant as a result of a slurry leak or spill due to equipment failure or human error; and

- at the dredge head as a result of the dredging action.

The potential for the first and second items occurring are small and similar to most dredging technologies discussed. The potential for the third item exists in varying degrees for each technology discussed. The resuspension of solids in the surrounding waters due to the disruption of sediments during the lifting attempt has been documented as being quite low in comparison to other dredges. Relative to ambient levels, suspended solids concentrations range from 1.7 to 3.3 mg/ℓ at the sediment surface and up to 7 mg/ℓ at 10 feet from the clean-up dredge head. The clean-up dredge has repeatedly demonstrated its ability to reliably remove "polluted ooze" with minimal resuspension of solids. Nonetheless, resuspended solids may still exist and may conceivably enter the food chain by ingestion of the contaminants by fish or migratory water fowl and subsequent harvesting for human consumption.

Volatilization of the contaminants contained in the dredged material may occur while the slurry is being pumped into and out of transportation barges and if leaks occur at the dredge, barge, or along the pipeline. PCBs that have entered the atmosphere may be inhaled by dredge plant operators and workers, and nearby residents.

Refresher Dredge

The potential for short- and long-term threats to human health associated with dredging and conveyance of the contaminated sediments using the Refresher dredge is similar to the threats discussed for the clean-up dredge. However, one area in which the potential for short- and long-term threats to human health will differ concerns migration due to the resuspension of solids at the dredge head as a result of the dredging action. The resuspension of solids in the surrounding waters due to the disruption of sediments during lifting has been recorded as being quite low. These resuspended solids levels were recorded while actual dredging projects were being conducted on sediments having a variety of physical characteristics. The measurements indicated that the Refresher dredge is effectively and reliably capable of producing one-fiftieth of the total resuspended solids than that associated with a conventionally rigged suction cutterhead dredge. Suspended solids levels from 4 to 23 mg/ℓ within ten feet of the dredge head are considered typical for the Refresher dredge.

For screening purposes, a comparison of the suspended solids numbers for the Clean-up dredge and the Refresher dredge shows a slight advantage to the Clean-up dredge. Relative to New Bedford Harbor, however, the physical characteristics of the contaminated sediments more closely match the characteristics of the sediments involved in the suspended solids measurements taken on the Refresher. It has not been determined what suspended solids levels can be expected when implementing the Clean-up dredge on sediments similar to those at the New Bedford Harbor site.

Pneumatic Dredges

Airlift Dredge

The potential for short- or long-term threats to human health associated with the dredging and transportation of contaminated sediments using the Airlift dredge is considered moderate compared to other dredging technologies.

Compressed air is used as the lifting force. After excavation, the air is then separated from the slurry and vented to the atmosphere. It is possible that PCBs may become volatilized and released into the atmosphere as a result of this air-slurry contact.

PCB exposure to the air as a result of slurry leaks or spills increases the risk of volatilization. Generating suspended solids in the surrounding water will also escalate the risk of endangering human health by making it possible for contaminants to enter the food chain via fish and or migratory waterflow ingestion.

The Airlift dredge may be supported from a self propelled vessel, a barge requiring a companion vessel, or a barge using spudpoles and anchors to facilitate maneuvering and holding position. The potential for threats to human health increase with the latter choice for dredge support, since maneuvering and setting equipment can disrupt the contaminated bottom sediments, resulting in an elevated risk to human health.

Pneuma Pump

The potential for short- and long-term threats to human health associated with the dredging and transportation of contaminated sediments using the Pneuma pump system exists in three forms: ingestion of the contaminants through bioaccumulation, inhalation of the volatilized contaminants, and dermal exposure to contaminants by workers.

Contaminant migration due to the resuspension of solids in which the contaminants reside may occur:

- at any point along the dredge plant as a result of a slurry leak or spill due to equipment failure or human error;

- if a vessel is used to support the operation, any anchoring or positioning device which disrupts the water bottom; and

- at the pump location due to sediment disruption.

The potential for the first and second items occurring are moderate. These are similar to most dredge operations employing anchors and/or spuds for positioning of the support vessel, and operations involving barges, scows, or a hydraulic pipeline for dredged materials conveyance. The potential for the third item exists to varying degrees. The resuspension of solids in the surrounding waters due to the disruption of sediments during lifting has been documented as being relatively low; when it does exist, it is short lived. During one test suspended sediment levels 3 feet above the pump were 48 mg/liter (USACE, 1985). The Pneuma pump has demonstrated its reliability in removing sediments with minor sediment resuspension. However, the contaminants may enter the food chain by ingestion of the suspended particles by fish or migrating water fowl.

Volatilization of PCBs may occur during the operation when cycle pressure inside the sediment cylinders is released to the atmosphere. Any time the dredge slurry is exposed to the atmosphere, the potential for volatilization, leaks, and the transfer of slurry to and from barges, scows, or hoppers are prime opportunities for volatilization to occur.

Dredge plant operators and workers may experience some increased levels of exposure during sediment removal, transportation, and delivery operations.

Oozer Pump

The potential for short- and long-term threats to human health associated with the dredging and transportation of contaminated sediments using the Oozer system exists in three forms: ingestion of the contaminants through bioaccumulation, inhalation of the volatilized contaminants, and dermal exposure to contaminants by workers.

Contaminant migration due to the resuspension of solids in which the contaminants reside may occur:

- o at the anchors and spudpoles as a result of the positioning and repositioning of the vessel through the operating area;

- at any point along the dredge plant as a result of a slurry leak or spill due to equipment failure or human error; and

- at the dredge head as a result of the dredging action.

The potential for the first and second items occurring are moderate and similar to most dredging technologies discussed.

The potential for the third item exists in varying degrees for each technology discussed. The resuspension of solids in the surrounding waters due to the disruption of sediments during lifting has been documented as being low in comparison to other dredges. Suspended solids concentrations measured during a particular dredging project were all within background concentrations of less than 6 mg/ℓ at 10 feet from the dredge head. The Oozer pump sediment system has repeatedly demonstrated its ability to reliably remove "polluted sediments" with minimal resuspension of solids. These resuspended contaminants may conceivably enter the food chain by ingestion of the contaminants by fish or migratory water fowl and subsequent harvesting for human consumption. It should be noted that this dredging system seems to have the least potential for resuspension of sediments of all the dredging technologies being evaluated in the detailed screening process.

Volatilization of the contaminants contained in the dredge material may occur while the slurry is being pumped into and out of transportation barges and if leaks occur at the dredge, barge, or along the pipeline. PCBs that have entered the atmosphere may be inhaled by dredge plant operators and workers, and nearby residents.

Portable Suction

MUDCAT Dredge

Short-term public health concerns from mudcat dredging are due to PCB volatilization, PCB-sediment resuspension, and PCB-sediment transportation. Short term health hazards also exist to on-site workers, however, these will be mitigated by proper health and safety procedures.

PCB volatilization is expected to create the largest impact to public health. PCB volatilization will be minimized during dredging activities by maintaining the auger below water level at all times during operation, maintaining pipes and pumps to minimize leaks, and insuring that the discharge pipe is submerged or covered at all times.

PCB sediment resuspension is not expected to create a significant threat to public health. The work area will be closed to the public and reopened only after monitoring results indicate that the PCB levels in the water column are at a safe level.

One of the options for removing the dredged sediment includes loading the sediment in tank trucks and transporting it to a disposal/treatment area. The loading station will be enclosed and each truck will be decontaminated prior to leaving the work area. Safe driving practices will be used and monitored to minimize the chance that accidents resulting in tank failure occur on public highways.

Long term public health effects are not anticipated as this technology will permanently remove the contaminated sediment.

Environment

The beneficial effects afforded the environment as a result of implementing removal technologies is relative to the extent the contaminant is removed. The degree to which the contaminant is removed depends on how effectively the sediment in which the contaminants reside may be removed from the harbor. The ability of each dredge to effectively remove the New Bedford Harbor sediments varies. The quality of the overlying water column will improve following the permanent removal of the contaminated sediment.

Since the contaminated sediments will be removed, the benthic organisms residing in these sediments will also be removed in the dredging process. Recolonization is expected to occur after dredging. By virtue of their low position in the food chain, the uncontaminated organisms will be consumed by organisms at higher trophic levels, thus improving the condition of species in New Bedford Harbor.

Concerning the potential for creating adverse environmental impacts, resuspension of contaminated sediments during dredging has the greatest potential for deleterious effects upon the environment. Areas of concern include resuspension at the dredgehead, at the spudpoles and anchors and at slurry leaks and spills, and volatilization of the contaminant, as a result of dredging and transportation. The sediment slurry is a concern but to a lesser degree due to the nature of the contaminants present. The ability of each removal technology to prevent contaminant resuspension and volatilization varies.

Modified Suction

Comparison of the two special purpose modified suction dredges for beneficial environmental effects indicates that the refresher dredge would be more effective than the clean-up dredge in removing the different types of sediments found in the New Bedford Lower Harbor/Bay study area.

The effective use of the Clean-up Dredge is limited to sediments exhibiting physical characteristics similar to the "polluted ooze" for which the dredge was developed (see Reliability Section). Knowledge of the Lower New Bedford Harbor and Buzzards Bay sediment properties raises serious concern over the Clean-up Dredge's potential effectiveness (higher sand, lower water content).

The refresher dredge on the otherhand, having its design based on the conventional cutter suction dredge is expected to effectively remove the New Bedford Harbor sediments in their in situ state. Dredging projects have been successfully conducted on sediments with grain size distributions and specific gravities on the order of the those in the Lower Harbor and Bay area of the New Bedford site.

It is recognized that both of these technologies have a potential for generating sediment resuspension. The measured amount of solids resuspension caused by the Clean-up and Refresher are on the same order of magnitude and are substantially less than those associated with conventional cutterhead dredging technologies (on the order of one fiftieth less). The Clean-up has demonstrated its ability to lift the soft polluted ooze with less secondary pollution than has the Refresher over a wider range of sediment types. However, the comparison is not parallel due to differing sediment types dredged while suspended solids measurements were taken.

Pneumatic

Of the three special purpose penumatic dredges being evaluated in this detailed screening step, the Oozer Dredge would be more effective in removing sediments over a greater portion of the New Bedford site and would do so with the least amount of sediment resuspension than the Pneuma or Airlift dredges.

Each of the three special purpose pneumatic dredging technologies possess their own strengths of application. Because the New Bedford Harbor site is large, contaminated sediment removal operations would involve working under a variety of static and dynamic conditions. Some on-site conditions lend favorably to the use of one or more particular technology(ies). Other conditions would disqualify the use of those technologies as being ineffective, unreliable or inefficient.

The Pneuma Dredge is best suited to operations in relatively small confined areas. Its best application is for localized "pocket" dredging. Minimum water depths are necessary for effective operation of the pneuma dredge and when advanced through large dredging areas difficulty in maintaining a continuous steady discharge was noticed (USACE, 1984).

The Airlift dredge is also best suited to operations in small areas. Its suction pipe is rigidly fixed to the vessel hull making continuous repositioning necessary. Minimum water depths of 10 to 15 feet are required to be effective, depending on type of material being lifted.

The Oozer dredge is a ladder-mounted, swing type dredge. It is moved through the dredging area by means of dredging arcs similar to the suction cutterhead.

The Oozer dredge may operate effectively on small localized sediment deposits provided that maneuvering area is present. Operations may also be effectively conducted on large expansive areas such as those comprising the majority of the New Bedford Harbor Site.

These pneumatic dredging technologies do have the potential for generating secondary pollution during the dredging process. The measured suspended solids associated with these dredges are at similar levels as the modified suction special purpose dredges. These levels are all significantly less than conventionally rigged cutterhead dredging technologies. Specific turbidity values are not available for the Airlift dredge but are expected to be on the same order of magnitude as the other members in the family of pneumatic dredges. Suspended solids measurements taken on the Pneuma and Oozer pump operations were acquired while each dredge worked in sediments exhibiting similar physical characteristics. On fine grained material at 23 feet above the water bottom, the Pneuma generated 4 mg/liter of suspended solids. At 3 feet above the water bottom this level increased one order of magnitude. A number of tests involving the Oozer working in fine-grained sediments indicated no detectable solids were added to the ambient water as a result of the dredging action.

Portable Suction

As outlined in the "Initial Screening of Removal Technologies," (E.C. Jordan, 1987) the MUDCAT has been tested by the EPA and proven effective in the removal of simulated hazardous waste. In addition, resuspension of the sediment was low and the resuspension plume was within 20 feet of the dredge. The MUDCAT is positioned by land-anchored cables and the dredge is moved by winching along this cable. This procedure eliminates any resuspension caused by dredge movement as spudding or anchoring is not required.

A potential adverse environmental impact may be the reduction of Estuary wetlands. A significant portion of the Estuary wetlands is contaminated with PCBs in excess of 50 ppm. If the PCBs removal target level is below 50 ppm then these wetlands may have to be excavated. To mitigate this environmental impact a wetlands reclamation program could be instituted.

5.3.3 Implementation

Technical Feasibility

The special purpose modified suction dredging technologies are being evaluated in this detailed screening process for the contaminated sediment removal in all three areas of the New Bedford Site. As part of this process, the feasibility of implementing these technologies in these areas is being considered. Specific site characteristics such as water depth, areas to be dredged, depth to cut to reach desired removal level and sediment physical properties, and operations characteristics such as vessel and machinery specifications, maneuverability, and maximum and minimum dredging capabilities are compared to assess their compatibility. These are compared and contrasted to operation processes, requirements and limitations of the removal technologies being considered.

Modified Suction

Clean-up

A portion of the contaminated sediments underlying the Lower Harbor and Bay areas may be removed using the Clean-up dredge. Quantifying this with an estimated percentage would not provide a reliable number since effectiveness information on the New Bedford type sediments have not been established for the Clean-up dredge. "Dredging soils (for the Clean-up) have been mainly soft mud and sand" (SATO, 1976). The maximum effective cutting depth per dredgehead pass is approximately one and a half feet. "When the cutting depth exceeds this value, turbidity generation increases and the possibility exists of sediments left undredged" (SATO, 1976). If the intended depth of removal exceeds 1.5' feet then an additional pass with the dredge would be required. TOA claims a dredging accuracy of ±0.1 meter when dredging in 5 to 10 meters water depth. This is exceptional in comparison to other dredging technologies.

Maneuverability, production rate and maximum and minimum dredging depths will vary with the particular piece of equipment selected. The largest Clean-up dredge is approximately 140' x 42' x6' (length x width x draft), has a maximum production rate of 2000 M^3/hr. and can operate in from 10 to 75 feet of water. Much of the Lower Harbor and Bay sediments are considered reachable by this particular dredge and it is expected that a vessel of this size may be able to operate over a wide range of sea conditions.

A smaller Clean-up dredge would be more maneuverable working in the vicinity of the many docks and piers in the harbor and yet would be unable to maintain the higher degree of stability a larger dredge would have in the swells and waves of the bay area. The smaller Clean-up dredge has hull dimensions of approximately

70' x 26' x 3' (length x width x draft). Maximum and minimum dredging depths associated with this vessel are 5 and 36 feet. Production rates range up to 500 cubic meters per hour.

Some question remains concerning the ability of the Clean-up to effectively remove all the sediment types found in the Lower Harbor and Bay areas. Concerning the implementability and the technical feasibility of the Clean-up conducting operations at New Bedford Harbor it is apparent that better choices do exist. A technology with a proven record of having effectively worked with sediments similar to those at the site, and still provide for a minimization of suspended solids during operations such as the cutterhead, would be a logical alternative to the Clean-up.

Refresher Dredge

Although, the Refresher dredge is capable of operating over a wide range of sediment physical characteristics with minimal solids resuspension, it is expected that the only constraint that will prohibit the removal of contaminated sediment would be water depth. Insufficient water depth to support vessel draft would range from 2.6 to 7.2 feet depending on vessel selection. Maximum dredging depth is dependent on ladder depth which for the smallest and largest Refresher dredge is 25 and 65 feet, respectively. The larger dredge has sufficient reach to enable it to remove sediment from any area at the site. It would be restricted for use in water depths exceeding 7.2 feet and would be insufficient at operating in narrow waterways and around docks and piers of the harbor due to its size (150' L x 44' B). Seas in the 2- to 3-foot range may affect the stability of the dredge to an extent that the contaminated sediment would not be effectively and reliably lifted with optimum dredging conditions to provide for the minimization of potential threats to the environment and public health. The smaller Refresher dredge with a loaded draft of 2.6 feet and a maximum dredging depth of 25 feet would be more effective in restricted areas but unable to operate in the varied sea conditions and to the depth a larger dredge would. It may be desirable to remove contaminated sediments from water depths in the 35 to 40 foot range, dependent on tidal conditions.

It may be necessary to combine different size dredges due to the range of constant and dynamic conditions that present themselves at the New Bedford. A larger deeper reaching, more stable Refresher may be recommended for sediment recovery in the bay. Concurrently, a smaller more maneuverable Refresher would be a more efficient operator in the shallower, narrower, more protected harbor areas.

Pneumatic

Airlift and Pneuma Dredge

Portions of the contaminated sediments in the Lower Harbor/Bay may be removed by using either the Airlift dredge or Pneuma pump. The areas in which these technologies may be implemented effectively are limited to:

- o sediments with overlying water depths exceeding five feet; and
- o localized areas not requiring continuous, high production rates.

Operation of the Airlift and Pneuma pump dredge in water depths less than 5 to 10 feet is questionable. The thrust provided by the hydrostatic head at lesser depths is not substantial enough to be a dependable excavating force. A vacuum applied to the Pneuma's filling stage decreases the minimum water depth required.

Provided the supplied compressed air has sufficient pressure to overcome the head pressure differences, maximum theoretical dredge depths may exceed several hundred feet. Tests conducted on a range of sediment types indicate these technologies are capable of lifting a variety of sediments from fines to gravels. Heavy, coarse-grained and compacted deposits require increased water depths for these technologies to be effective. Literature on the Airlift dredge quotes percent solids lifting capabilities as being 33 percent to 50 percent. The Pneuma pump without the vacuum was able to pump sand at less than in situ specific gravities. The percent solids discharge in sand was in the range of 10 percent to 25 percent. Corresponding specific gravities were 1.41 to 1.17. Average specific gravities of the sediment to be removed at the New Bedford Harbor site is 1.45. Percent solids discharge when pumping fine grained sediments paralleled the range of in situ sediment density.

The Airlift and Pneuma pump dredge are best suited for operations in localized areas where continuous high production rates are not required. Deployment methods used make it difficult to continue pumping sediments for sustained lengths of time (i.e., 15 minutes).

Oozer

Approximately half of the contaminants in the Lower Harbor and Bay are accessible to the Oozer dredge. Specific areas within the Lower Harbor and Bay that may not be accessible to the Oozer are:

- sediments with overlying water depths of ten feet or less at mean low tide;

- o narrow areas where maneuverability is restricted.

Specific areas within the Lower Harbor and Bay in which implementing the Oozer will have questionable result include:

- o areas where the sediments are consolidated, coarse, or heavy grained;

- o water content of material to be dredged less than 100 percent.

Insufficient water depth to support vessel draft would limit operations to ten feet of water at mean low tide. The oozer dredge hull specifications are:

Overall Length	121'
Beam	39'
Depth	10'
Draft	7'
Max. Dredging Depth	55'

Maneuverability around deep water (>10') piers will be limited considering the vessel dimensions.

Dredge test results on the Oozer leave questions as to its ability to remove materials other than the "polluted ooze" and "sludges" described in the manufacturers test reports. The sediments dredged in the performance tests typically exhibited the following characteristics:

Specific Gravity (dry)	2.57
Water Content	150-250 percent
Grain Size Distribution	
- Gravel	0 percent
- Sand	1 percent
- Silt	50 percent
- Clay	49 percent

New Bedford Lower Harbor sediments typically have the following properties:

Specific Gravity (dry)	2.5-2.7
Water Content (composite)	58.7-68.6 percent
Grain Size Distribution	
- Gravel	0-8 percent
- Sand	0-95 percent
- Silt	0-30 percent
- Clay	0-15 percent

Few similarities exist between the two sediment types. It may be possible for the Oozer pump dredge to remove some New Bedford Harbor sediments with some degree of efficiency. Technologies with proven track records of working in sediments similar to those in New Bedford Harbor may be a more advisable choice.

Portable Suction

Mudcat Dredge

The MUDCAT Model MC-915 is well suited for the removal of contaminated materials in the Hot Spot, Estuary and shoreline areas of the Lower Harbor and Bay.

The MC-915 has a vessel draft of 21 inches and a total working depth of 15 feet. It is pontoon mounted and transported by flat bed trucks. The MC-915 is well suited for these areas because:

- o The shallow vessel draft will allow it to work in the contaminated shoreline areas.
- o Obstruction of harbor traffic with the land-based cable and pipeline is not anticipated.

Level of Development

When conducting operations on soft mud and free flowing fines, the Clean-up dredge is an efficient and reliable machine. Depending on operator experience and dredging technique employed, the percent solids in slurry may reach 30 to 40 percent.

Modified Suction

Clean-up

The Clean-up dredge has been used since 1973. Since the first Clean-up dredge was put into operation, four sister vessels have been constructed and are presently in operable condition.

A total of 42 dredging projects were completed from February 1973 to September 1981 with a total volume of material removed of over 2 million cubic meters. Average efficiency figures for these projects were:

- o pumping volume 264.0 m^3/hr.
- o percent solids 30.9 percent
- o dredged volume 105.5 m^3/hr.

Soil characteristics involved were predominantly organic soils, oily soils and silts.

Refresher Dredge

The demonstrated performance for the refresher dredge is somewhat less than extensive. From 1976 to 1981, four dredging projects were completed using the Refresher dredge. A total of approximately 325 thousand cubic meters of material were lifted during these projects. Physical properties of the sediments involved varied in range, those ranges included:

- o Specific Gravity 2.58 - 2.80
- o Percent Water 146 - 230 percent

Penta-Ocean Construction, the dredge manufacturer, claims 30-40 percent solids in slurry is possible.

Special purpose dredges substantially reduce the resuspension of sediments in comparison to conventional hydraulic dredges; however, most have associated lower production rates.

Pneumatic Dredges

Airlift Dredge

The Airlift dredge operates with greatest effectiveness on free flowing and unconsolidated materials. Consequently, development and primary application of the Airlift dredge has centered around recovering sand and gravel from lakes. These dredges have been used as single and double units. Production rates may reach approximately 400 to 1,000 cubic yards per hour, respectively. Sand and gravel has been lifted by this dredge from depths of up to 300 feet.

Pneuma Dredge

The Pneuma pump was first developed in 1971 by the Italian firm S.I.R.S.I. The City of Osaka, Japan Port and Harbor Bureau recognized a possible dredging application for the Pneuma pump. Experimental dredging was conducted to determine the effectiveness of the Pneuma pump systems in removing polluted mud from the rivers and bays of western Japan. The favorable results of the experiments prompted the Bureau in 1974 to modify the grab dredge "Shunkai" to a Pneuma pump dredge. This dredge has been engaged in polluted mud dredging operations since November 1974.

In 1976, the shallow water operating efficiency of the Pneuma pump dredge "Shunkai" was improved by the addition of a vacuum generator. An absorption tower was developed and added to the system as well. This tower serves as an air washer, silencer and solids remover for the pump exhaust air.

From November 1975 to March 1982, the Pneuma pump dredge "Shunkai" dredged a total of 2,551,780 cubic meters of contaminated sediments with an average solids concentration of 57 percent (USACE, 1984).

In 1976, the Pneuma pump system was successfully used in PCBs cleanup operations after a still of 255 gallons of Arochlor 1242 in the Duwamish Waterway in Seattle, Washington (USACE, 1985).

In 1978 the USACE Waterways Experiment Station conducted a series of field tests on the model 600/100 Pneuma pump. Sixty-one test runs were made. Over 51 hours of pumping data and four hours of turbidity measurements were logged (USACE, 1984).

The Pneuma pump has been tested and used extensively throughout Japan and Europe. A number of developmental changes have been implemented on the system since its first experimental dredging application in 1974.

Oozer Dredge

The Oozer pump dredge was developed and constructed in 1974 by Toyo Construction Co. LTD of Tokyo, Japan. Literature published by the manufacturer claim that strenuous efforts have been made to improve the Oozers suction mouth and monitoring devices in order to prevent the resuspension of solids. Approximately one million cubic meters of contaminated sediments have been dredged by the Oozer dredge from 1974 to 1984.

In March 1980 and August 1980 the Japanese government conducted sediment removal tests on organic sludges of Osaka Bay using the Oozer pump dredge.

Portable Suction

Mudcat Dredge

The MUDCAT MC-915 has been in use for twelve years. It has been improved and modified over that time and currently more than 500 MUDCATs are in operation. The MUDCAT has not been used extensively for hazardous waste remedial action but has been tested successfully using simulated hazardous waste. In addition, the MUDCAT dredge was the chosen technology for removal of contaminated sediment at the Marathon Battery Superfund site.

The MUDCAT is a proven technology. Failure/downtime is estimated to be 20 percent. This may be reduced if the operational constraint of dredging only with the incoming tide is implemented.

Support Requirements

Support requirements necessary for the implementation of the special purpose dredges in these areas are typical to most dredging operations. The dredges are not usually self propelled and therefore require a tug or tow vessel to move between locations. Once in operation the dredge is advanced and maneuvered by means of self-hauled anchors and spudpoles or the straightline cable and winch arrangement. The exception would be the Pneuma, which may be supported by a self-propelled crane vessel.

The dredged material is discharged from the dredge vessel by the dredge pump through a hydraulic pipeline. This pipeline can either transport the slurry directly to an onshore disposal or treatment site or to a barge or scow first and then transported in bulk to an onshore facility for unloading and handling. Some barges and scows are self propelled, those that are not would require a companion tow vessel. Pontoons or pipe floats are used to support the pipeline over water crossings. A pair of pontoons is usually placed every nineteen feet at the connection between pipe lengths. Pipe diameter should match pump discharge size and pontoon size selection will be proportioned to assure pipeline buoyancy and stability.

Support crews and vessels will be necessary for the inspection and maintenance of the hydraulic transport pipeline. This will aid in minimizing the potential for leaks and help pipeline integrity so that slurry is not lost during conveyance.

Mudcat Dredge

Several different scenarios were developed to determine the support requirements and subsequent costs. For each of the three study areas, it was assumed that the MUDCAT would transport the dredged material to an in-harbor containment area, an upland disposal site located within 1.5 miles of the Hot Spot area, and into tank trucks. The tanks trucks were assumed to transport the material to a disposal/treatment area located at either the generic off-site disposal area, the New Bedford Municipal Landfill, or the Conrail railyard. It is important to note that there have been additional sites chosen as treatment/disposal/containment areas.

Support requirements for pumping to an in-harbor containment area and the upland disposal site 1.5 miles from the Hot Spot are similar. Laborers will be required to install the pipe and booster pumps. Laborers will also be needed to monitor the pipe and pump system during operation to identify and repair malfunctions and leaks. If it is determined that silt curtains and/or oil booms are required, additional labor will be needed for their installation, monitoring and repositioning.

Additional support will be needed if the dredged material is pumped into tank trucks. A truck loading area and decontamination station will need to be constructed, operated, and maintained. It is estimated that only one laborer will be required to load the trucks and operate the decontamination station.

Availability - Modified Suction

Clean-up Dredge

Currently there are five Clean-up dredges in existence. All are owned and operated by TOA Harbor Works Co., LTD in Tokyo, Japan. Due to the Clean-up system being of Japanese manufacture, its availability for domestic projects may be subject to U.S. government control.

Refresher Dredge

Penta-Ocean Construction Co. Ltd. of Tokyo, Japan has built and presently maintains three Refresher dredges. Like the Clean-up dredge, its availability for conducting operations in the United States may be subject to U.S. Government control.

Pneumatic

Airlift

According to the NUS Draft Feasibility Study of Remedial Action Alternatives for the Acushnet River Estuary above Coggeshall Street Bridge, New Bedford Site, Bristol County, Massachusetts, August 1984, the Airlift dredge is manufactured in the United States and may require up to six months to obtain. No additional information concerning the availability of this particular dredge was located.

Pneuma

The availability of the Pneuma pump is limited in the United States. In the late 1970's S.I.R.S.I., the Italian firm that developed the pump established a U.S. licensee to market the pump. This company was called "AMTECH," which stood for American Technology. In 1982 this firm changed its name to "NAMTECH" for North American Technology. Efforts to contact this firm for availability information concerning the Pneuma pump or Pneuma pump dredges have been unsuccessful.

Oozer

There is one Oozer pump dredge in existence today. It is called the "Taian Maru." It is the property of Toyo Construction Co. and is operating in Japanese waters. Due to this pump being of Japanese manufacture its availability for domestic projects may be subject to U.S. Government control.

Portable Suction

Mudcat Dredge

At present, the availability of MUDCAT dredges is excellent. MUDCAT dredges can either be leased or purchased from Ellicott Machine Corporation. Little land will be required for the actual dredging operation. Site access will be required and a right of way may be needed if pipe is used to transport the dredged material via pipeline. Site access is not anticipated to be a problem as several areas exist along the Estuary and Lower Harbor and Bay to launch the dredge.

Installation

Dredge size is a combination of operational tradeoffs including water depths to be worked, vessel draft, volume to be removed, dredge output capacity and maneuverability.

Modified Suction

For both the Clean-up and Refresher Dredge Systems a vessel with a hull size in the 50" x 20" 3" to 70" x 30" 5" (L x W x D) range would be an appropriate size for work in the Lower Harbor and Bay area. Since the dredgehead of the dredges being considered is securely fastened to the dredge hull by means of the ladder, a one foot rise in hull elevation caused by waves translates to a one foot differential in dredgehead elevation (position). It would be difficult to maintain the dredging precision which is required in removing contaminated sediments in seas which would significantly effect overall hull elevation. It would also be impractical to bring a larger dredge with a deeper draft that would provide for a more stable work platform to the site for work only in rough water periods. Operations would cease when, in the judgement of the dredge crew, sea conditions endanger the safety of the crew or equipment or where they are incapable of controlling the dredge head in a manner that provides for best operational results (i.e., minimize secondary pollution and complete removal of contaminated sediment with high solids concentration).

If the removal target level is established at detectable levels, then a more substantial area (an order of magnitude) will be dredged. It is felt that if such a clean-up level were established, a larger dredge capable of operating during rougher sea conditions in Buzzards Bay would be warranted.

Pneumatic

The Airlift dredge is typically comprised of six or seven individual units. These units are mounted on pontoons and fastened together. In this fashion, the Airlift dredge may be transported by truck and assembled at the project site. An assembled Airlift dredge plant may measure 80 feet in length, 70 feet in width and have a five foot draft. A vessel with these dimensions would be appropriate for work in the Lower Harbor/Bay. Like the ladder dredges, the Airlift's suction pipe is rigidly fixed to the vessel hull. Stability changes at the hull directly affect the suction pipe elevation relative to the ocean floor. Contaminated sediment dredging requires dredgehead positioning accuracy so that the contaminants may be removed completely and so resuspension of contaminated sediments may be minimized. Removal operations would therefore need to be conducted during periods of calm seas. Operations would cease, when in the judgement of the dredge crew, sea conditions endanger the safety of the crew or equipment or when they are incapable of controlling the dredgehead in a manner that provides for best operational results (i.e., minimize resuspension of solids and complete removal of contaminated sediment with a high solids concentration slurry).

Pneuma pump operations may either be supported from a dock for dredging activities in the vicinity of that dock or from a self propelled or barge type vessel for offshore operations. For offshore operations, the Pneuma pump may be suspended by wire rope and crane or fixed to a ladder mounted on the support vessel. Regardless of the method of pump deployment and retrieval the support vessel should be of a size similar to those previously described. The range of most commonly occurring fair weather surface sea conditions should not affect dredgehead stability to an extent that sediment removal precision will be comprised.

The Oozer pump dredge is approximately 120' x 40' x 7' (L x W x D). This dredge is substantially larger than what is considered necessary to conduct operations in the Lower Harbor and Bay. Its larger size will allow operations to be conducted over a wider range of sea conditions. It will also limit its effective use to those areas offering the additional maneuvering room necessary. A choice in vessel dimension will only be available if a new Oozer pump dredge is built. This dredge is not self propelled nor portable.

Portable Suction

Mudcat Dredge

Minimal time will be required to design and construct the installation of the MUDCAT. As the Hot Spot and Estuary areas are used less extensively it would be appropriate to dredge in these areas during the summer. The Lower Harbor and Bay would then be dredged during the off season when recreation activities are less. In the Hot Spot and Estuary dredging should be able to continue during most weather except thunderstorms and high winds.

For the Lower Harbor/Bay, dredging will only be allowed during fair weather. This is because wave action affects the safety and accuracy of the operation. This is critical in the Lower Harbor and Bay where contamination is only known to occur in the top six inches of sediments. For these reasons, the use of the MUDCAT in the Lower Harbor and Bay is limited to shallow areas (<10'). By doing this, the MUDCAT can only remove approximately 45 percent of the contaminated sediment. Another removal technology would be required to remove the remaining 55 percent.

Time

Modified Suction

The Clean-up and Refresher dredges are not portable dredges. Transportation of machinery along with an inventory of spare parts and special tools from Tokyo to New Bedford would be an undertaking of a substantial and possibly cost-prohibitive nature. Should the Clean-up and/or Refresher dredge technologies be selected to participate in the contaminated sediment removal efforts at New Bedford Harbor, domestic machinery conversion should be considered. These systems are compatible to existing

American made equipment. An integrated governmental and private business effort may reduce the time and cost of placing these technologies in New Bedford Harbor.

The beneficial effect to the environment as a result of implementing either of these special purpose modified suction dredges will be immediate.

Pneumatic

The Airlift and Pneuma are portable dredges. Approximately forty-eight hours would be required to assemble and put these dredges into operation upon their delivery to the project site. The Oozer pump dredge is not portable or self propelled. A considerable mobilization fee would be involved for its delivery from Japan to the United States. Domestic machinery conversion should be considered if the Oozer is selected to have a part in the New Bedford clean up effort.

The beneficial effects to the environment as a result of implementing these sediment removal technologies will be immediate.

Portable Suction

The time required to dredge the Hot Spot, Estuary and Lower Harbor and Bay is proportional to the PCBs target level that is to be removed. Section 5.3.4 outlines the times required to complete dredging in each area as a function of target level and disposal alternative. It is estimated that the Hot Spot can be removed within a two month period. The contaminated sediment in the Estuary can be removed within eight to 89 months depending upon the PCBs target levels. Similarly, the removal time for the Lower Harbor and Bay is estimated to range from 1 to 58 months.

Safety

Short-term health threats to workers and area residents may exist from exposure to volatilization of PCBs, exposure to the pipes and pumps during the upland site disposal alternative, and the exposure to the disposal trucks during the increased truck traffic under the tank alternative. No long-term threats to public health are anticipated to occur from dredging activities.

Monitoring and Maintenance Requirements

Monitoring and maintenance required for dredging operations would include: monitoring of suspended solids generation at the suction intake, monitoring of the dredge material transport pipeline integrity (if used) and maintenance of the applicable dredge plant components (dredge, barges, work boats, pipeline and pontoons).

For the purpose of monitoring resuspension levels at the dredge head, a turbidimeter may be mounted in the immediate vicinity of the dredging action so that resuspension of solids as a result of dredging may be monitored in real time. Position of the meter should be such that only those solids resuspended by the dredge head and not lifted by the suction pipe are measured. This monitoring may be performed and recorded on a continual basis.

It is recommended that for each mile of pipeline to be maintained in the hydraulic conveyance of the dredged material, one work crew be responsible for monitoring the integrity of the floating and shore pipeline. A typical pipeline monitoring crew might consist of two men in a small U.S. Coast Guard approved shallow draft boat equipped with an outboard motor and fuel tank capacity for a full work days' continuous operation. Portable VHF radios may be included so that communications are possible between all aspects of the operating dredge plant. This monitoring crew may as well be equipped to remedy situations requiring minor repair or replacement such that operations need not be shut down for repairs.

Separate pipeline construction and maintenance barges are advisable so that if a problem or the potential for a problem arises, the maintenance barge may be dispatched directly to the area in need of repair. In this manner, use of time is optimized.

Scheduled maintenance to the dredge itself may well be accomplished during the evening hours while operations have ceased for the day. A preventive maintenance schedule will minimize the potential for unscheduled repairs and lost production time.

Permitting

Permits should not be required to conduct dredging operations as described. Some ARARs however will either apply or be used as guidance during remedial alternative designs and implementation (e.g., USACE Dredge and Fill Requirements).

Legal Constraints

It is not expected that opposition to removal efforts such as those previously described will exist. Permission from the state will need to be obtained for the use of the New Bedford State Pier for the deployment and retrieval of the dredging plant and its use as a staging area and decontamination corridor throughout the life of the project, if use of the facility is included in the remedial alternative design.

Impacts on Historical and Critical Resources

Archeological resources are not known to exist at the New Bedford Harbor site. However, operations shall cease if during the course of operations any archeological, historical, or critical resources are discovered or if the potential for such resources to be uncovered is apparent. Operations will not resume until such time as it is deemed safe to do so by the federal, state, and local agencies governing such resources.

5.3.4 Costs

Cost scenarios were developed for the MUDCAT dredge, the special purpose dredge which has been demonstrated as possessing the strongest attributes for clean-up application in New Bedford Harbor.

Costs for operating the MUDCAT were developed for each study area using three different scenarios. These scenarios were: dredging and pumping to an in-harbor containment area; pumping to an off-site disposal area located 1.5 miles from the Hot Spot; and pumping into tank trucks. For the tank truck scenario three different disposal/treatment areas were chosen. These are the Conrail Railyard, a generic off-site disposal area 1.5 miles from the Hot Spot, and the New Bedford Municipal Landfill. These scenarios were chosen because they are probable disposal/treatment locations. In addition, three different size tank trucks were evaluated to determine the difference in cost and number of trucks needed to complete the job expeditiously. The tank truck sizes evaluated were 3,000, 4,000, and 5,000 gallons. They were evaluated in order to determine a range of costs and do not necessarily represent the final dredging costs. Final dredging costs will be determined in the feasibility study after remedial alternatives are developed and analyzed.

Hot Spot

Table 5-11 summarizes the results of the cost analysis. Dredging costs to the generic off-site disposal location were the lowest because the pumping distance is the shortest. The cost for pumping to any of the tank truck scenarios was the highest because of the additional cost incurred with renting and operating the trucks, and constructing and operating the decontamination station. This scenario also has the disadvantage of increased community impact by the additional traffic and associated safety concerns. This alternative would only be chosen if direct pumping was not possible.

A present worth analysis of rental versus purchase was performed for the MUDCAT under each scenario. In each case, rental costs were substantially lower than purchase costs primarily due to the

TABLE 5-11
MUDCAT RENTAL COSTS - HOT SPOT

	Pump to In-Harbor	Pump to Upland Site	Pump to Tank Truck* Landfill	Upland Site	Railyard
* SEDIMENT TO BE REMOVED (YD^3)	16,246	16,246	16,246	16,246	16,246
MONTHS OF OPERATION	2	2	2	2	2
PRESENT WORTH COST ($)	81,625	75,188	301,429	184,345	228,252
*** UNIT COST ($\$/YD^3$)	5.02	4.63	18.55	11.35	14.05
# OF TRUCKS NEEDED	--	--	15	7	10

* 5,000 gallon trucks were chosen because there would be less trucks operating on the public roads and the truck costs were generally the lowest.

** Times dredge efficiency factor yields actual volume to be removed.

*** Unit cost of removing target level contaminated sediment in place.

short amount of time (2 month) required to dredge the Hot Spot sediment.

Cost sensitivity analyses were performed to determine which factors have the greatest impact on dredging costs. Cost sensitivity analyses were performed for pumping rate and flow costs. A cost sensitivity analysis was not performed changing the interest rate because interest rate has little effect over a short time period (two months).

Figure 5-29 shows the effect a change in pumping rate has upon project costs. Project costs remain relatively stable in the range of 1500 gpm to 2300 gpm. Project costs escalate below 1500 gpm due to the change in rental period. Substantial cost savings could be achieved if the pumping rate could be sustained to 2500 gpm or greater. This is impractical, however, for the MUDCAT as the dredge pumps are incapable of this continued pumping rate.

A change in labor costs is presented in Figure 5-30. This graph illustrates that a 50 percent increase in labor costs from the base cost of $20/labor hour to $30/labor hour translates to an increase in project costs of approximately $6,000. Conversely, labor costs of $10/labor hour would save the project approximately $6,000. A change in labor costs does not have a significant effect on project costs as the labor rate is not tied to the

Figure 5-30

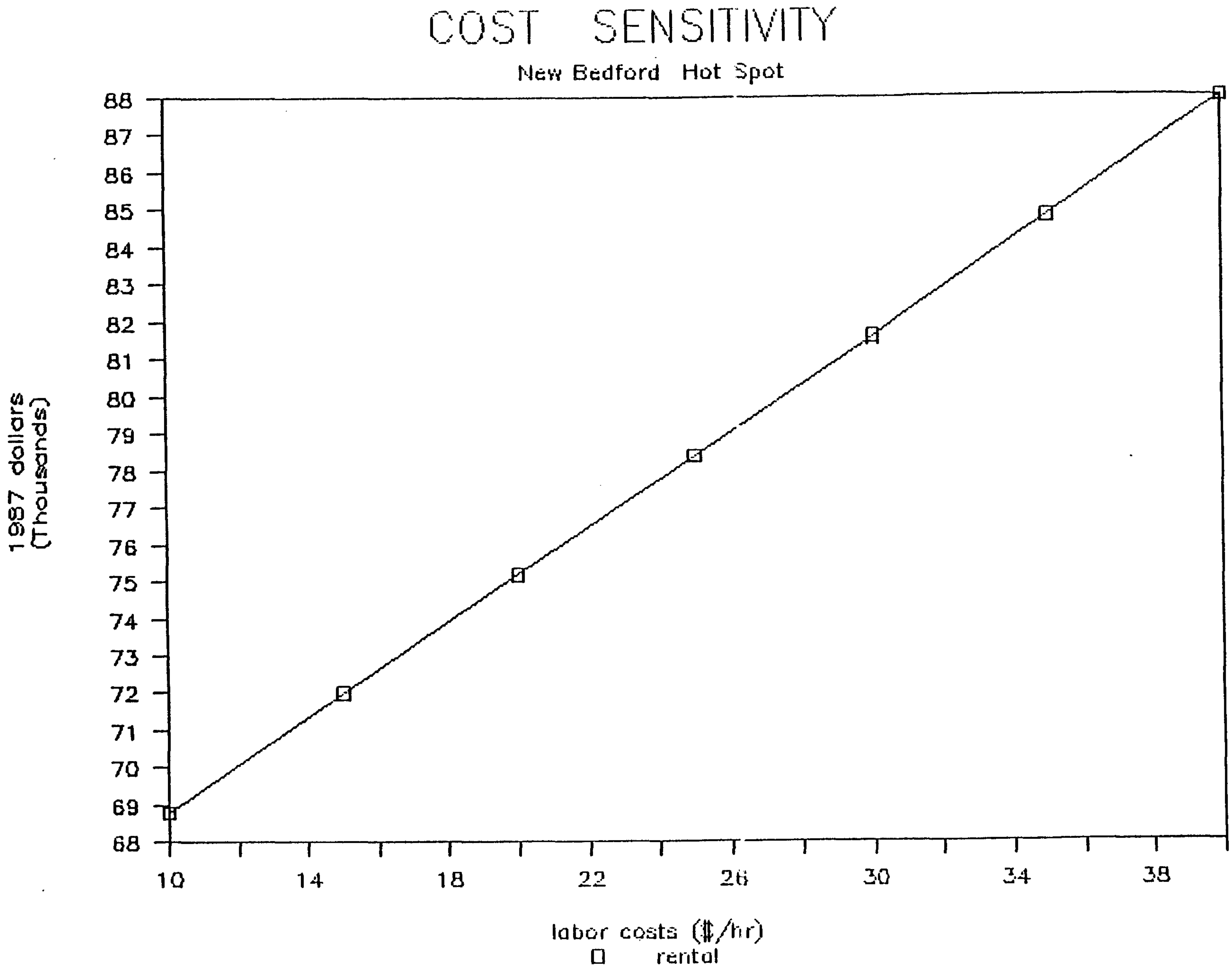
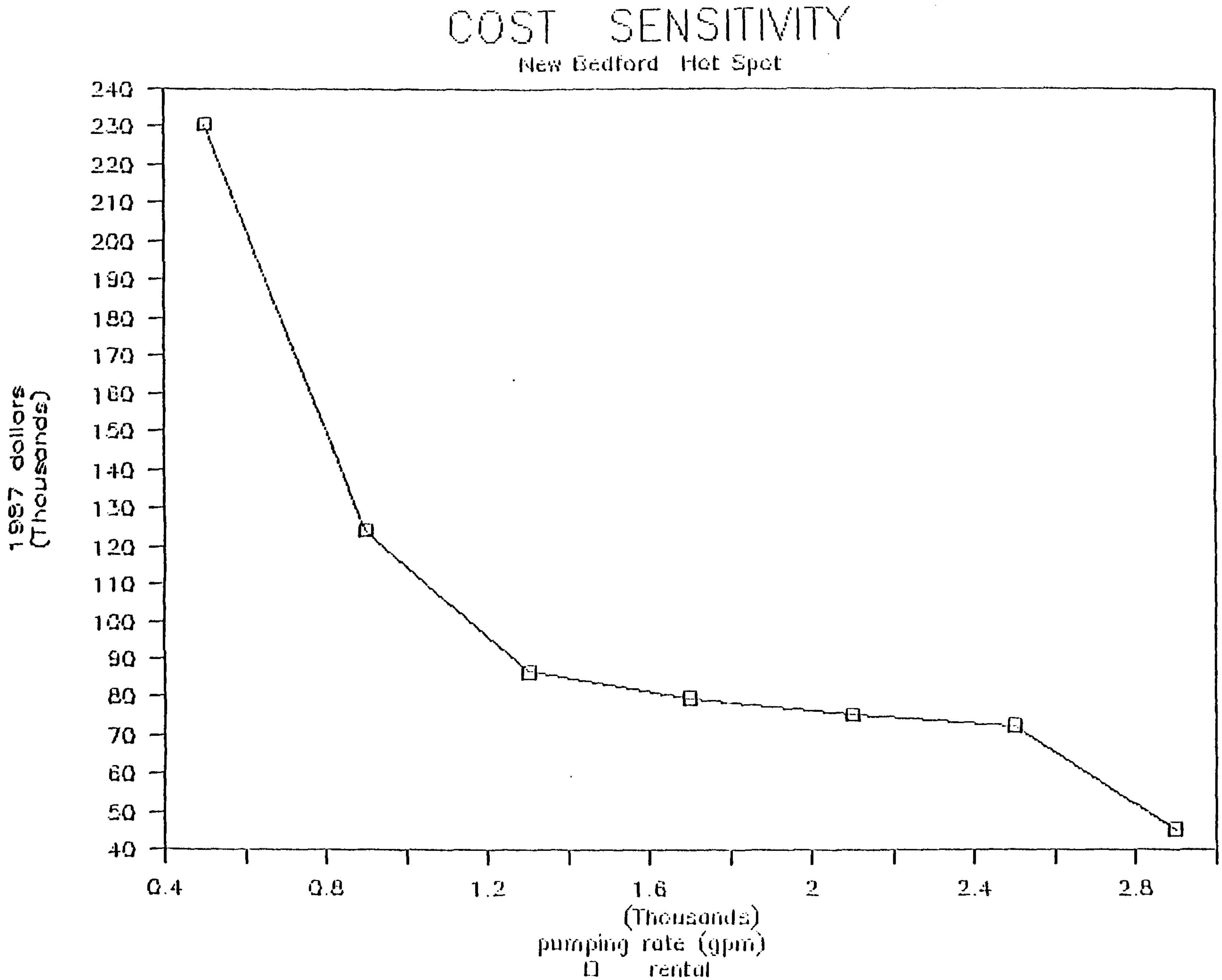

COST SENSITIVITY
New Bedford Hot Spot
1987 dollars
(Thousands)
88
87
86
85
84
83
82
81
80
79
78
77
76
75
74
73
72
71
70
69
68
10
14
18
22
26
30
34
38
labor costs ($/hr)
rental

Figure 5-29


COST SENSITIVITY
New Bedford Hot Spot
1987 dollars
(Thousands)
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
0.4
0.8
1.2
1.6
2
2.4
2.8
(Thousands)
pumping rate (gpm)
rental

dredge rental period. The dredge rental period appears to have the largest effect on project costs.

Estuary. Costs developed for the estuary area were determined in a similar fashion as those for the Hot Spot; however, since a specific PCBs target level has not yet been established, costs were developed for seven different target levels. These target levels are >5000 ppm, >500 ppm, >100 ppm, >50 ppm, >10 ppm, >1 ppm, and >0 ppm. Sediment removal volumes were determined relative to these target levels.

A present worth analysis of rental versus purchase was performed for the MUDCAT at each target level. Figure 5-31 illustrates that at a target level less than 500 ppm it becomes cheaper to purchase the MUDCAT. The "gap" between rental and purchase increases as the target level is decreased to lower PCBs concentrations. Thus, a break even point exists around 400 ppm. Present worth costs for the Estuary were developed using the rental costs for >5000 and >500 ppm target levels and purchase costs for the remainder of the target levels.

Table 5-12 presents a summary of the results of the cost analysis for pumping to the in-harbor site.

Table 5-13 presents a summary of the results of the cost analysis for pumping to the generic upland disposal site.

Figure 5-31

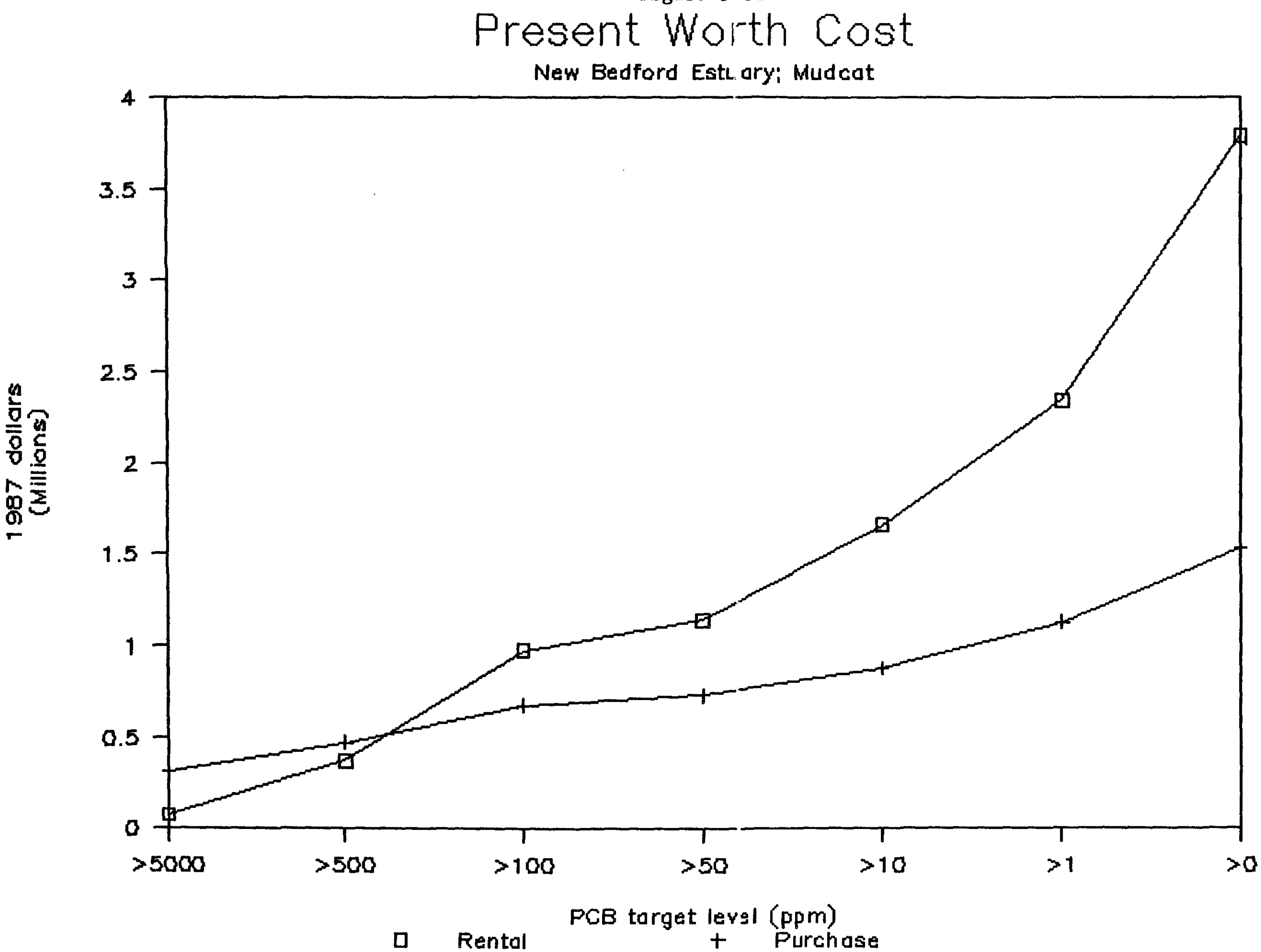

Present Worth Cost
New Bedford Estuary; Mudcat
1987 dollars
(Millions)
4
3.5
3
2.5
2
1.5
1
0.5
0
>5000
>500
>100
>50
>10
>1
>0
PCB target level (ppm)
Rental
Purchase

TABLE 5-12
MUDCAT PURCHASE COSTS - ESTUARY AREA
IN-HARBOR DISPOSAL - SITE I

	PCB Target Level (ppm)						
	>5000	>500	>100	>50	>10	>1	>0
* SEDIMENT TO BE REMOVED (YD^3)	(Hot Spot) 16,240	91,062	269,641	326,860	466,144	623,411	1,205,179
MONTHS OF OPERATION	2	8	21	25	36	47	89
PRESENT WORTH COST ($)	81,525	291,398	610,934	662,745	775,153	902,468	1,253,386
** UNIT COST ($/$YD^3$)	5.02	3.20	2.14	1.93	1.62	1.41	1.04

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

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0002.0.0

TABLE 5-13
MUDCAT PURCHASE COSTS - ESTUARY AREA
UPLAND DISPOSAL

	PCB Target Level (ppm)						
	>5000	>500	>100	>50	>10	>1	>0
* SEDIMENT TO BE REMOVED (YD^3)	16,246	107,302	285,881	343,106	482,384	639,651	1,221,419
MONTHS OF OPERATION	2	8	21	25	36	47	89
PRESENT WORTH COST ($)	75,188	368,165	676,128	727,939	877,375	1,125,447	1,539,361
** UNIT COST ($/YD)	4.63	3.43	2.37	2.12	1.82	1.76	1.26

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

5.87.76T
0003.0.0

Table 5-14 is a summary of the cost analysis results for pumping into 5,000-gallon tank trucks and driving to a disposal/treatment area located at either Conrail Railyard, New Bedford Municipal Landfill, or an upland site 45 miles from the harbor. As with the Hot Spot area, 5,000-gallon tank trucks were chosen because the DCA operating costs were generally less and fewer vehicles would be required.

Figure 5-32 shows the cost for each scenario versus target level. It is obvious from these cost curves that disposal to the in-harbor disposal site is the cheapest. This is because of the shorter pumping distance from the Estuary to the in-harbor area. Costs for pumping to the generic upland site are no longer the cheapest because the pumping distance now exceeds that of the in-harbor containment area. As with the Hot Spot area, the cost of pumping into tank trucks and transporting the dredged material to a disposal/treatment area is the highest cost. This scenario does not have an economic or public safety advantage over the other scenarios and would only be used as a last resort.

Cost sensitivity analyses were performed to determine which factors have the greatest impact on dredging costs. Cost sensitivity analyses were performed for the in-harbor scenario for the following factors; pumping rates, labor costs, and interest rates.

TABLE 5-14
MUDCAT PURCHASE COSTS - ESTUARY AREA
TANK TRUCK DISPOSAL

	PCB Target Level (ppm)						
	>5000	>500	>100	>50	>10	>1	>0
* SEDIMENT TO BE REMOVED (YD^3)	16,246	107,302	285,881	343,106	482,384	639,651	1,221,419
MONTHS OF OPERATION	2	8	21	25	36	47	89
PRESENT WORTH ($) QUARRY	200,149	841,940	1,918,920	2,190,294	2,842,679	3,484,815	5,421,188
PRESENT WORTH ($) LANDFILL	317,233	1,394,627	3,304,069	3,818,849	5,063,840	6,281,656	9,960,214
PRESENT WORTH ($) RAILYARD	244,056	1,049,198	2,438,351	2,801,002	3,675,614	4,533,630	7,123,323
** UNIT COST ($\$/YD^3$) QUARRY	12.32	7.85	6.71	6.38	5.89	5.45	4.44
** UNIT COST ($\$/YD^3$) LANDFILL	19.53	13.00	11.56	11.13	10.50	9.82	8.15
** UNIT COST ($\$/YD^3$) RAILYARD	15.02	9.78	8.53	8.16	7.62	7.09	5.83

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

FIGURE 5-32

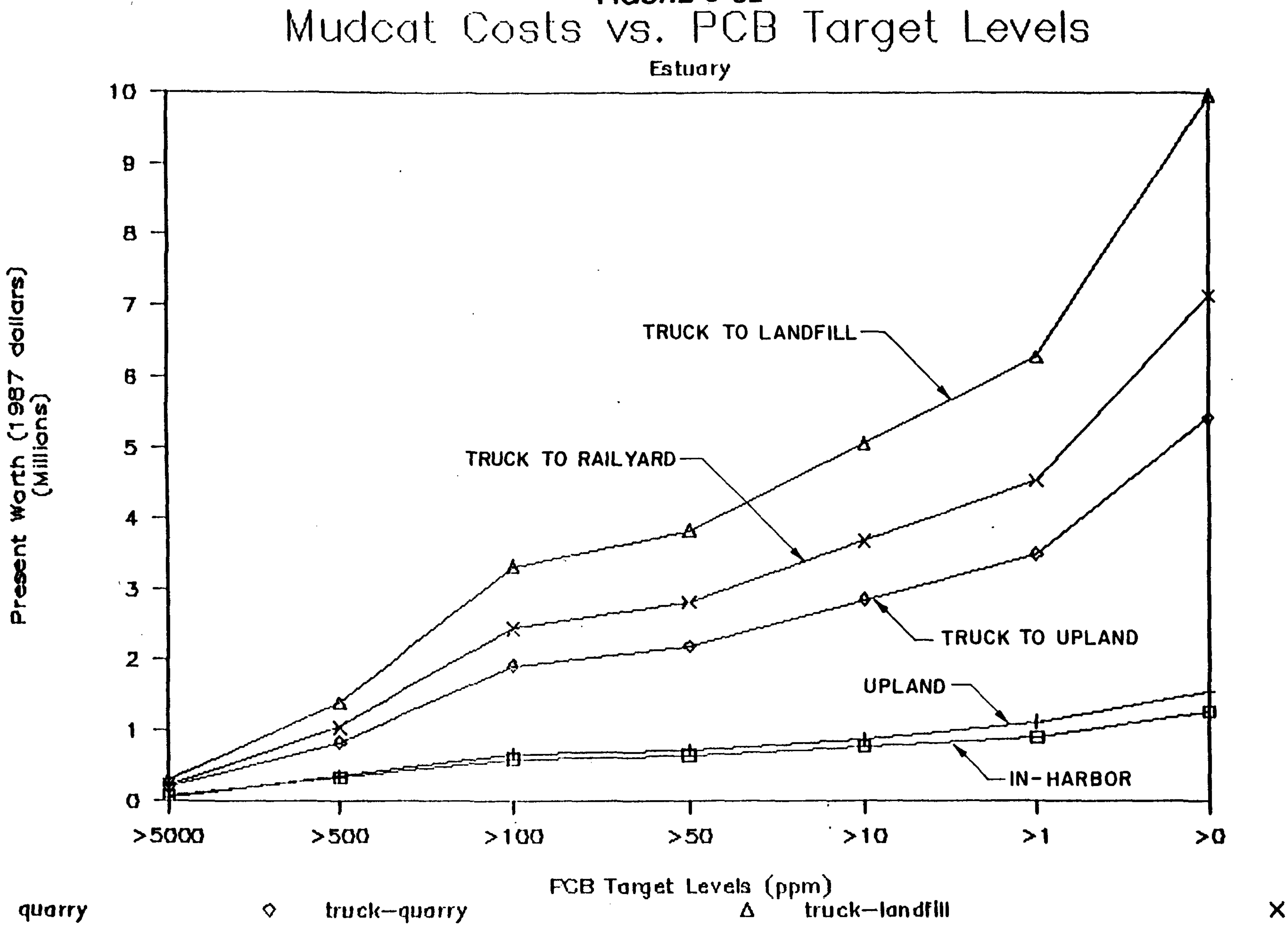
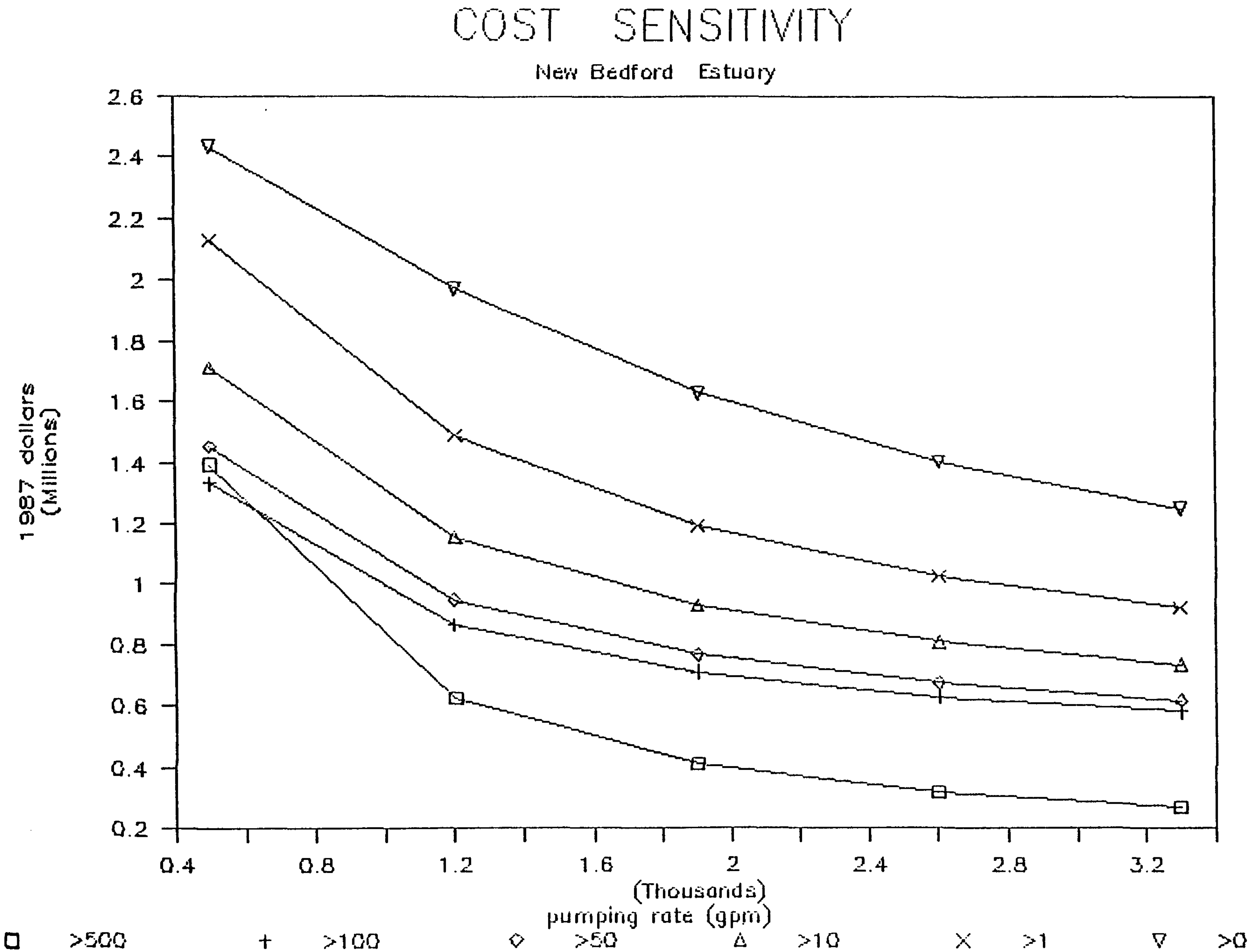

Mudcat Costs vs. PCB Target Levels
Estuary
Present Worth (1987 dollars) (Millions)
10
9
8
7
6
5
4
3
2
1
0
TRUCK TO LANDFILL
TRUCK TO RAILYARD
TRUCK TO UPLAND
UPLAND
IN-HARBOR
>5000
>500
>100
>50
>10
>1
>0
PCB Target Levels (ppm)
quarry
◇ truck-quarry
Δ truck-landfill
×

Figure 5-33 illustrates the effect of pumping rate on costs. Lower pumping rates have the greatest effect on the costs for dredging the >500 ppm sediment because under this scenario the MUDCAT is still rented. Thus, below 1200 gallons per minute the rental period increases. At the remainder of the target levels, the MUDCAT is purchased. At these levels, there is a decrease in cost associated with an increase in pumping rate. This is due to the lower operating times (and costs) at the increased pumping rate. Costs generally increase with a decrease in the PCBs target level due to the additional volume of sediment required to be dredged with each subsequent target level.

The effect of labor costs on project costs is highlighted in Figure 5-34. Once again, project costs generally increase with the lower target levels. This is due to the additional volume of sediment which has to be removed. Total project costs increase with an increase in labor costs. The rate of cost increase, however, varies with each target level. The higher rates of cost increase are also associated with the lower target levels. This is again due to additional volume which has to be dredged and subsequent increase in operating hours to obtain these target levels.

The effect of interest rates on project costs is shown in Figure 5-35. The present worth of dredging for each target level decreases with an increase in the interest rate. This is to be

Figure 5-33



COST SENSITIVITY
New Bedford Estuary
1987 dollars
(Millions)
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
(Thousands)
pumping rate (gpm)
>500
>100
>50
>10
>1
>0

Figure 5-34

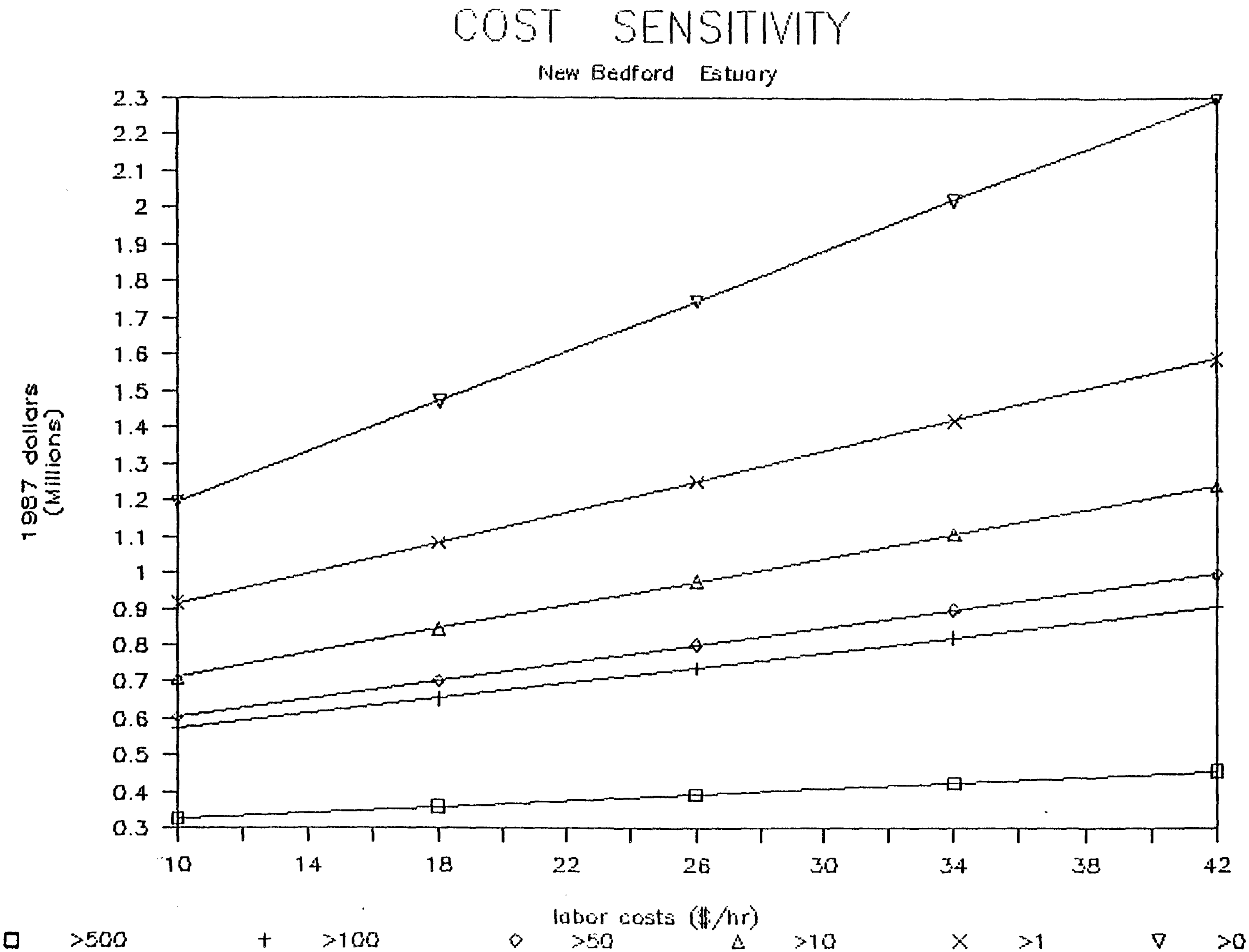
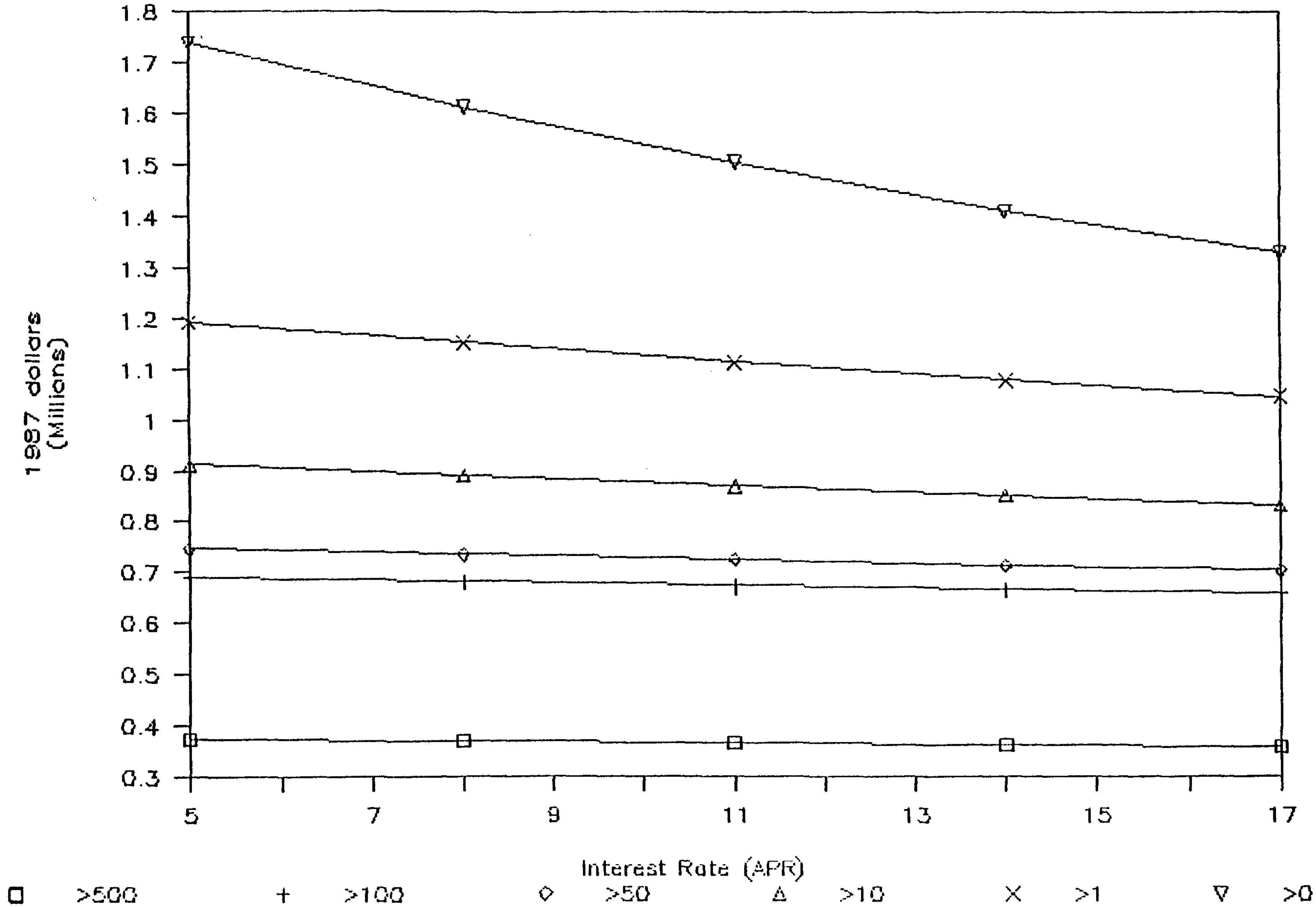

COST SENSITIVITY
New Bedford Estuary
1987 dollars (Millions)
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
10
14
18
22
26
30
34
38
42
labor costs ($/hr)
>500
>100
>50
>10
>1
>0

Figure 5-35

COST SENSITIVITY

New Bedford Estuary

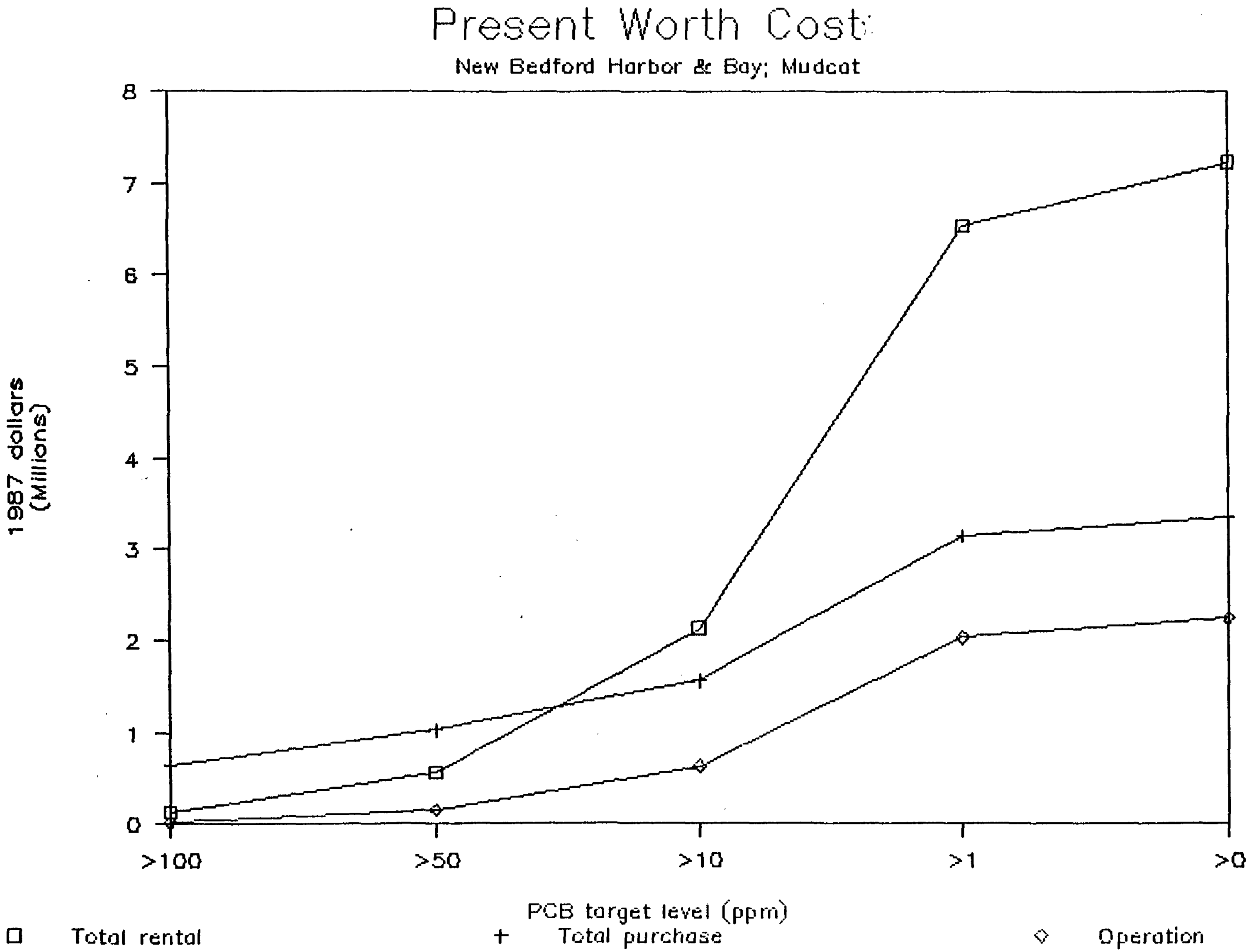


expected. The change in interest rate has little total effect on the project costs at target levels >10 ppm or higher. This is because the projects are of short duration (i.e., less than 3 years) and the time value of money does not change greatly over such short time periods. A change in the interest rate has the greatest effect on project costs when a clean-up goal of >0 ppm is chosen. In this case, a five percent change in the interest rate will effect project costs approximately $150,000 - $200,000. This is due to the time value of money because the project duration is now 7.5 years.

Lower Harbor and Bay. Dredging costs for the Lower Harbor/Bay were determined in the same way as for the Hot Spot and Estuary. The target levels for PCBs contaminated sediment were changed for the Lower Harbor/Bay to >100 ppm, >50 ppm, >10 ppm, >1 ppm, and >0 ppm. PCBs contamination in excess of 500 ppm was not found in the Lower Harbor/Bay.

A present worth analysis of rental versus purchase was again performed for the Lower Harbor/Bay. The results of this analysis, illustrated in Figure 5-36 are insignificant. In the Estuary area the break-even point for purchasing a MUDCAT was around 400 ppm, therefore, at >100 ppm the dredge has already been purchased. The significant part of this figure lies in the operating costs represented by the bottom line. These are the costs required to operate the purchased MUDCAT in the Lower Harbor and Bay for each

Figure 5-36


Present Worth Cost
New Bedford Harbor & Bay; Mudcat
8
7
6
5
4
3
2
1
0
1987 dollars (Millions)
>100
>50
>10
>1
>0
PCB target level (ppm)
Total rental
Total purchase
Operation

of the PCBs target levels. The remainder of the cost discussion will pertain to the operating costs.

Table 5-15 outlines the results of the costs analysis for the pumping to the upland disposal area.

The costs for dredging the Lower Harbor/Bay and pumping to the in-harbor containment area is included in Table 5-16.

Table 5-17 is a cost summary for pumping into 5,000 gallon tank trucks and driving to a disposal/treatment area at the New Bedford Municipal Landfill or an upland disposal site. The truck loading area is located at the Conrail Railyard and pumping to this site is equivalent to in-harbor site 7, summarized in Table 5-16.

Figure 5-37 illustrates the dredging costs for each scenario versus PCBs target level. This graph shows that pumping to either of the in-harbor sites is the cheapest and total pumping costs are almost identical for each in-harbor site. Pumping to an upland site is significantly more expensive for the Lower Harbor and Bay sediment than the Estuary sediment because the pumping distance has increased significantly. Once again pumping to tank trucks and driving the dredged slurry to either of the disposal/treatment scenarios is the highest cost; approaching an order of magnitude.

TABLE 5-15
MUDCAT OPERATING COSTS - LOWER HARBOR
AND BAY
UPLAND SITE DISPOSAL

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
* SEDIMENT TO BE REMOVED (YD^3)	2,700	31,500	123,100	1,043,400	1,179,600
MONTHS OF OPERATION	1	5	18	66	75
** PRESENT WORTH OPERATING COSTS ($)	160,569	292,075	776,315	3,150,984	3,382,546
** UNIT OPERATING COSTS ($/$YD^3$)	59.47	9.27	6.31	3.02	2.87

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

*** Includes purchase costs for pipe lengths and booster pumps

TABLE 5-16
MUDCAT OPERATING COSTS - LOWER HARBOR
AND BAY
IN-HARBOR DISPOSAL SITE NO. 7

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
* SEDIMENT TO BE REMOVED (YD^3)	2,700	31,500	123,100	1,043,400	1,179,600
MONTHS OF OPERATION	1	5	18	66	75
*** PRESENT WORTH OPERATING COSTS ($)	151,700	189,879	397,586	1,329,085	1,459,135
** UNIT OPERATING COSTS ($/YD)	56.19	6.03	3.23	1.27	1.24

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

*** Includes purchase costs for pipe lengths and booster pumps

TABLE 5-17
MUDCAT PRESENT WORTH OPERATING COSTS - LOWER HARBOR
AND BAY
TANK TRUCK DISPOSAL

	PCB Target Level (ppm)				
	>100	>50	>10	>1	>0
* SEDIMENT TO BE REMOVED (YD^3)	2,700	31,500	123,100	1,043,400	1,179,600
MONTHS OF OPERATION	1	5	18	66	75
*** PRESENT WORTH	263,901	777,790	2,412,806	7,407,633	8,120,130
*** PRESENT WORTH LANDFILL ($)	283,566	905,441	2,864,403	8,911,298	9,625,851
** UNIT COSTS	97.74	24.69	19.60	7.10	6.88
** UNIT COSTS ($/$yd^3$) LANDFILL	105.02	28.74	23.27	8.54	8.16
# OF TRUCKS LANDFILL	16	16	16	16	16
# OF TRUCKS QUARRY	13	13	13	13	13

* Times dredge efficiency factor yields actual volume to be removed.

** Unit cost of removing target level contaminated sediment in place.

*** Includes purchase costs for pipe lengths and booster pumps

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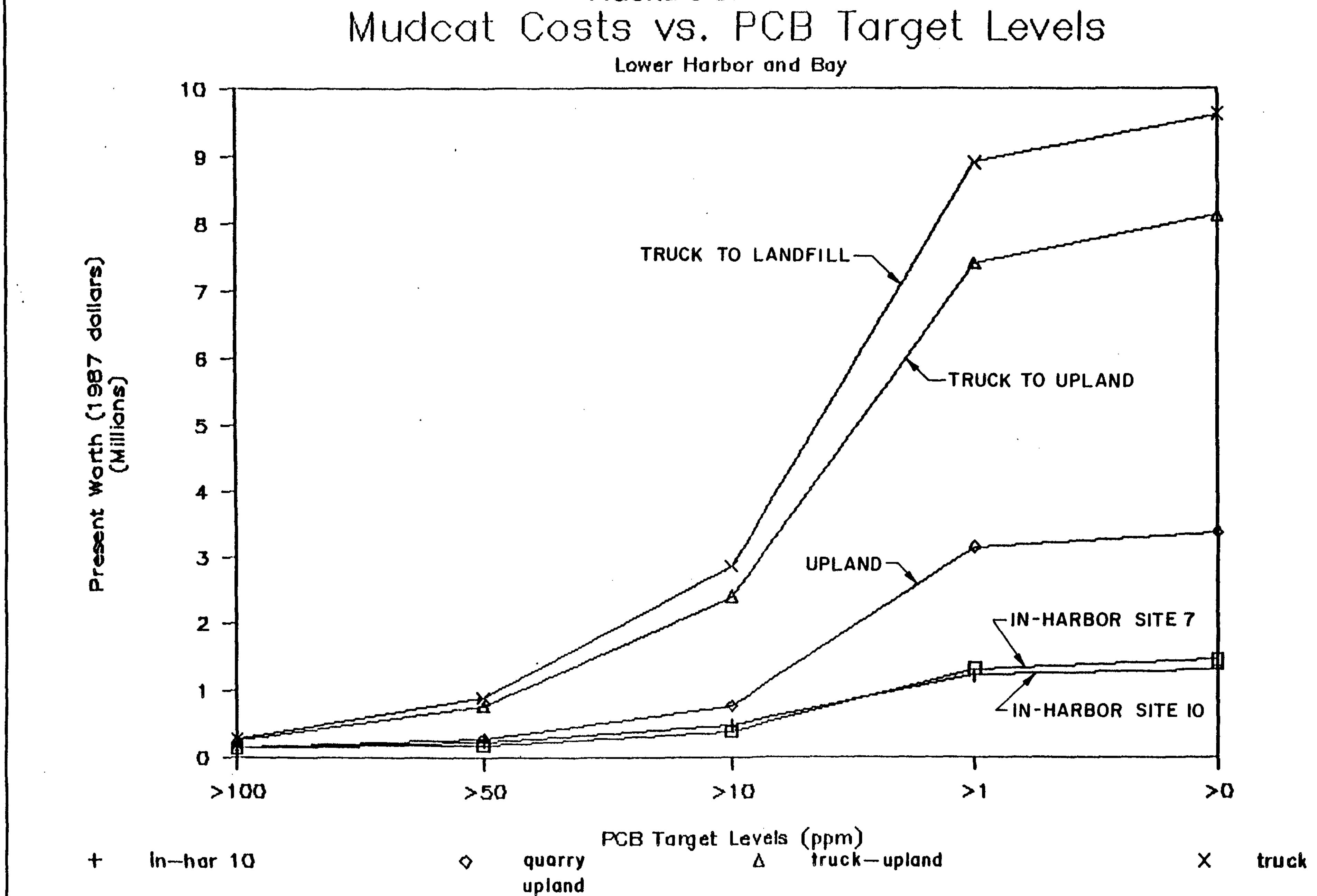
FIGURE 5-37


Mudcat Costs vs. PCB Target Levels
Lower Harbor and Bay
Present Worth (1987 dollars) (Millions)
0
1
2
3
4
5
6
7
8
9
10
>100
>50
>10
>1
>0
PCB Target Levels (ppm)
TRUCK TO LANDFILL
TRUCK TO UPLAND
UPLAND
IN-HARBOR SITE 7
IN-HARBOR SITE 10
+ In—har 10
◇ quarry upland
Δ truck—upland
X truck

Cost sensitivity analyses were performed to determine which factors have the greatest impact on dredging costs. The same factors, pumping rates, labor costs, and interest rates were used for analyses. Figures 5-38 through 5-40 present the results of these analyses. The results are similar to those obtained in the Estuary area and, therefore, detailed explanations will not be repeated. In all three figures, a lower PCB target level translates to higher sediment volumes to be dredged. Higher sediment volumes means an increase in operating time and operating costs. The location of the lines on these figures and the slopes are directly related to dredged volumes and/or operating time.

5.3.5 Summary

The detailed evaluation procedure indicates one sediment removal technology, the MUDCAT dredge, possesses the strongest qualifications of the special purpose dredges discussed. The MUDCAT exhibits a better combination of the following points over the widest range of site conditions:

- minimization of material resuspension;
- minimization of adverse environmental effects;
- maximization of production efficiencies; and

Figure 5-38

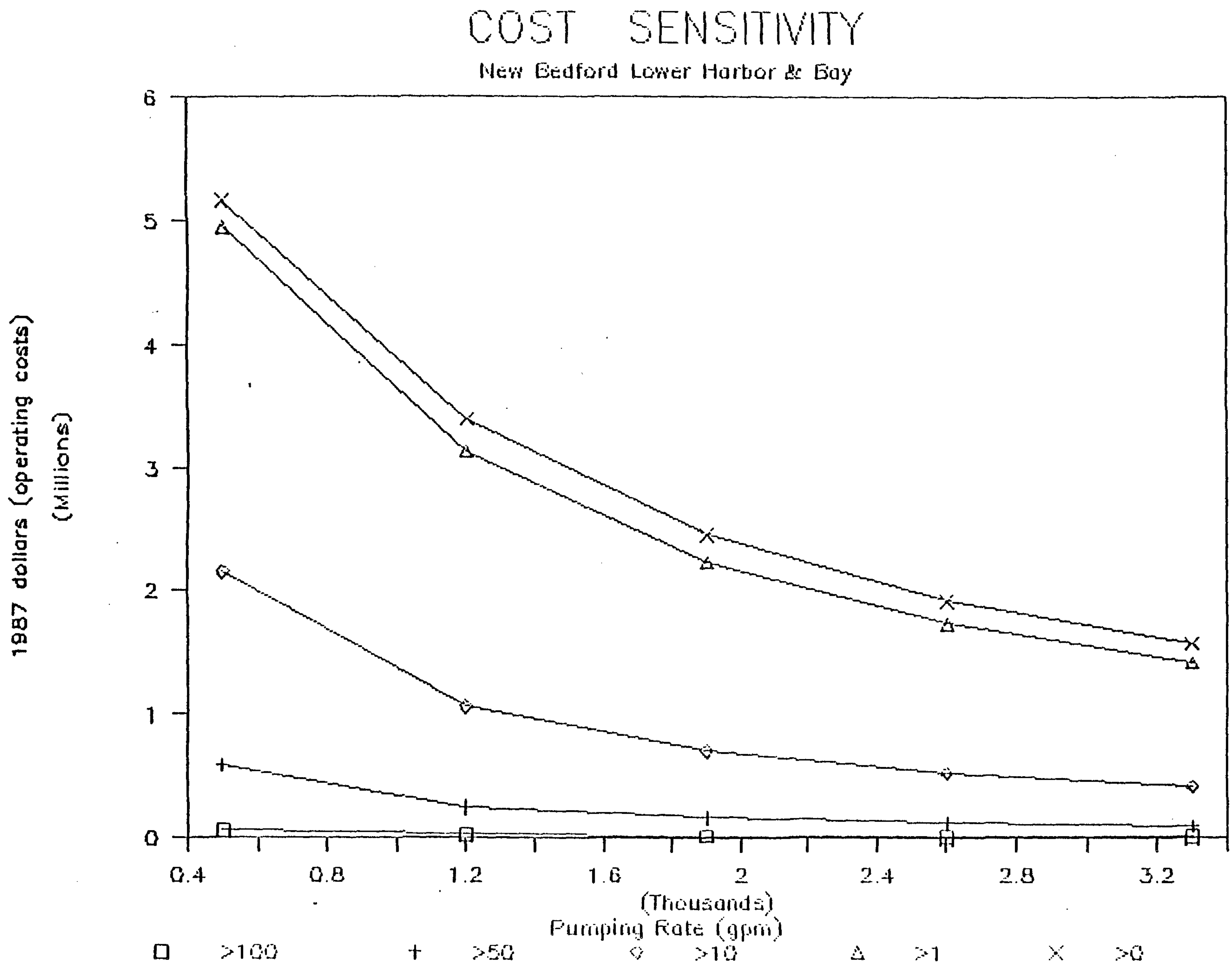

COST SENSITIVITY
New Bedford Lower Harbor & Bay
1987 dollars (operating costs)
(Millions)
6
5
4
3
2
1
0
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
(Thousands)
Pumping Rate (gpm)
>100
>50
>10
>1
>0

Figure 5-39

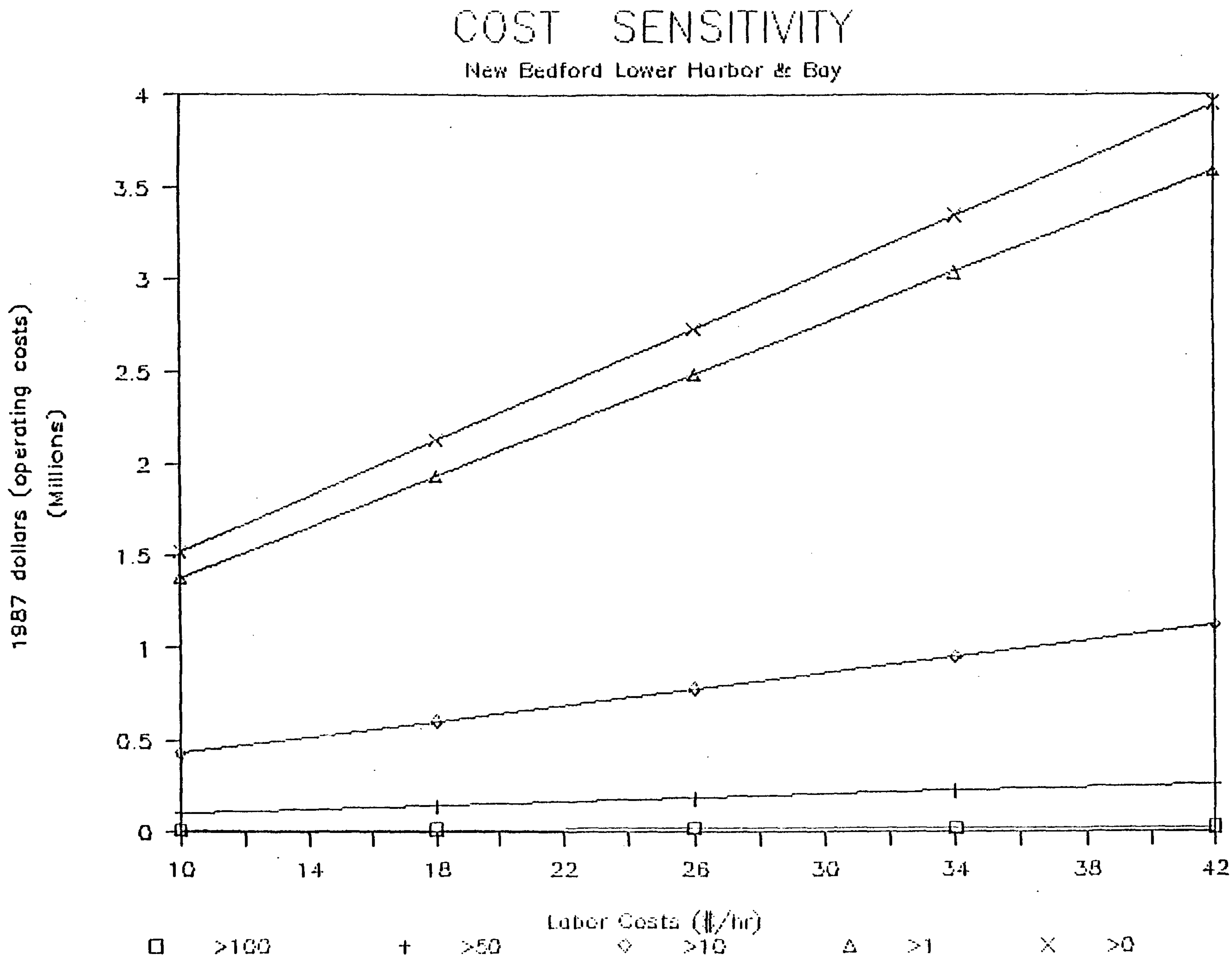
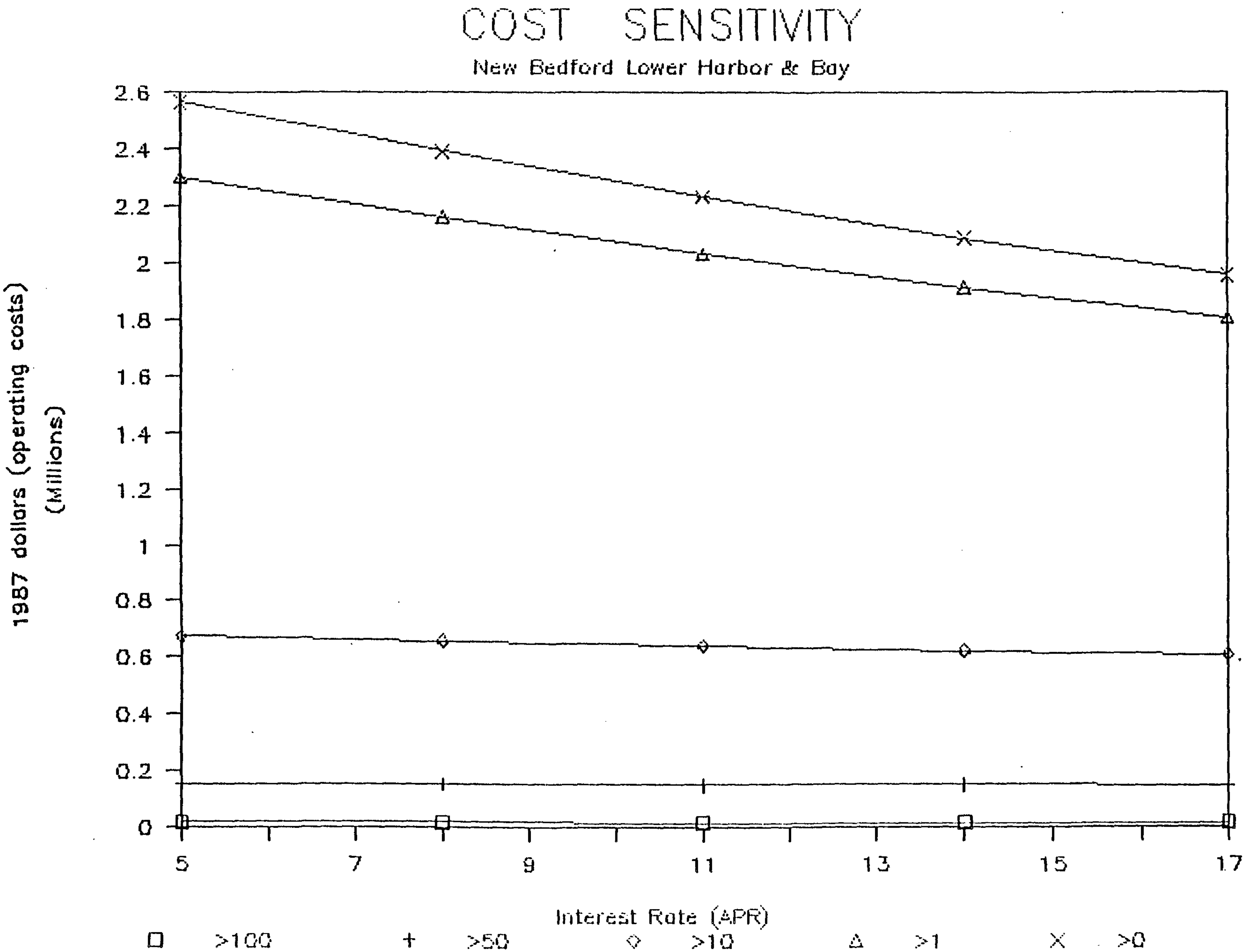

COST SENSITIVITY
New Bedford Lower Harbor & Bay
1987 dollars (operating costs)
(Millions)
4
3.5
3
2.5
2
1.5
1
0.5
0
10
14
18
22
26
30
34
38
42
Labor Costs ($/hr)
>100
>50
>10
>1
>0

Figure 5-40


COST SENSITIVITY
New Bedford Lower Harbor & Bay
1987 dollars (operating costs)
(Millions)
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
5
7
9
11
13
15
17
Interest Rate (APR)
□ >100
+ >50
◇ >10
△ >1
× >0

- precision, accuracy and control over the sediment removal process.

In the course of the detailed screening process, two additional technologies were identified as having some application potential at the New Bedford Harbor site: the Refresher dredge and the Pneuma Pump merit consideration as possible back-up systems to the removal technologies selected for site work.

The Refresher system has the ability to conduct effective operations on a majority of the area at the New Bedford Harbor Site. Operation of the Refresher may be considered comparable to that of the suction cutterhead dredge. The dredges and their operation are quite similar given the structural modifications and operational techniques described in Section 5.2.5 are applied to the suction cutterhead dredge. This point plus the limited availability of the Refresher dredge disqualifies it as a first choice for clean-up operations in New Bedford.

The Pneuma pump dredge has demonstrated its ability to dredge some of the New Bedford Harbor sediments in small localized areas. A majority of the situations in which use of the Pneuma may be applicable however may be covered just as well by either the MUDCAT or cutterhead dredge. The Pneuma may be of use in the overall clean up effort as a supplementary technology. This logic will be addressed during the development of remedial alternatives.

MUDCAT operations in all three New Bedford Harbor areas may provide a permanent remedy to the contaminated sediment problem, by reducing PCB volume. It is recommended that MUDCAT operations be conducted in all areas of the Hot Spot and Estuary and in areas of the Lower Harbor and Bay with approximately ten or less feet of overlying water (mean sea level).

5.4 EXCAVATION

5.4.1 Description

Dragline

The dragline was retained for detailed analysis for the removal of the Hot Spot sediment. Embankments would need to be constructed around and within the Hot Spot to allow access to the PCBs-contaminated sediment. The dragline, working on top of the embankment, would excavate the sediment and load trucks waiting on the embankment. The dragline, bucket, and truck fleet would be designed to provide optimum excavation and haul efficiencies.

Embankment construction would precede the sediment excavation to allow the dragline an adequate working surface. Upon the completion of sediment excavation, the embankment would be removed by the dragline. The embankment would need to be sampled prior to its removal to insure that any part of the embankment which has been contaminated with PCBs sediment is excavated and treated accordingly. It is anticipated that the outer two feet of the embankment would be contaminated during the sediment removal operation.

The dragline is a conventional excavation technology and has been used for years in the excavation of sediments and other materials. Draglines are readily available in a variety of sizes with varying boom lengths and bucket sizes. For the Hot Spot area, crawler mounted draglines were chosen with working radii of 68 and 96 feet. The corresponding bucket sizes were 3.5 and 2.25 cubic yards.

Clamshell

The clamshell was retained for detailed analysis for the removal of the Hot Spot sediment and removal of contaminated sediments adjacent to shoreline areas. As with the dragline, embankments would need to be constructed around and within the Hot Spot to allow access to the PCBs-contaminated sediment. It is also expected that site access work would be required in the Estuary and Lower Harbor/Bay for any area where the clamshell were to work from the shore. Like the dragline, the clamshell would work upon the embankment or shore, and load waiting trucks. The clamshell, bucket, and truck fleet would be designed to optimize excavation activities and haul cycles.

Clamshells are conventional excavation equipment and readily available throughout the United States. Clamshells are available in different sizes, boom lengths, and bucket sizes. For the New Bedford Harbor Project clamshells can be either truck or crawler mounted. Clamshells with working radius of 60 and 80 feet were evaluated with corresponding bucket sizes of 1.75 and 1.25 cubic yards.

Clamshells have an advantage over draglines in that they create less resuspended sediment and therefore, are more suited for work in areas where sediment resuspension is harder to contain or more likely to be a problem (e.g. Estuary area). The clamshell has a disadvantage over the dragline in that the working radius is reduced because the bucket can not be thrown any additional distance. in order to excavate the same volume of sediment, additional embankments would need to be constructed.

Watertight Clamshell

The watertight clamshell is a conventional clamshell fitted with a special watertight bucket. The conventional clamshell bucket has teeth and is not watertight. Upon removal of the bucket from the water column, the conventional bucket will drain of most of the free water causing additional sediment resuspension. The conventional clamshell bucket creates sediment resuspension when it impacts the sediment, pulls from the sediment and water, and drains above the water. The watertight clamshell bucket is designed to enclose the excavated sediment such that sediment resuspension caused by pulling the bucket through the water column and draining above the water is minimized. The watertight clamshell bucket has a disadvantage over a conventional bucket in that the watertight seals are subject to damage. It is difficult to dredge areas with debris or boulders because these can damage the rubber and prevent a good seal, thus negating the bucket's effectiveness.

The watertight clamshell bucket produces the least sediment resuspension of the three excavation technologies and is best used in an area where sediment resuspension must be kept to a minimum (e.g., Estuary). Its use in the Hot Spot area is not warranted because sediment resuspension would be contained by the embankments surrounding the Hot Spot area.

5.4.2 Effectiveness

Reliability

Dragline

Draglines are very reliable at removing sediment. The removal of the Hot Spot sediment will not slow dragline performance because all sediment resuspension will be contained within the embankment.

Sediment sampling will be performed following excavation to insure that all the PCB-contaminated sediment has been removed. Any area still containing PCBs above the clean-up level will be further excavated to insure complete removal of the contaminated sediment.

The removal of the Hot Spot sediment with the dragline will provide permanent reduction of the PCBs contaminated sediment with an infinite effectiveness life provided further PCBs contamination does not take place.

Clamshell

The reliability of the clamshell in the Hot Spot area is identical to that of the dragline. The reliability of the clamshell to remove the PCB-contaminated sediment in the Estuary and Lower Harbor/Bay is limited. This is primarily due to the limited reach of the clamshell. A clamshell with a 70 foot working radius would be an appropriate sized machine for shoreline excavation in the New Bedford area. Only a small portion of contaminated sediment in the Estuary and Lower Harbor/Bay exists within this 70' radius. This band is then further reduced by site access constraints, whether physical or legal, throughout most of these two areas.

The reliability of the clamshell is further reduced by the potential for the release of PCBs from the sediment to the water column. During the excavation of the contaminated sediment adjacent to the shoreline, the clamshell would not remove all the PCBs contaminated sediment because sediment resuspension, tidal action, and flow currents could carry the sediment out of reach of the clamshell. Environmental controls would most likely be required of any clamshell dredging outside of an embankment. The use of silt curtains with oil booms would be appropriate to minimize sediment migration. These curtains, however, would need to be kept as close to the work area as possible without interfering with the removal operation. Even with these controls, the probability of contamination migration to adjacent areas is great. The clamshell would not be able to retrieve this contamination and therefore, has questionable reliability. For these reasons, further discussion of the clamshell will pertain to its use only in the Hot Spot area where sediment resuspension is contained by embankments.

As discussed in Section 2.5.1, the watertight clamshell would not be used in the Hot Spot area because there is little need to control sediment resuspension after this area is contained. The watertight clamshell suffers from the same limited working radius as the regular clamshell. The watertight clamshell is more reliable than the regular clamshell bucket in the removal of contaminated sediment only because there is less sediment resuspension and subsequent migration of contaminants from the clamshell's reach. Environmental controls may still be required and would be determined based upon operational monitoring. The watertight clamshell would be ineffective in removing the majority of the contaminated sediment from the Estuary and Lower Harbor/Bay. It may be ideal, however, for small shoreline areas that pose operational constraints for dredging. Therefore, for these reasons, further discussion of watertight clamshell's will pertain only to small areas (i.e., less than 10,000 ft^2) in the Estuary and Lower Harbor/Bay.

Public Health

Dragline, Clamshell

Since the dragline or clamshell permanently removes the contaminated sediment, there are minimal long term public health effects with this alternative. The public may be exposed to short term risks by the increase in truck traffic associated with the construction of the embankment, removal of the contaminated sediment, and removal of the embankment. Trucks carrying the contaminated sediment will be decontaminated prior to entering the public highways. The possibility does exist that one of these trucks will have an accident and spill some of the contaminated sediment in public areas.

The volatilization of PCBs from the Estuary sediment and during remedial action at other PCBs-contaminated sites has been documented. The mechanical excavation of this material, swinging of the bucket, and drop loading of the sediments into trucks will increase the rate of volatilization. It is difficult to determine the extent of the increase, but it is expected to be substantial. Operational controls such as water or foam sprays at the loading area would reduce the PCBs volatilization contribution by loading, however, the contribution by excavation and bucket swing would not be effected. To reduce the volatilization of PCBs by exposed sediment and the excavation of this sediment, the Hot Spot area should be maintained below water level. Regardless, it is expected that there will be a short-term public health effect associated with PCB volatilization from the removal activities. Air monitoring during excavation, coupled with the operational controls discussed earlier, will be needed to recognize and minimize volatilization during sediment removal.

Watertight Clamshell

The watertight clamshell is not expected to be used by itself but, rather in conjunction with another removal technology (i.e., dredge). It is assumed therefore, that significant long term public health effects will not occur as all PCBs contaminated sediment will be removed to below the target level.

The potential for short term public health effects exist with the watertight clamshell. The risks are again associated with increased truck traffic and PCBs-volatilization. These risks, however, are significantly less than those outlined for work in the Hot Spot because:

- the volumes are minimal (maximum 1,500 cubic yards);
- work duration in any one area is short;
- most excavation will occur under the water; and
- the concentration of the PCBs in the sediment are less than the Hot Spot.

Environment

Dragline, Clamshell

The dragline and clamshell would each provide a benefit to the environment by the removal of the most contaminated sediment. The isolation of this material by embankments and subsequent removal would eliminate it as a source of PCBs to the remainder of the ecosystem.

The excavation of the Hot Spot by either the dragline or the clamshell has little adverse effect upon the environment. The construction of the embankment to support the dragline/clamshell operation however, has a significant impact on the aquatic environment. Although the actual length and volume of the embankment is dependent upon the working radius of the dragline/clamshell, it is expected that as a minimum 4,375 feet of embankment will need to be constructed at a total of 97,200 cubic yards. The embankment would first be constructed to isolate the Hot Spot area. Next, inner embankments would need to be constructed to provide adequate access to all the sediment. The outer embankment would be constructed outside of the Hot Spot in the sediment which contains PCBs in excess of 500 ppm.

Although the embankment construction will not take place in the Hot Spot, it is being constructed within the next highest contaminated area. Sediment redistribution and subsequent PCBs migration is expected to be significant. Environment controls will be mandatory and the installation of a more permanent barrier (e.g., cofferdams) is anticipated. The probability of dam failure and/or environmental control failure is significant and the predominant factor will be local weather events. Even if the environmental controls are successful in stopping the secondary pollution from reaching other areas of the Estuary and harbor, the increased contamination will still need to be retrieved from within the control area prior to the removal of control structures. A special purpose dredge such as the MUDCAT would need to be secured to remove this material.

In addition, an assessment will need to be performed to determine what effect the construction and subsequent removal of this embankment has on the Estuary environment, adjacent wetlands, and Estuary hydraulics. Although the operation of the dragline/clamshell has little adverse environmental effect, the construction of the embankment needed for their equipment appears to have significant adverse environmental consequence.

Watertight Clamshell

Use of the watertight clamshell will have a beneficial environmental effect in that it will remove the PCB-contaminated sediment from small localized areas.

Use of the watertight clamshell will have a short-term adverse effect on the environment by creating sediment resuspension and subsequent PCBs-migration. It is expected that the water quality in these areas will decrease due to the increased sediment and additional PCBs available for biological uptake. The watertight clamshell, if used, should only be used in small, shoreline areas where its total adverse affect on the environment is expected to be minimum.

5.4.3 Implementation

Technical Feasibility

Dragline/Clamshell

The technical feasibility of using the dragline/clamshell to remove the Hot Spot sediment is excellent. Draglines/clamshells are very effective at sediment removal and as the material is contained within an embankment there is little concern over sediment resuspension. The construction of the embankment although technically feasible will be more timely and require extensive construction monitoring procedures.

Watertight Clamshell

The technical feasibility of using the watertight clamshell in localized areas of the Estuary and Lower Harbor/Bay is good. The areas that are to be excavated by the watertight clamshell will need to checked prior to excavation to insure that they are free of rocks, debris or other material that would render the watertight bucket ineffective.

Level of Development

Dragline/Clamshell

Both the dragline and clamshell are conventional excavation equipment for sediment removal. They are widely used throughout the world and there is little need for bench or pilot testing. As with the other dredges, downtime is estimated to be 20 percent.

Watertight Clamshell

The watertight clamshell was developed in Japan for the removal of contaminated sediment. It has been tested in the United States by the USACE and determined to be effective in removing contaminated sediment with less resuspension than a conventional clamshell bucket. Bench or pilot scale testing is not anticipated. Downtime is estimated to be 20 percent.

Support Requirements

Dragline/Clamshell

The use of the dragline/clamshell to remove the Hot Spot sediment requires extensive support activities. An embankment network needs to be constructed to allow the equipment access to the sediment. A truck fleet will also be required to haul away the contaminated sediment and embankment fill material. Miscellaneous support equipment (dozers, graders, water trucks) will more than likely be required to maintain the working area. In addition, a decontamination station will be required to decontaminate all equipment prior to leaving the work area.

Watertight Clamshell

The use of the watertight clamshell to excavate small areas in the Estuary and Lower Harbor/Bay will require similar support equipment as outlined for the dragline/clamshell but, on a much smaller scale. It is anticipated that some fill and/or grading will be required for each work area. A small fleet of support equipment (trucks, graders, loaders) will be required to accompany the clamshell as well as a decontamination unit.

Availability

Dragline/Clamshell

The availability of draglines/clamshells and the required support equipment is excellent in the eastern United States. Little difficulty is anticipated in securing the required equipment.

The availability of the land required to establish the embankment and set up the decontamination station is not known at this time.

This will need to be researched prior to selecting this technology as a removal alternative.

Watertight Clamshell

The current availability of watertight clamshell buckets is poor in the United States as they have only been used on a experimental basis. A conventional bucket can be modified, however, to a watertight bucket. The availability of conventional clamshell buckets is excellent and the fabrication of a watertight bucket is not anticipated to be difficult. Site access availability for the areas to be excavated by the watertight clamshell has not been determined because the specific areas have yet to be identified. These areas will be identified during the formulation of remedial alternatives. Site access availability will be determined at that time.

Installation

Dragline/Clamshell

The installation of the embankment is an integral part of the implementation of these technologies. The embankment needs to be constructed out into the Estuary on poor foundation material. In order to ensure embankment stability, a geofabric will need to be installed below the embankment. Installation of the geofabric is expected to be difficult as workers will need to ensure proper placement under water while at the same time minimizing contact with sediments containing PCBs concentrations in excess of 500 ppm.

Embankment placement can begin following the installation of the geofabric. The embankment will contain a estimated minimum of 92,200 cubic yards of fill material. This material will need to be placed, compacted and graded. Rip rap will be placed on the Estuary side of the embankment to protect the embankment from water action.

Embankment stability will have to be insured before the equipment can be allowed to work on the embankment. Settling of the embankment is expected to occur continuously throughout the embankment life, but it is expected to be greatest during the first year. Continuous filling, grading, and compacting of low areas may be required during the first year.

The construction of the embankment is estimated to take a minimum of one year to complete. Unsuitable weather conditions, unanticipated site conditions, and unfavorable sediment resuspension can have a major impact on the cost, duration and success of this project.

The installation of the embankment and the subsequent use of a dragline/clamshell does not appear to be wise based upon the expected difficulties associated with the embankment construction and subsequent removal. It is anticipated that approximately 45 percent of the embankment will be contaminated and require PCBs treatment or disposal. This has the potential for increasing the amount of contaminated material three fold. Based on the above points, the use of a dragline/clamshell to remove the contaminated sediment is questionable.

Watertight Clamshell

The installation of a watertight clamshell in selected areas of the Estuary and Lower Harbor/Bay is not expected to be a problem. The clamshell will only be used in areas where site access is available or can be constructed. Unsuitable weather conditions will have little effect upon the clamshell operation as the machine will be shore mounted and not subject to washout or embankment failure.

Time

Dragline/Clamshell

The time required to construct the embankment is estimated to be a minimum of one year. Construction time could increase up to three years, however, based upon working conditions encountered during construction. Once the embankment is constructed, the removal of the contaminated sediment is expected to take less than two months. Embankment removal would follow sediment removal and will take an additional two to four months depending upon the machine used.

Watertight Clamshell

The time required to implement the watertight clamshell is dependent upon the location and size of the area to be dredged. As all of these areas are expected to be small, a total time of one month per area is anticipated.

Safety

Dragline/Clamshell

There are two potential short-term safety threats associated with this operation. The first is the potential for accidents with the increased truck traffic associated with the construction and removal of the embankment, and removal of the contaminated sediment. The second is the potential for an increase in PCBs volatilization from the removal activities. Both of these safety concerns are short-term and exist only for the duration of the project. There are no long-term safety concerns associated with this operation.

Short-and long-term safety threats for workers will be monitored closely and safety equipment will be adjusted as needed. To minimize these threats mandatory adherence to the HASP will be required.

Watertight Clamshell

The short- and long-term safety threats to the community and workers are the same as those listed under the dragline/clamshell except smaller. As the watertight clamshell will only be used in small localized areas, continued truck traffic and PCB volatilization will not occur in the same area. Worker safety will be protected by strict adherence to the health and safety plan.

Monitoring and Maintenance Requirements

Dragline/Clamshell

Environmental monitoring will be required prior to embankment construction to monitor the effect of the embankment construction on the Estuary. This monitoring will also assess the success of the environmental controls and provide data to determine if additional environmental controls are needed.

Embankment monitoring and maintenance will be completed on a daily basis to ensure that the embankment is safe and repaired if needed. Embankment monitoring will consist of a daily visual inspection to identify any large areas of movement and a weekly surveying of embankment monuments to determine any long time movement trends.

Machine maintenance will be completed as required. Downtime of the equipment is expected to average 20 percent.

Watertight Clamshell

Environmental monitoring will be required in all areas excavated by the watertight clamshell. This monitoring will document the extent of sediment resuspension and the success of the environmental controls. Operational adjustments to reduce the amount of sediment resuspension, will be made based on the results of this monitoring.

Machine maintenance is expected to be on an as-needed basis with downtime estimated at 20 percent.

Permitting

Dragline/Clamshell/Watertight Clamshell

No permits are anticipated to be required for the construction of the embankment and removal of the contaminated sediment as all work is being conducted within the site boundaries. The permitting requirements of several ARARS, however, will need to be followed (e.g., USACE dredge and fill permit).

Legal Constraints

Dragline/Clamshell/Watertight Clamshell

Site access for each of the excavation technologies is of critical importance. Specific location for site access will be determined during the formulation of remedial alternatives. At this point land ownership and the potential for legal constraints will be determined.

A substantial increase in truck traffic will occur with each one of these excavation technologies (dragline/clamshell). Many of these trucks will be transporting the contaminated sediment along public streets in New Bedford and neighboring towns. It is probable that local community groups could be formed to block the transportation of this sediment along public roads. These groups, concerned about the health and safety of their families, could impose legal constraints upon the project which can not be quantified at this time.

Impacts on Historical and Cultural Resources

Dragline/Clamshell/Watertight Clamshell

Currently there are no known archaeological, historical, or cultural resources located within the New Bedford Harbor site. If any of these resources are uncovered during excavation, all operations will cease until the appropriate state and federal authorities have checked the area and cleared it for further excavation.

5.4.4 Costs

Costs were determined for the removal of the Hot Spot sediment using both the dragline and clamshell. For each piece of equipment three different scenarios were evaluated. The different scenarios are disposal/treatment at the Conrail railyard, New Bedford Municipal Landfill, and the granite quarry located due east of the Hot Spot area. For both the dragline and clamshell, two different truck fleets (8 cubic yards and 20 cubic yard trucks) were evaluated.

The last variable evaluated was the bucket size. Two different bucket sizes were evaluated for each piece of equipment. The bucket size effects costs in two ways. The first is operating time. The smaller the bucket the longer it takes to load the trucks. This results in longer operating hours but fewer trucks. The second is the amount of embankment needed. Smaller buckets are associated with larger boom lengths. The longer the boom on the dragline or clamshell the greater the reach of the equipment and therefore, less linear feet of embankment are required.

Costs were not determined for the watertight clamshell because the exact areas and volumes are not known at this time. Detailed costs will be determined following the development of remedial alternatives. The costs for the watertight clamshell are expected to be low, however, as the areas to be dredged are small and limited site preparation is anticipated.

Dragline

The excavation costs for the removal of the Hot Spot sediment using the dragline are illustrated in Table 5-18. This table presents the total cost associated with this technology and includes the cost to construct the embankment, excavate the sediment, and remove the embankment. The costs are only shown for the 20 cubic yards trucks because this option is the cheapest and uses the least amount of trucks.

An analysis was not performed on rental versus purchase because the project duration is too short to warrant the purchase of a dragline and/or trucks. In all cases it was assumed that the dragline would use the larger bucket to excavate the embankment and the contaminated fill material would be hauled to the appropriate treatment site. The clean fill would be hauled to no appropriate fill location.

It is apparent from Table 5-18 that using the smallest dragline bucket (2.25 cubic yards) with treatment at the upland disposal area is the lowest cost scenario at $2,315,054. The smaller bucket gave the lowest costs under each scenario because less trucks and embankment were required. It is also apparent from this table that the costs associated with the actual sediment removal are a fraction of the total cost, in all cases less than seven percent. This is because an extensive embankment network

TABLE 5-18
DRAGLINE EXCAVATION COSTS - HOT SPOT AREA

Bucket Size (yd^3)	3.5	3.5	3.5	2.25	2.25	2.25
Treatment Site	Landfill	Railyard	Upland Area	Landfill	Railyard	Upland Area
Truck Size (yd^3)	20	20	20	20	20	20
Number of Trucks Needed	16	10	7	10	7	5
Months of Excavation	3	3	3	3	3	3
Dragline Working Radius (ft)	60	60	60	70	70	70
Embankment Volume (yd^3)	120,000	120,000	120,000	97,200	97,200	97,200
Sediment Volume (yd^3)	16,246	16,246	16,246	16,246	16,246	16,246
Embankment Costs ($)	$2,000,000	2,000,000	2,000,000	1,620,000	1,620,000	1,620,000
Sediment Removal Costs ($)	$178,984	136,473	115,217	147,861	123,763	107,697
Embankment Removal Costs ($)	$636,904	636,904	636,904	587,357	587,357	587,357
TOTAL COST	$2,815,888	2,773,377	2,752,121	2,355,218	2,331,120	2,315,054
% Sediment Removal Cost	6.36%	4.92%	4.19%	6.28%	5.31%	4.65%
Unit Cost of Contaminated Sediment ($/yd^3)	173.33	170.71	169.40	144.97	143.49	142.50

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must be constructed (and removed) in order to reach all the contaminated sediment.

Costs were not included for the environmental control features as total costs for these technologies are an order of magnitude above those for the MUDCAT. The cost associated with the design and installation of silt contains and oil booms is expected to approach $700,000.

Clamshell

The costs of excavating the Hot Spot sediment with a clamshell are shown in Table 5-19. The assumption stated for the dragline in Section 2.5.4.1 are identical to those used for the clamshell.

It is apparent from Table 5-19 that the actual cost for removing the sediment is a fraction of the total cost. Clamshell costs exceed those of the dragline because of the smaller bucket sizes and working radius. As stated for the dragline, excavation costs associated with the clamshell are an order of magnitude greater than those of the MUDCAT.

Sensitivity Analyses

Three sensitivity analyses were performed on the dragline and clamshell operation to determine what effect an increase in haul

TABLE 5-19
CLAMSHELL EXCAVATION COSTS - HOT SPOT AREA

Bucket Size (yd^3)	1.75	1.75	1.75	1.25	1.25	1.25
Treatment Site	Landfill	Railyard	Upland Site	Landfill	Railyard	Upland Site
Truck Size (yd^3)	20	20	20	20	20	20
Number of Trucks Needed	7	5	4	5	4	3
Months of Excavation	5	5	5	6	6	6
Dragline Working Radius (ft)	60	60	60	70	70	70
Embankment Volume (yd^3)	121,100	121,100	121,100	120,000	120,000	120,000
Sediment Volume (yd^3)	16,246	16,246	16,246	16,246	16,246	16,246
Embankment Costs ($)	$2,020,000	2,020,000	2,020,000	2,000,000	2,000,000	2,000,000
Sediment Removal Costs ($)	$141,190	121,385	111,482	179,007	162,615	146,223
Embankment Removal Costs ($)	$667,789	667,789	667,789	665,165	665,165	665,165
TOTAL COST ($)	$2,828,979	2,809,174	2,799,271	2,844,172	2,827,780	2,811,388
% Sediment Removal Cost	4.99%	4.32%	3.98%	6.29%	5.75%	5.20%
Unit Cost of Contaminated Sediment ($/$yd^3$)	174.13	172.91	172.31	175.07	174.06	173.05

distances, truck rental costs, and labor costs had on the excavation costs. These sensitivity analyses were performed on the least cost scenario of excavating the material and hauling it to the upland site. Even though the actual sediment excavation costs are a small percentage of the total costs, Figures 5-41 through 5-43 illustrates the project sensitivity to these factors. In each case the dragline costs are less than those for the clamshell. Change in haul distance has the greatest effect on project costs as illustrated in Figure 5-41. This is because additional trucks need to be added to optimize the productivity of the excavating machine. The costs to rent and operate the additional trucks drive the total costs up. A change in labor rate as shown in Figure 5-43 has the least effect on project costs.

5.4.5 Summary

Based upon the results of the detailed screening, the dragline and clamshell will be eliminated from future consideration as removal technologies. Although these technologies permanently remove the volume of contaminated Hot Spot material, they do not reduce the toxicity, volume, or mobility of the remaining PCB-contaminated sediment. In fact, PCB sediment mobility may be increased by the embankment construction activities. In addition to the potential for long term adverse environmental effects caused by the embankment construction, the potential for construction

Figure 5-41

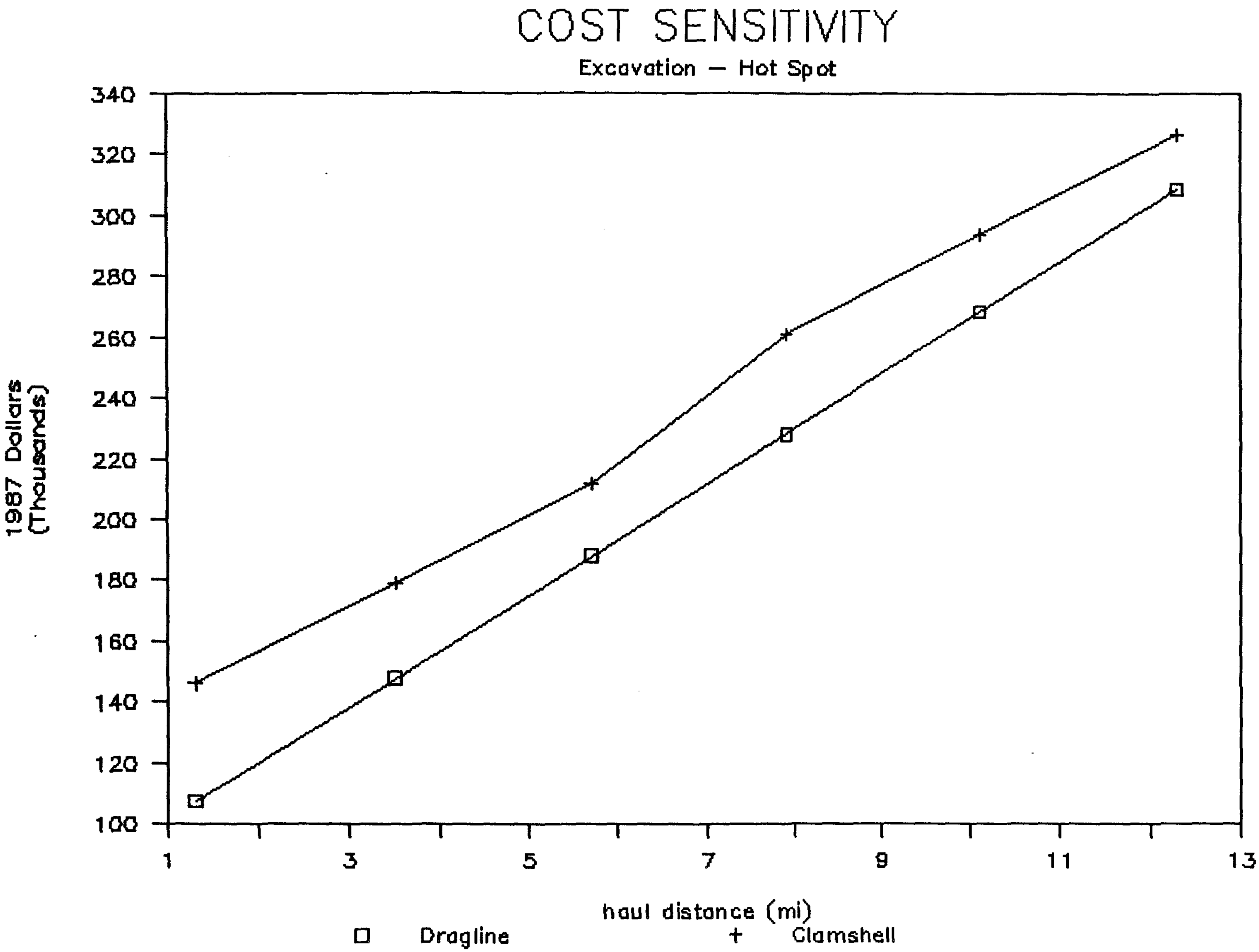
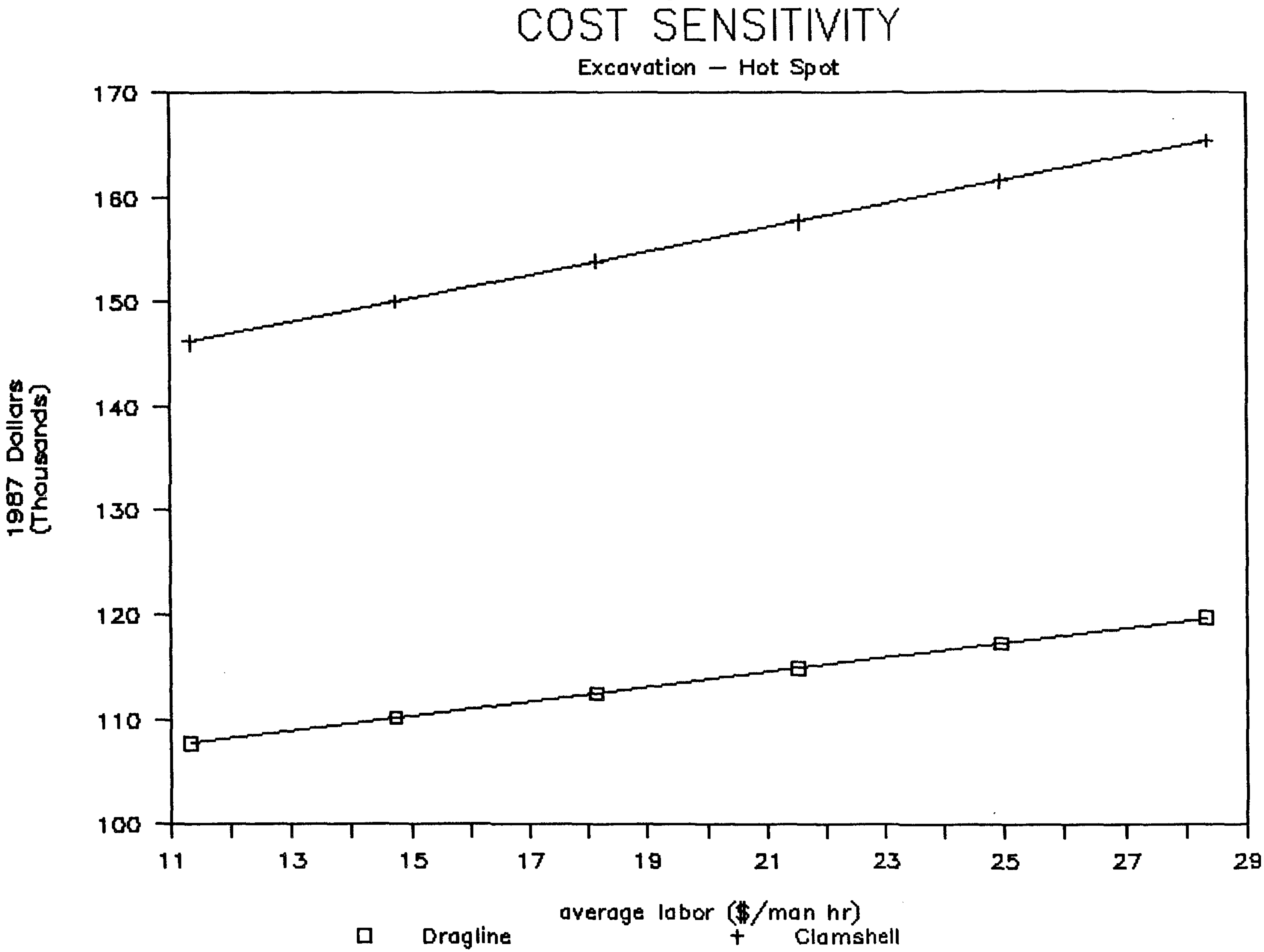
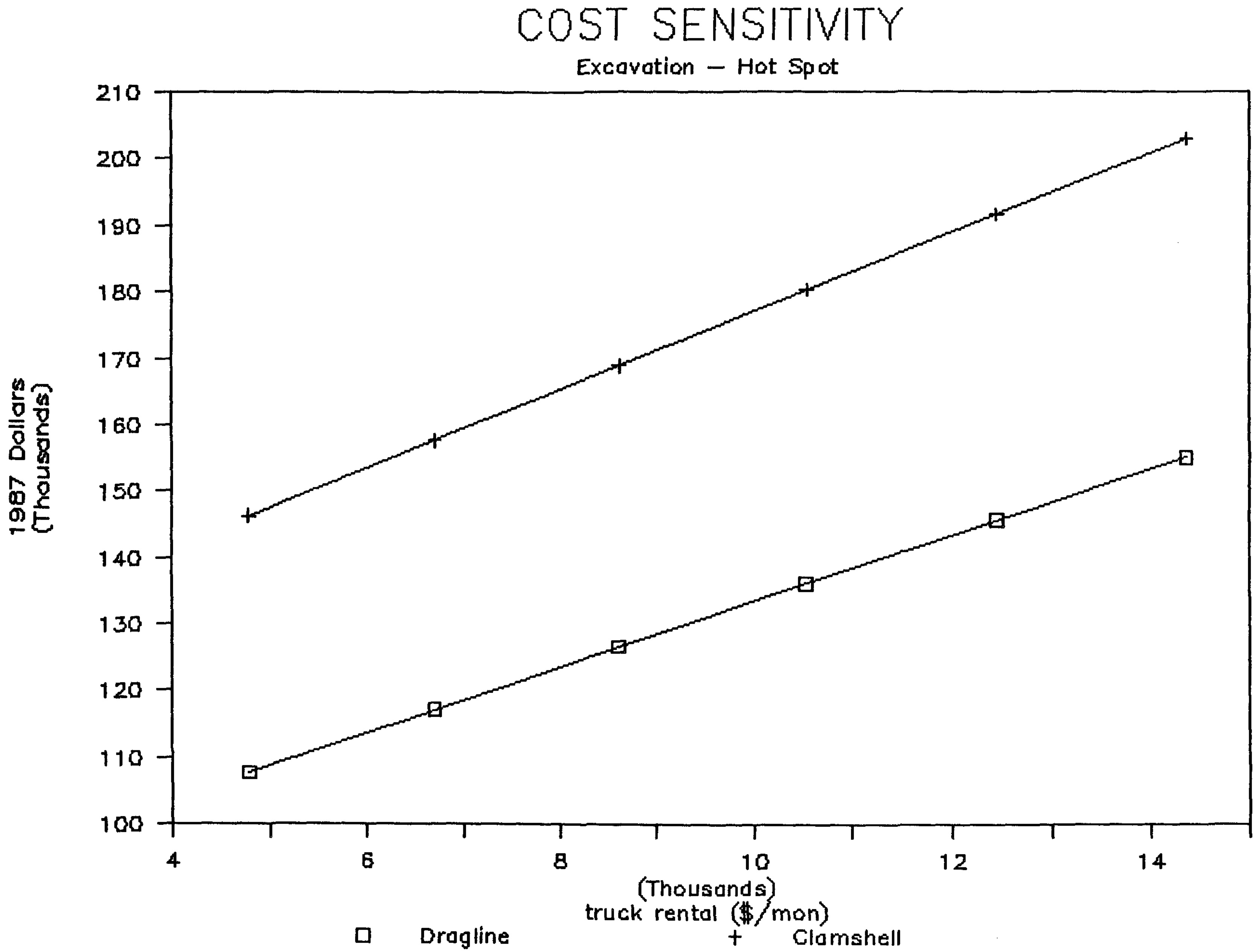

COST SENSITIVITY
Excavation — Hot Spot
1987 Dollars
(Thousands)
340
320
300
280
260
240
220
200
180
160
140
120
100
1
3
5
7
9
11
13
haul distance (mi)
Dragline
Clamshell

Figure 5-43



COST SENSITIVITY
Excavation — Hot Spot
1987 Dollars (Thousands)
170
160
150
140
130
120
110
100
11
13
15
17
19
21
23
25
27
29
average labor ($/man hr)
Dragline
Clamshell

Figure 5-42


COST SENSITIVITY
Excavation — Hot Spot
1987 Dollars (Thousands)
210
200
190
180
170
160
150
140
130
120
110
100
4
6
8
10
12
14
(Thousands)
truck rental ($/mon)
Dragline
Clamshell

difficulties in building the embankment and higher costs (order of magnitude) lessen the acceptability of these technologies.

The watertight clamshell has been retained for use in the Estuary and Lower Harbor/Bay. The watertight clamshell will only be used in shoreline areas that are too difficult to access with a dredge. This technology will supplement the dredge chosen for these areas. This will be formulated during the development of remedial alternatives and will insure complete removal of the contaminated sediments.

6.0 TREATMENT TECHNOLOGIES

6.1 ADVANCED BIOLOGICAL METHODS

6.1.1 Description

Laboratory research has demonstrated that lower chlorinated PCB congeners (mono-, di-, and trichlorobiphenyls) are degraded by aerobic bacteria (Furukawa, 1982; Bedard, et. al., 1984 and 1986a; Unterman, et. al., 1985; Gibson, et. al., 1986; U.S. Environmental Protection Agency, 1986; Bopp, et. al., 1986) and by fungi (Bumpus, et. al., 1985a; Bumpus and Aust, 1986; Dodge, et. al., 1979; Smith and Rosazza, 1974; Wallnofer, et. al., 1973). Recent research involving studies of PCB-contaminated sediments in subaqueous environments has identified specific patterns of dechlorination of higher chlorinated PCB congeners, presumably mediated by anaerobic bacteria (Brown, 1986; Brown and Sloan, 1986; Brown, et. al., 1984, 1986a, 1986b, and 1987; Tredge, et. al., 1986). The current state of knowledge regarding PCB degradation by microbes is summarized in the following paragraphs.

Several bacterial isolates have been demonstrated to have the capability of degrading PCBs under aerobic culture conditions. Extensive studies have been conducted to ascertain mechanisms of degradation, products of PCB degradation, and factors that may enhance bacterial degradation of PCBs. Most bacterial isolates capable of degrading PCBs employ a 2,3-dioxygenase system which hydroxylates and cleaves the aromatic ring between the 2 and 3 positions. PCB congeners not dechlorinated by this enzyme system include those that are chlorinated at the 2,3 and 5,6 positions of one or the other rings, as well as diortho-chlorinated congeners. A second type of aerobic degradation system has been identified whereby aromatic ring cleavage occurs at the 3,4 or 4,5 positions. Congener-specificity has also been observed with this system. A third system has recently been identified whereby epoxide intermediates are formed, presumably by the use of a mono-oxygenase. This system does not require that vicinal carbons be dechlorinated, because a 2,4,5-chlorinated ring is attacked by the enzyme. The mechanism by which this latter system operates is unknown, and further research is required to understand the relative distribution of this system in nature, and the types of congeners that it may degrade.

GE researchers who have been investigating the fate of PCBs in river sediments have obtained indirect evidence that congener-specific degradation systems are active in river sediments contaminated with PCBs. PCB congeners that appear to be most rapidly degraded in the sediments are those that would be attacked by a 2,3-dioxygenase system.

The results of the GE-supported research also suggest that reductive dechlorination of PCB congeners occurs in river sediments. Analyses of river sediments indicate that, during the course of several years, there is a gradual disappearance of higher chlorinated congeners, and a relative increase in the proportion of certain lower chlorinated congeners. The GE researchers speculate that reductive dechlorination is mediated by microbes. There is no published evidence to prove this, and laboratory studies have failed to unequivocally demonstrate microbially-mediated anaerobic dechlorination of PCBs. There are several reports, however, of microbial anaerobic dechlorination of aromatic compounds other than PCBs (see citations in Tredge, et. al., 1986).

The degradation of aromatic hydrocarbons by fungi occurs through the use of an enzyme system that is different than the bacterial system. The results are similar in that vicinal carbon atoms are hydroxylated prior to ring cleavage. In addition, monohydroxy PCB derivatives have been identified in fungal cultures inoculated with PCBs. The only other studies that describe PCB degradation by fungi have been conducted by researchers who have utilized a white rot fungus which produces an extracellular lignin-degrading enzyme system that is capable of non-specific degradation of certain xenobiotic compounds. However, studies with ^{14}C-labeled 3,4,3',4'-tetrachlorobiphenyl and 2,4,5,2',4',5'-hexachlorobiphenyl showed only 2 percent degradation to $^{14}CO_2$ occurred after 60 days (Bumpus, et. al., 1985a). In a separate report, 18 to 20 percent degradation of ^{14}C-labeled Aroclor 1242 and 1254 to $^{14}CO_2$ occurred after 60 days (Bumpus and Aust, 1986). In the latter study, no details were provided on how the Aroclor preparations were radiolabeled; therefore, it is unknown which congeners were degraded.

Communications with vendors have suggested that microbes have been developed that are capable of completely degrading PCBs under certain conditions (E.C. Jordan Co., 1986a, 1986b, 1987a, 1987b). These claims have not been substantiated by published reports, nor is supporting evidence available for critical review.

The use of biodegradation to degrade PCBs in New Bedford Harbor sediments would require the use of either proprietary organisms, organisms available from research laboratories, or cultures from commercial sources. Based on the current knowledge about PCB biodegradation research, the type of organisms utilized would likely be aerobic bacteria. At present, none of the bacteria reported to degrade PCBs were isolated from marine environments. It is highly unlikely that any of these bacteria could grow in a saline environment. The use of previously isolated or proprietary bacteria to degrade PCBs in New Bedford Harbor sediments would therefore require desalination of the sediments. The design and operation of a desalination facility would encounter several problems, including: (1) siting of the facility; (2) quality control; (3) generation of enormous volumes of PCB-contaminated water; and (4) high cost and length of time to complete desalination. Consequently, the only feasible manner of implementing biodegradation as a remedial technology for New Bedford Harbor sediments would be to enhance the capability of indigenous microbes to degrade PCBs.

GE researchers have analyzed PCBs in the New Bedford Harbor sediments. Their reported results indicate that reductive dechlorination and aerobic biodegradation of PCBs may be occurring at a relatively slow rate. Extensive bench testing of small-scale systems would yield data as to whether PCB degradation could be enhanced in the sediments. Several factors could be examined, such as:

- enriching for PCB-degrading microbes in the sediments;

- optimal temperature, pH, aeration, and nutritional requirements;

- the ability of microbes to utilize PCBs as the sole carbon source, or to cometabolize PCBs;

- the enhancement of anaerobic reductive dechlorination (or by some other process) to yield more readily degradable PCB congeners; and

- mechanisms for enhancing the availability for PCBs to the microbes, such as optimal mixing methods and the use of surfactants.

It is unlikely that complete degradation of PCBs could be attained because, as described in the preceding discussions, the diortho-chlorinated PCBs and PCB congeners with six or more chlorines are resistant to degradation. An estimate of the amount of PCB degradation to be expected would also require knowledge of the relative proportions of the various PCB congeners present in the sediments. It is reasonable to assume that, if biodegradation rates could be enhanced by optimizing treatment system conditions, 40 to 80 percent of the PCBs would be transformed within two to three weeks; a greater proportion of diortho-chlorinated congeners and higher chlorinated (six or more) congeners would likely remain. A greater degree of biodegradation could be achieved if the natural dechlorination process could be enhanced. In particular, if ortho-chlorinated and higher chlorinated congeners could be dechlorinated in a pretreatment process, biodegradation of greater than 90 percent of the PCBs could possibly be achieved. This might be accomplished through the use of photodegradation. In laboratory studies of the photdegradation of PCBs it has been observed that ortho-chlorines and higher chlorinated congeners are more rapidly photodechlorinated than other types of congeners (Bunce, et. al., 1978; Ruzo, et. al., 1974; Wagner, 1979).

Based on the results obtained from bench-scale tests, a smaller version of a full-scale system could be tested. Operational requirements and further modifications of the system design would be refined at this level. A full-scale treatment system could then be designed and constructed at the site.

6.1.2 Effectiveness

The evaluation of the effectiveness of any biodegradation system employed at New Bedford Harbor relies on the following assumptions. It is assumed that bench-scale testing would be performed, and that the results of these tests would demonstrate that biodegradation of PCBs in sediments could be enhanced within a reasonable time period. It is also assumed that tests would be conducted to determine optimal conditions to enhance the rate of degradation, and that the degree of degradation and the products of degradation would be considered acceptable in terms of risk management.

Reliability. The reliability of the biodegradation system would depend on the maintenance of normal operational conditions, and on the control of the substances entering the system. There are several types of wastewater treatment systems in operation throughout the United States that contain biological treatment components potentially applicable for treating the PCB-contaminated sediments in New Bedford Harbor. The systems used in the United States are highly reliable, as they operate successfully on a daily basis. As with any biological wastewater treatment system, the input of toxic substances, or matter with a high BOD, could be detrimental to the system. This would not be expected to be a problem with the New Bedford Harbor sediments for the following reasons. The bench-scale tests would determine if there would be detrimental effects due to toxic substances in the sediments (e.g., heavy metals), and the treatment system would be designed to overcome any potential deleterious effects. No additional toxic substances should enter the system, as only the sediments would be treated. In conclusion, if bench-scale tests indicate that a biological treatment system would be feasible for New Bedford Harbor sediments, it is expected that a highly reliable system could be designed and operated.

Public Health. The removal of a majority of the PCBs from the sediments would appreciably reduce the toxicity and volume of PCBs in sediments. The relative risk associated with any PCBs remaining in the sediments would depend on: (1) the ultimate disposal site for the treated sediments; (2) the mode of treatment or disposal of the process water; and (3) the types of PCB congeners or degradation products remaining in the sediments. For example, higher chlorinated congeners are generally less toxic than lower chlorinated congeners. In addition, the products of PCB degradation would have to be identified or tested to ascertain their toxicity. It is expected that bench-scale tests would yield the type of data necessary to conduct a detailed assessment of the risks associated with any remaining PCB residues in the treated sediments. Disposal of the treated sediments in a secure landfill would reduce the relative risks to human health compared to returning the sediments to the harbor. Finally, the wastewater would have to be treated or disposed in a safe manner which would be determined based on the results of the bench tests.

Operation of the treatment system is not expected to pose any danger to public health. There would be little chance, if any, of PCBs escaping the system. PCBs are not highly volatile or reactive, and the system could be designed to trap any PCB residues that may volatilize. The effectiveness of the system could be determined through pilot testing, modeling, and air monitoring.

The health risks associated with removal of sediments from the harbor are not considered here, since they were discussed in Section 5.

Environment. The impacts on the environment would depend on the same factors discussed in the preceding section on public health. The ultimate disposal site for treated sediments, and the manner of treatment or disposal of wastewater, would be governed by bench-scale test results and the predicted impacts of remaining PCB residues and degradation products on potential receptors. The biological treatment system would only be implemented if it appreciably reduced the toxicity and volume of PCBs in the sediments, and if there were no adverse environmental impacts associated with the treatment or disposal of the wastewater. Therefore, a biological treatment system would have a beneficial effect on the environment, relative to current baseline conditions. Short- and long-term toxic effects on the benthic populations would be greatly reduced by the reduction of PCB residues in the sediments. In addition, the potential for long-term bioaccumulation would be appreciably reduced because a large proportion of PCB-contaminated microinvertebrates present in the treated sludge would be removed from the ecosystem. Therefore, the continued migration of PCBs and exposure of additional organisms would be significantly reduced.

The impacts on the environment associated with sediment removal from the harbor are discussed in Section 5.

6.1.3 Implementation

Technical Feasibility. The major question with the biological treatment system is whether degradation of PCBs can be enhanced in the sediments, such that the rate and amount of degradation are considered acceptable. Bench-scale tests can be designed to ascertain the feasibility of constructing a biological treatment system at the site.

PCBs tend to absorb to organic matter. The process design considerations will, therefore, require an analysis of methods to increase availability of the PCBs to the microbes. This could include the addition of surfactants to the system, which would be a relatively simple process. It is more likely, however, that mixing and aeration of the sediments will be of primary concern in the design of the system. The system would have to be capable of maintaining the heavy solids in suspension, and adequately mixing the suspension to ensure availability of the PCBs to the microbes.

The system design would likely be similar to a proven wastewater treatment system. Consequently, design and construction of the system would present no special concern. The siting of the facility is likely to pose problems. The facility should ideally be sited in a location that has sufficient area for an additional facility to store the sediments. The siting of a 3-million gallon capacity treatment facility would require about two acres. Three such facilities could be sited in an area of about five acres to hasten completion of remedial action. At present, most undeveloped areas of this size adjacent to the harbor contain wetlands, a factor which would result in concern over siting a facility in these areas. Additional consideration in siting the facility would have to be given to disposal of post-treatment wastewater and sediments, e.g., access to transportation and disposal/treatment facilities.

Level of Development. The level of development of this technology has not surpassed bench-scale testing. One vendor is under consideration to conduct field studies on biodegradation of PCBs in Texas under the EPA SITE program. These activities will continue to be monitored for information useful to the New Bedford Harbor remedial studies. Bench-scale and pilot studies with sediments will be required to evaluate implementation at New Bedford Harbor.

Support Requirements. Several support requirements would need to be considered for implementation of a biological treatment system at New Bedford Harbor. Initial sediment removal and dewatering are discussed separately in Sections 5 and 7.1, respectively. In addition, it may be feasible to remove heavy solids from the sediments prior to treatment, if testing determines that the heavy solids fractions do not contain significant quantities of PCBs. This would be desirable and very important to the successful operations of the treatment facility. Therefore, a facility may be constructed to remove heavy solids prior to treatment.

Storage of sediments prior to treatment would require the design and construction of a storage facility. The storage facility would ideally be located proximal to the treatment facility to facilitate sediment processing. If this is not possible, a plan for transportation of sediments to the treatment facility would need to be designed. The storage facility could be either in an upland portion of the harbor area, or in an enclosed subaqueous site.

Bench-scale testing may identify pretreatment processes which could enhance the biodegradation rate in the treatment system. For example, if significant dechlorination of PCBs could be easily achieved through a relatively simple pretreatment process (e.g., anaerobic dechlorination, or by alkaline stripping of chlorines), then a pretreatment facility may need to be constructed adjacent to the biological treatment facility. Finally, pretreatment and operating support requirements would include obtaining access to a continued source of microbes, nutrients, reagents, and water for the system.

The operating treatment system would require ready access to a laboratory to monitor quality control objectives. Ideally, the laboratory would be constructed adjacent to the treatment facility. These requirements are discussed further in monitoring and maintenance requirements.

Post-treatment support requirements would include the design and construction of a treated sludge dewatering facility. In addition, a transportation plan and disposal plan for the treated sludge would have to be designed and implemented. Finally, the disposal of the wastewater from the treatment facility would have to be considered (e.g., whether the wastewater required further treatment prior to discharge, and the location of the discharge point). Water treatment is discussed separately in this report in Section 7.2.

Availability. A predesigned/constructed biological treatment system is not available for construction or erection at the site. The design and construction of a system would require engineering capabilities in wastewater treatment systems, planning, and hazardous waste management. Such services are readily available throughout the northeast region of the United States.

Installation. Installation of the treatment system would pose no special concerns, once design and siting concerns and requirements have been satisfied.

Time. Bench-scale testing would require approximately 4 to 6 months to complete. If the results of these tests suggested that further tests were warranted, the design and implementation of large-scale bench tests (>100 gallons) could be completed within 3 months, assuming rapid approval by EPA. These test results would be available within about 3 more months. Consequently, all tests could be completed within one year. The time required to complete full-scale treatment of harbor sediments would depend on several factors, including:

- the amount of sediments to be treated;

- the target level set for PCBs;
- the results of the bench tests regarding the time required to achieve the desired PCB levels;
- regulatory review and approval processes;
- the number of treatment units constructed and operated; and
- the number of monitoring and maintenance issues that need to be satisfied.

It is expected that it could take up to 10 years to treat several hundred thousand cubic yards of sediments. However, multiple treatment units could be operating simultaneously to reduce total treatment time if this were determined to be cost-effective. One treatment unit operating with a solids retention time of 15 days, and with a capacity for three million gallons could treat 72 million gallons of sediments (at 5 percent solids) a year. This would be equivalent to about 35,000 cubic yards of undiluted harbor sediments (assuming dredged sediments contain 50 percent solids). Solids retention times and facility capacity would depend on the results of bench-scale tests and cost considerations.

Safety. Special safety precautions would be required in transporting the hazardous sediments to the treatment facility, and in the process of feeding the sediments into the facility. The major exposure route during these activities would be through dermal contact. Minimal exposure to sediments would occur during the operation of the treatment facility. The only expected routes of exposure would be through direct contact or inhalation by workers conducting monitoring and maintenance activities. Health and safety plans would be designed to cover these activities. During normal operations, no exposure to humans would be expected as access to the facility would be restricted. If volatilization were considered to pose a health threat, air monitoring equipment could routinely ensure safety. If this were considered a problem, however, the facility could be designed with an enclosure and air pollution devices to prevent the escape of volatilized PCBs.

Monitoring and Maintenance Requirements. It is expected that only minimal maintenance would be required for a biological treatment facility. Projected maintenance requirements would be readily determined during the design phase, based on available knowledge regarding wastewater treatment systems currently in operation in the United States. If the heavy solids fraction of the sediments require treatment, this will result in significant additional maintenance costs associated with periodic removal of these solids.

Monitoring requirements would be stringent. Quality assurance objectives would be established, and frequent routine monitoring activities would be required to ensure compliance with the objectives.

The influent and effluent would be analyzed for PCBs by gas chromatographic techniques to allow for analysis of specific PCB congener degradation patterns. The wastewater would be monitored continuously for parameters which would indicate normal functioning of the system, e.g., flow rates, dissolved oxygen, sediment loading, total solids, suspended solids, BOD, aeration rates, microbial counts, temperature, and pH.

Additional monitoring requirements may be established for safety reasons. For example, volatilization of PCBs may be considered to pose a health threat to nearby receptors. Safety measures would be designed to eliminate this potential threat, and routine air monitoring programs would have to be implemented to ensure the adequacy of the measures.

<u>Permitting</u>. According to current statutes (CERCLA as amended), permits would not have to be obtained by EPA to implement remedial actions at the site; however, permit requirements would have to be satisfied. The following federal and state standards applicable to the following activities would have to be considered in the design of the bioremediation plan (dredging, sediment dewatering,

and water treatment activities are discussed in Sections 5, 7.1, and 7.2, respectively):

- o design and operation of the sediment pretreatment storage facility (e.g., RCRA, TSCA, DEQE hazardous waste standards, and Wetlands Protection Act);

- o transportation of sediments to the treatment facility, if necessary (e.g., TSCA, and federal and state DOT);

- o design and operation of the treatment facility (e.g., RCRA, TSCA, CWA, and Wetlands Protection Act);

- o discharge or treatment of the post-treatment wastewater (e.g., CWA and state effluent standards); and

- o disposal of the treated sediments (e.g., CERCLA, RCRA, TSCA, and DEQE hazardous waste standards).

Legal Constraints. Concerns associated with siting the facility are likely to present an obstacle to implementation of this technology. There are few available undeveloped land areas adjacent to the harbor that are not inhabited by wetlands species. Attempts to site the facility in wetlands areas would probably raise the most concern. The use of a biological treatment facility to treat the PCBs should not be of significant concern to the local government and citizens if the system's efficacy can be demonstrated. Wastewater treatment facilities are acceptable to the public, provided there are no problems with odor, as would be expected in this case. Citizen concern could be anticipated over the use of genetically engineered microbes in a biological treatment system; however, it is expected that naturally-occurring microbes would be used to treat New Bedford Harbor sediments.

Impacts on Historical and Cultural Resources. No potential impacts on historical or cultural resources are expected from the implementation of a biological treatment system at the New Bedford Harbor site.

6.1.4 Costs

The costs associated with application of biological treatment to New Bedford Harbor sediments are difficult to estimate. The field application of bioremediation of hazardous wastes has been limited to treatment of contaminated groundwater and soils, oily sludges, and coal tar wastes. Most of these applications involve nonchlorinated aliphatic and aromatic compounds. There are no reported applications of biological treatment methods to contaminated sediments. At present, biological treatment of soils contaminated with waste oils is being field-tested at only one Superfund site, the Old Inger site in Louisiana (Environmental Solutions, Inc., undated). Therefore, the only information available on the efficacy and costs of bioremediation processes are related to proprietary ventures, and it is insufficient to make critical analyses of purported successful field applications of the biological treatment technologies.

The costs quoted by vendors for in situ land or refinery sludge treatment systems are generally about $70 to $80 per ton or cubic yard. These costs are based on relatively simple process design considerations (i.e., culturing microbes, addition of nutrients, and mechanical aeration), and consist largely of monitoring and analytical costs. It would be expected that costs for treatment of New Bedford Harbor sediments would be greater.

A recent report prepared by Research Triangle Institute presented the results of evaluations of treatment technologies for cleanup of PCB-contaminated sediments in the Hudson River (Carpenter, 1987). A microbial degradation process proposed by Bio-Clean, Inc. was described in the report. The cost estimate proposed for this process was $187 per cubic meter, and included the costs for construction of a floating treatment facility and laboratory as well as for post-treatment of wastewater. Details concerning the level of PCBs that would remain in the sediments were omitted, and the efficacy of the proposed process is unproven.

The biodegradation of PCB-contaminated sludge from Madison (Wisconsin) Metropolitan Sewerage District sludge has been examined at the bench-scale and pilot-scale (100-gallon) levels by researchers at the University of Wisconsin (Chantry and Boyle, 1986). The sludge contained PCBs up to 120 ppm. Up to 90 percent degradation was observed in shake culture experiments, and up to 65 percent degradation was observed in bench-scale continuous-feed reactors. The results obtained in the bench-scale reactors were confirmed on the pilot-scale level. The researchers developed a cost estimate for full-scale treatment of 312 million gallons of Madison sewage sludge contaminated with PCBs up to 180 ppm. Their estimated cost was less than $10 million and assumes that PCBs will be treated to less than 50 ppm. If it is assumed that New Bedford Harbor sediments could be treated similar to the Madison sludge, cost estimates for reducing the PCB levels in the sediments by 65 percent can be estimated. The Madison sludge contained 4 percent solids, whereas the New Bedford Harbor sediments are assumed to contain 50 percent solids. For cost estimating purposes, it is assumed that the sediments would be diluted with seawater to yield 5 percent solids for treatment. The cost to treat New Bedford Harbor sediments accordingly, expressed on an undiluted volumetric basis, is estimated at $65 per cubic yard. The actual costs would be much greater because the following factors would have to be considered:

- o the sediments to be treated would likely contain a greater average concentration of PCBs than the Madison sewerage sludge, and a longer solids retention time may be required to achieve reduction of PCB levels to acceptable levels;

- o the costs for diluting the sediments (and pretreating if necessary);

- o the costs for dewatering and disposing of the treated sludge;

- o if the length of time for treatment is considered a problem, multiple treatment units may be built at added costs; and

- o stringent monitoring requirements may impose burdensome costs.

More detailed cost estimates would require bench-scale test data to define the treatment system process requirements.

6.1.5 Summary

Advanced biological methods have been retained for further consideration in the development of remedial alternatives for the New Bedford Harbor site. Biological treatment of the contaminated sediments would result in reduction of the toxicity and volume of PCB residues. Biodegradation may be enhanced by pretreatment processes. The results of bench-scale tests would be required to adequately assess the effectiveness of the remedy and the public health and environmental benefits to be derived by using this technology. If proven to be effective, a reliable biological treatment system could be implemented utilizing readily available technologies and resources. Time requirements may pose special concerns because several years would be required to treat large volumes of sediments. The cost of implementing a biological treatment system can not be estimated with any degree of accuracy without benefit of bench-scale data.

6.2 SOLVENT EXTRACTION

Solvent extraction and supercritical fluid extraction processes remove PCBs from sediment by dissolving the PCBs in a solvent.

6.2.1 Description

Solvent extraction processes involve mixing a solvent with either a liquid or solid to remove a contaminant. As applied to New Bedford Harbor, a solvent would be mixed with the sediments and the PCBs (and other organic compounds) would move into solution. After mixing, the sediments settle and the PCB-laden solvent is decanted from the mixture. A separation step then removes the PCBs from the solvent, which is reused for extraction.

Supercritical fluid extraction uses a supercritical fluid as the solvent to remove PCBs from sediment in a manner similar to solvent extract processes. The difference between the processes is the way the PCBs and other organics are removed from the supercritical fluid. After the fluid is decanted from the sediment, the pressure is reduced and supercritical fluid flashes off as a gas.

Because the solvent extraction and supercritical extraction processes are similar, they are both discussed herein under the category of solvent extraction. Any differences between the processes are noted in the text.

Solvent extraction removes only a portion of the PCBs from the sediments in one extraction step. The amount of contaminant which can be removed from the sediment during an extraction step is limited by:

- o the contaminant's solubility in the solvent;
- o the solvent and sediment mixing efficiency;
- o mass transfer coefficients governing the rate at which the contaminant dissolves;
- o the time the solvent and sediment are in contact;

- the ability to separate solvent from sediment; and

- the presence of interfering substances in the sediment.

Reported removal efficiencies for solvent extraction vary from under 50 percent removal per step to 90 percent per step. The removal efficiency is theoretically independent of the contaminant concentration in the sediment; therefore, additional removal can be achieved by repeating the extraction steps on the sediment.

Water and fine-grained materials inhibit some solvent extraction processes. This is an important factor for New Bedford Harbor since 40 to 90 percent of the Acushnet River Estuary sediments will pass a 200 mesh sieve, and the sediments contain about 50 percent water.

Fine grain materials settle slowly because their weight is low compared to the attractive forces between the solvent and the individual particles. This increases the settling time required after the solvent is mixed with the sediments. If insufficient time is allowed for settling before the solvent is decanted, the fine grained material will be carried over with the solvent, increasing the amount of material ultimately requiring treatment or disposal.

Water can inhibit the extraction process by inhibiting the mixing of the solvent and sediment or by creating a colloid with the solvent and sediment. If mixing is inhibited, the removal efficiency of the process is lowered. A colloidal mass will not settle and must be flocculated or otherwise destroyed to separate the sediment from solvent and water.

Besides removing PCBs from the sediment, solvent extraction will remove other non-polar compounds. This includes polynuclear aromatic compounds and other toxic organic compounds as well as naturally occurring organic matter such as decaying vegetation, or humic matter. Since the organic content of the sediments in the Estuary is between 5 percent and 28 percent, a large amount of contaminated material would be generated by solvent extraction.

Metals present in the sediments will not be removed by the solvent extraction processes considered here because they are not soluble in the same solvents used for PCB removal.

After the PCBs are extracted from the sediment, the solvent must be treated to remove PCBs from the solvent. This is accomplished by either changing the temperature of the solvent to change the solubility of the PCBs; by distilling the solvent off the PCBs; or in the case of supercritical fluid extraction, by reducing the pressure to flash off the solvent.

The PCBs (and the other organics removed from the soil) are not destroyed by the extraction process. Solvent extraction must therefore be combined with another treatment technology to destroy the PCBs. Other applicable treatment technologies are discussed in this chapter.

After the extraction is complete, some solvent remains in the treated sediments. This residual solvent may pose a separate problem if the solvent is toxic. This evaluation considers the toxicity and amount of solvent remaining in the soil for each promising solvent extraction process.

For the solvent extraction processes, there is insufficient information in the literature to determine whether they will be effective on the Bedford Harbor sediments. Treatability studies (bench tests) using New Bedford Harbor sediments will be required to assist in evaluating the applicability of solvent extraction.

Information from the bench testing will aid in determining:

- the effect of water and fine grained materials on solvent extraction;
- the time required for various treatment steps; and
- the costs for treatment.

6.2.2 Effectiveness

The effectiveness of solvent extraction processes was evaluated based on the following factors:

- the amount of PCBs removed from the sediment;
- the amount and toxicity of solvent which remains in the sediment;
- the risk of the treatment process (including the risk of contaminant release during treatment); and
- the potential for interference by water or fine grained materials on the process.

B.E.S.T. Process

The Basic Extractive Sludge Treatment (B.E.S.T.) process uses an amine based solvent (often triethylamine) for extraction. The amount of PCBs (and other organics) removed from the sediment is estimated to be about 80 percent per extraction step. The B.E.S.T. process has treated sludge containing up to 10 ppm PCBs, (leaving less than the detection limit of 5 ppm) (Austin, 1986).

Triethylamine is a moderately toxic compound comparable to the solvents used for other extraction processes. The process uses a dryer to remove remaining water and solvent from the sediment after treatment.

Water does not affect removal efficiency of the process. Fine grained materials constituted a part of the materials which were treated at Savannah, Georgia, where no significant carryover of fines occurred.

Steiner Extraction

The Steiner process uses an acetone solvent to extract PCBs from sediments and then extracts the PCBs from the acetone using kerosene (Rugg, 1987). Extraction removal efficiencies of up to 85 percent per extraction step are possible. For full scale operation, Steiner proposes use of a counter current extraction vessel large enough to achieve final PCB concentrations of 5 ppm in the treated sediments (Steiner, et. al., 1987).

Acetone and kerosene are both moderately toxic compounds. Conceptually, acetone would be removed from the extracted soil by steam stripping. No data are available on the amount of acetone which would remain in the soil after the treatment is complete. The process is being designed to handle 50 percent water.

Adequate testing data are not available to determine if fine grain materials will present a problem.

Soilex Process

The Soilex process, developed by Oak Ridge National Laboratories, uses a mixture of kerosene and water to treat soil (or sediment). Removal efficiencies of 52 percent per extraction step are reported for an overall removal of 85 percent for a three stage extraction (Saunders, 1985). Much of the kerosene (up to 25 percent by weight) remains with the treated soil. The treated soil has been land farmed to allow the kerosene to evaporate. Water does not interfere with the process. In fact, water content of about 60 percent was found to optimize the process. Fines were not reported to be a problem. However settling times of 16 hours per batch were required to separate the solid from the kerosene/water.

Acurex Solvent Wash Process

Acurex is investigating the use of a proprietary solvent mixture to extract PCBs from soils (or sediments). Acurex reports 50 percent removal of PCBs for each wash cycle (Weitzman, 1985). During Acurex's tests, PCB concentrations were reduced to less than 2 ppm in less than 12 extraction steps (initial concentrations ranged from 37 ppm to 1,900 ppm).

Since the solvent mixture is proprietary, no information is available on the toxicity of the solvent. Also no information is available on the amount of solvent which remains in the treated sediments. The process tolerates up to 40 percent water. Acurex has indicated that fine grain materials cause materials handling and fines carryover problems for their process.

OH Materials

The OH Materials methanol extraction process was field tested in EPA Region III. Seventy-five percent removals are possible per extraction step using methanol as the solvent (Carpenter, 1986).

The extracted soil is dried, then subject to land farming to biologically degrade (or evaporate) the residual methanol. Water and fine grained materials cause problems for the process. During the field test, solvent mixed with the water and fines, creating a colloid. A large volume of sludge consisting of solvent, water, fines, and PCBs resulted. Disposal of the sludge and reclaiming the solvent presented a major problem.

CF Systems

CF Systems uses a compressed gas such as carbon dioxide or propane near its critical point for their extraction process. Depending on the waste stream being treated, CF Systems can operate the process at temperatures and pressures below the critical point to reduce capital and operating costs. The CF System removes 80 to 90 percent of the PCBs and organics during each reaction step using propane. Ninety nine percent removal is achieved after three steps.

One of the big advantages of supercritical extraction is that virtually all the solvent will be removed from the sediment by lowering the pressure; the propane or CO_2 simply vaporizes off and is subsequently collected and recondensed. Both propane and CO_2 are non-toxic and small amounts (less than 1 percent) remaining in the sediment or volatilizing into the atmosphere are not a concern.

Water does not affect the removal efficiency of the process. Water is necessary to make the sediment a pumpable slurry. The only effect of water on the process is to increase the volume of material requiring treatment (with an associated increase in cost).

Very little of the fine grained material will carry over with the solvent. The pressure on the solvent is reduced prior to separation from the sediment, causing the density to decrease. Settling occurs more rapidly under these conditions and the amount of solvent removed as a liquid can also be adjusted to ensure that fines do not carryover.

6.2.3 Implementation

Because the solvent extraction processes vary in solvent use and stage of development, the implementability criteria for each process require separate evaluations.

However, three of the implementability evaluation criteria are common to all of the solvent extraction processes. Permitting, institutional constraints and impacts on historical and cultural resources are discussed below.

Permitting: Solvent extraction would be an on-site remedial action and is exempt from permitting requirements. However, air emissions, water discharges, and residual solvent in the treated sediments must still meet the applicable regulatory requirements. These requirements will be addressed in the detailed evaluation of alternatives.

Institutional Constraints: Land to set up and operate solvent extraction will be required.

Public concern over sediment treatment using solvent extraction would most likely result from a concern for the environmental discharges (i.e., air emissions, water discharges, and residual solvent in treated sediments) from the process. An aggressive public education program for the treatment process can be combined with an education program for the dredging and disposal of treated sediments to address these concerns.

Solvent extraction will not impact historical or cultural resources.

B.E.S.T. Process

Technical Feasibility: It may be technically feasible to implement solvent extraction at New Bedford Harbor using the B.E.S.T. process. Water does not present a problem for this process. No problems have been reported for fine grained materials. Bench test information would be necessary to determine if the B.E.S.T. process is feasible for New Bedford Harbor sediments.

Demonstrated Performance: Resources Conservation Company's (RCC) B.E.S.T. process is the only solvent extraction process being evaluated which has been used on a full scale project. RCC used the process to treat 3,700 tons of an oil sludge waste contaminated with PCBs. The treated sludge contained less than 5 ppm PCBs. This is the only cleanup RCC has performed to date. RCC reports that bench and pilot scale data from the operation show good removal efficiency of oils from waste.

Support Requirements: Dewatering is not needed to support the B.E.S.T. solvent extraction process; in fact, the process requires water to perform extraction. The main support requirement is drying the sediments after extraction to remove residual solvent. Metals may become less mobile; however, solidification of the sediments may be required to further bind the metals, depending on the disposal option chosen. not be required because the amine treatment raises the pH of the solids, and thereby reduces their leachability.

Availability: Only one full scale unit is presently available for the B.E.S.T. process. This unit is designed for a 100-ton-per-day operation. Larger units can be built if needed for New Bedford Harbor.

Installation: RCC's estimate of the time required to set up the process is 14 to 16 months. This includes design, fabrication, installation, and start-up. It is estimated that 4 acres would be required to place a 520-ton-per-day unit. Other site requirements include electricity and cooling water to operate the process.

Monitoring and Maintenance Requirements: This process requires both operational and analytical monitoring. Analyses of the untreated and treated sediments, discharge water and the air emissions for PCBs, other toxic compounds, and amines would be necessary.

The B.E.S.T. process uses several pieces of equipment, including mixers, centrifuges, dryers, a condenser, and a stripping column, all of which may require periodic maintenance. Downtime to perform this maintenance is estimated to be 10 percent.

Steiner Extraction

Technical Feasibility: The Steiner extraction process may be feasible for use at New Bedford Harbor. Although water slows the settling of fine material in the solvent, settling still occurs.

Demonstrated Performance: The Steiner process is still in the laboratory/research stage. The process has never been demonstrated on anything beyond laboratory (bench) scale. Much more information is necessary to accurately determine how effective the process will be on the New Bedford sediments, to evaluate whether the process will work on a larger scale in the presence of water and fines, and to accurately estimate costs.

This process would require additional test information before it can be further evaluated.

Support Processes: The Steiner process would require dewatering of the sediments to 50 percent solids with subsequent treatment of the water from the dewatering process.

Further treatment (i.e., solidification) may be required to stabilize the extracted sediments and to prevent metals from leaching.

Availability: No full scale or pilot scale units are available for this process. However, individual unit operation components which would comprise the process train are readily available.

Installation: At least 2 years would be needed to perform bench and pilot scale tests and to construct a full scale unit. The process requires electricity and fresh water (for steam).

Monitoring and Maintenance Requirements: Seven operators per shift will be required to operate a 100-ton-per-day extraction system (Rugg, 1987).

Sampling of waste streams for environmental analyses would be needed for the extracted PCBs, treated sediment, treated water, and any air emissions. Analyses necessary for process monitoring and control are needed for the recycled kerosene and decontaminated acetone.

Soilex Process

Technical Feasibility: It is not technically feasible to implement the Soilex process at New Bedford Harbor. The only tests performed on the Soilex process indicated two major problems:

- o Solvent (kerosene) remained in the treated soils - the treated soils contained up to 25 percent by weight kerosene.

- o The extended settling time required - the Soilex process used 16 hours per extraction step to allow for settling of the soils in the solvent.

Oak Ridge National Laboratory is no longer pursuing this technology because of these problems. The Soilex process will not be considered further in this evaluation.

Acurex

Technical Feasibility: Research on the Acurex process is being funded by the Electric Power Research Institute. Information on this process is limited. Representatives of Acurex stated that a serious problem was being investigated concerning the carryover of fines with the solvent during the extraction process. Research continues, but Acurex does not feel that the process will be available for pilot or full scale testing in the near future.

This process will not be considered further in this evaluation.

OH Materials

Technical Feasibility: The OH Materials methanol extraction process has been pilot tested at the Minden Site in West Virginia. EPA Region III and OH Materials representatives have confirmed that the tests were not successful (Insalaca, 1986; Caron, 1986).

During the tests the solvent intermixed with water and fines forms a colloid which was not easily separated by mechanical means. This resulted in a sludge consisting of solvent, fine grained material, water, and PCBs. Disposal of the sludge and reprocessing the solvent presents a major economic and technical roadblock.

Since this process will not be effective on the New Bedford Harbor sediments, it will be eliminated from further consideration.

CF Systems

Technical Feasibility: The CF Systems' supercritical extraction process is probably technically feasible for the New Bedford Harbor sediments. Water is necessary for the process to create a pumpable slurry; fine grained sediments should not significantly impact the process. Bench scale testing will provide more information to evaluate the feasibility of this process.

Demonstrated Performance: CF Systems has demonstrated supercritical extraction on the bench and pilot scale. CF Systems has treated wastewater and oily sludges with the process on a pilot scale and has treated soils in bench scale tests.

Support Requirements: Sediment dewatering will reduce the volume of material treated. Enough water must be left in the sediments to allow pumping; dewatering to 50 percent solids should be sufficient.

Large objects must be removed from the waste stream. Screening through an No. 8 mesh screen will be required prior to treatment.

Availability: No full scale sediment (solids) treatment units have been built. CF Systems is presently building a full scale water treatment unit and plans to build a full scale solids treatment unit by 1988.

Installation: The process equipment and ancillary facilities would require a space of about 1 acre for a 200-cubic-yard-per-day unit. The process will use about 250 kW electricity and will require cooling water. CF Systems would presently need about one year to fabricate equipment needed for a full scale cleanup.

Monitoring and Maintenance Requirements: Analyses of the treated sediments and organic extract will be required. Air monitoring will ensure that unacceptable levels of solvent (propane or CO_2) are not escaping.

CF Systems estimates that 10 percent downtime will be necessary for equipment maintenance.

6.2.4 Costs

Tables 6-1 and 6-2 present cost estimates for solvent extraction and supercritical fluid extraction. These cost estimates are based on treating 500,000 yd^3 of sediment.

The cost information is based on questionnaires from vendors and on engineering estimates.

Sensitivity Analysis

Solvent extraction and supercritical extraction costs are dependent on:

- o the extent to which the sediments can be dewatered (i.e., the volume of material to be treated);
- o the amount of organics and fines extracted by the solvent; and

TABLE 6-1
SOLVENT EXTRACTION COST ESTIMATE

Capital Costs	
Equipment	$9,000,000
Mobilization/Demobilization	5,400,000
Engineering	1,000,000
Permitting/Administration	2,000,000
Site Preparation	1,000,000
Total Capital Costs	18,400,000
Operating Costs	
Maintenance	$6,600,000
Labor	33,000,000
Protective Equipment	5,625,000
Fuel and Utilities	7,500,000
Monitoring	7,500,000
Solvent	1,500,000
Miscellaneous	2,000,000
Extract Disposal	20,000,000
Total Operating Costs	$83,725,000
Total Capital and Operating Costs	$102,125,000
Unit Cost	$204/cy

Note: These estimates are based on treating a 500,000 cubic yard volume.

TABLE 6-2
SUPERCRITICAL FLUID EXTRACTION COST ESTIMATE

Capital Costs	
Equipment	$34,500,000
Mobilization/Demobilization	3,000,000
Engineering	1,000,000
Permitting/Administration	2,000,000
Site Preparation	1,000,000
Total Capital Costs	$41,500,000
Operating Costs	
Maintanence	$4,400,000
Labor	21,600,000
Protective Equipment	3,750,000
Fuel and Utilities	6,000,000
Monitoring	7,500,000
Solvent	2,000,000
Miscellaneous	2,000,000
Extract Disposed	20,000,000
Total Operating Costs	$67,250,000
Total Capital and Operating Costs	$108,750,000
Unit Costs	$217/cy

Note: These estimates are based on treating 500,000 cubic yards.

- o the treatment time or rate.

The extent of dewatering will determine the volume of material requiring treatment and will therefore have a direct effect on the cost.

Any organics, PCBs, and fines extracted by the solvent will require treatment to ultimately destroy the PCBs. This cost estimate assumes that this extract stream (fines, organics, and PCBs) from the sediment will be about 10 percent of the original sediment volume. If the extract stream is a greater percentage of the sediment, a cost increase would result.

The solvent and supercritical extraction processes are labor intensive, and costs are highly dependent on the treatment time. Because the New Bedford Harbor sediments contain a high percentage of fines, settling after extraction will occur relatively slowly. This will be a limiting factor in treatment rate.

Figure 6-1 shows how solvent extraction costs will vary as a function of volume percent extracted. Figure 6-2 shows the effect of treatment time on costs.

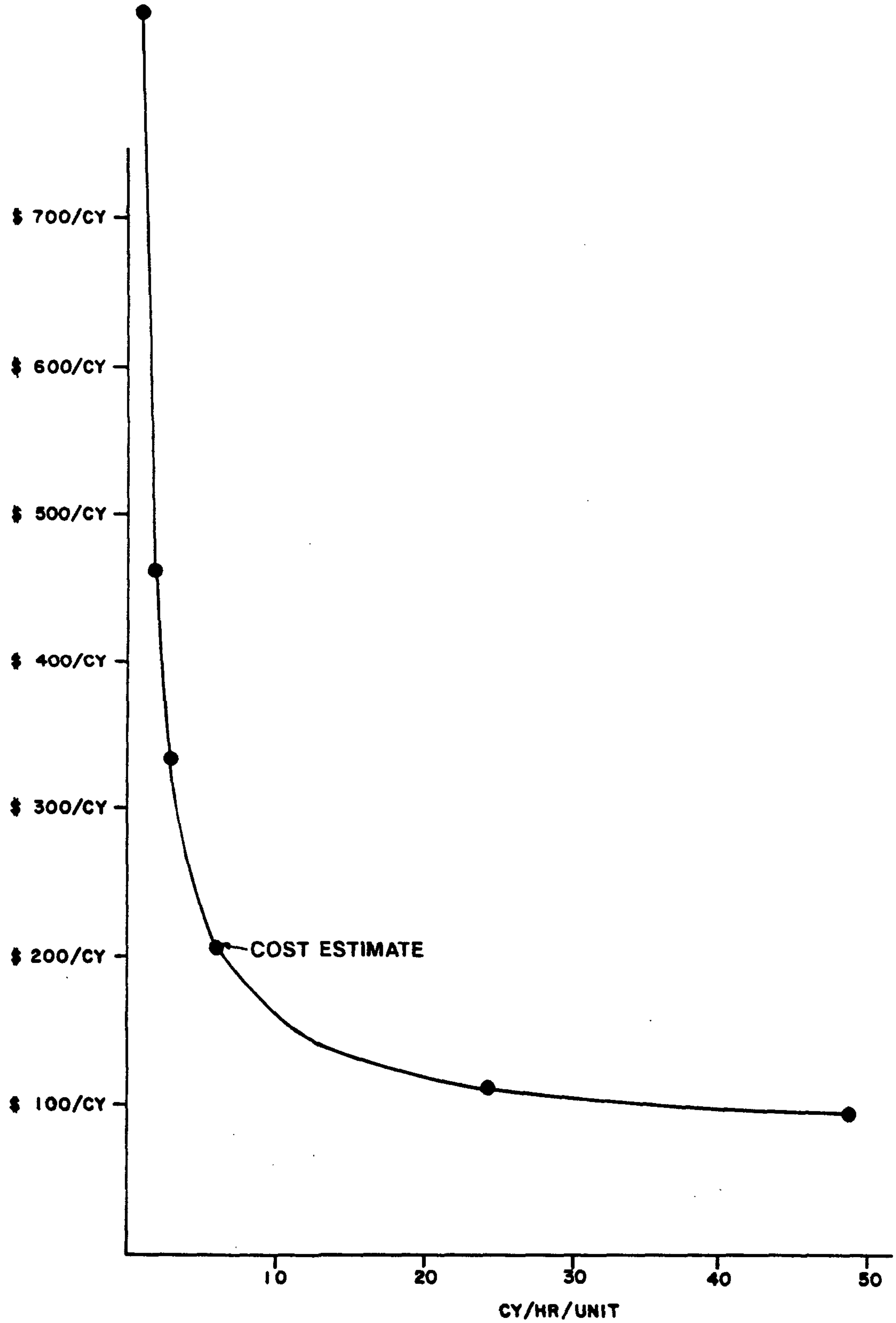


FIGURE 6-1
EFFECT OF TREATMENT RATE ON COST FOR SOLVENT EXTRACTION NEW BEDFORD HARBOR MASSACHUSETTS

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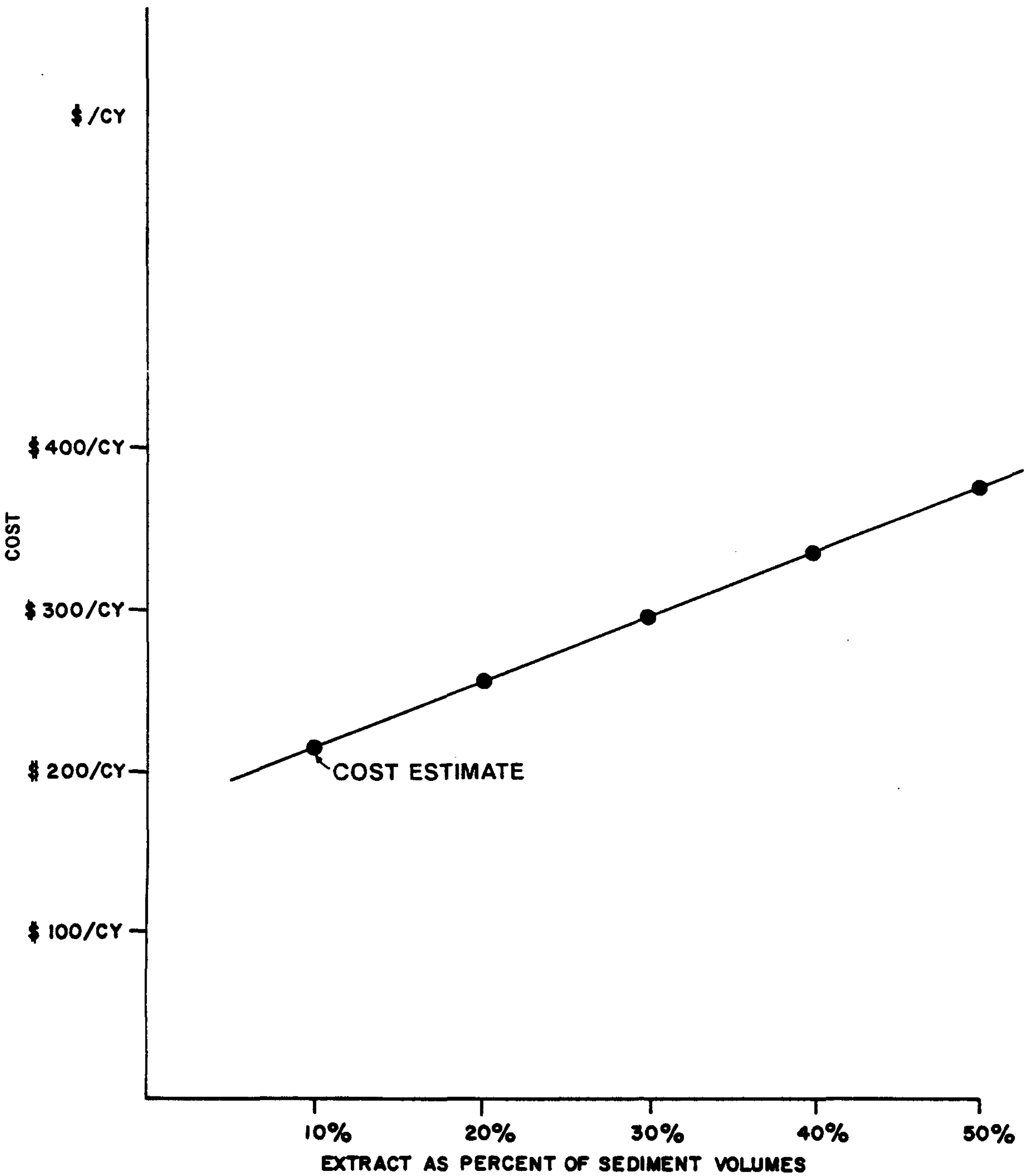

FIGURE 6-2
EFFECT OF EXTRACT VOLUME ON COST
FOR SOLVENT EXTRACTION
NEW BEDFORD HARBOR
MASSACHUSETTS

6.2.5 Summary

Solvent extraction and supercritical fluid extraction are not proven processes. These processes have not treated the type of waste present at New Bedford Harbor on a pilot or full scale. Bench scale testing data will provide information necessary to evaluate the processes' effectiveness for New Bedford Harbor and will help better define the cost.

Solvent extraction meets the SARA requirements by permanently and significantly reducing the volume of waste and the toxicity of the treated sediments. The PCBs are extracted into a low volume concentrated waste stream.

Solvent extraction and supercritical extraction will be used in the development of alternatives pending the results of bench scale testing.

6.3 SOLIDIFICATION

6.3.1 Description

The term solidification applies to the process of mixing a setting agent with a waste stream to form a hard, durable product of low solubility in water and in which contaminants are chemically bound and/or entrapped by the solidified mass. The treated end product can be a solid, monolithic structure or a dry, soil-like material.

Hazardous wastes are solidified to accomplish the following goals:

- o improve the handling and physical characteristics of the waste;

- o decrease the surface area across which transfer or loss of contained pollutants can occur; and

- o reduce the solubility and/or toxicity of the contained pollutants.

Typical additives include Portland cement, flyash, kiln dust, lime, soluble silicates, gypsum, and various combinations of these.

Related terms, such as chemical immobilization or fixation, generally refer to the addition of materials that act primarily to maintain the wastes in their least toxic or mobile form, and may or may not cause a change in the physical characteristics of the waste. In this report, solidification will refer to the addition of any material or combination of materials to accomplish any or all of the above goals.

There are several available publications which describe solidification in some detail. The two most comprehensive of these publications are "Guide to the Disposal of Chemically Stabilized and Solidified Waste" (USEPA, 1982), and "Handbook for Stabilization/Solidification of Hazardous Waste" (USEPA, 1986). These and other references are listed at the end of this report.

Detailed information regarding the application of the solidification technology under specific conditions existing at New Bedford Harbor was collected primarily through vendor contacts, as well as discussions with solidification experts within the USACE. Cost and time estimates are based on information provided by vendors and on previous experiences with the technology. USACE is currently conducting bench scale tests on solidification of New Bedford Harbor sediments, and this information will continue to be considered as it becomes available.

Traditionally, solidification has been used for inorganic and radioactive wastes, and substantial documentation of the effectiveness of the process exists for these waste types. Organic wastes, however, are less amenable to conventional solidification treatment technology. Some organic contaminants will actually interfere with the setting reactions, while others will not be adequately bound within the solidified waste structure to prevent long-term leaching. Therefore, until recently solidification has not been considered a viable technology for the treatment of organic wastes.

Of the available solidification processes currently being marketed, most can be classified as either Portland cement based or silicate based. Other processes, such as thermoplastic techniques and polymeric processes, have specialized applications and would not be appropriate for solidifying the large volume of contaminated sediments present at New Bedford Harbor.

Cement based solidification involves mixing the waste stream with Portland cement. Mixing is accomplished with conventional, readily available equipment. The cement reacts with water and solidifies, incorporating the waste within a solid matrix. The final product can be either in the form of monolithic blocks or a dry, soil-like material.

The primary benefit of cement based solidification is improved handling characteristics. The process is also beneficial for reducing the mobility of metals since, at the elevated pH of the cement mixture, most metals will be converted to insoluble hydroxides or carbonates. Unfortunately, this conversion can be reversed under acidic leaching conditions; therefore, cement solidification alone may not be an acceptable final treatment for metal wastes.

Organic wastes are not effectively immobilized by cement solidification. Organics can interfere with the setting reaction of the Portland cement, affecting the durability and leaching characteristics of the final product. Generally, this precludes the use of cement solidification as a treatment for organic wastes.

Silicate based solidification involves the addition of a source of silicates along with a setting agent. Silicates are often added in the form of fly ash, blast furnace slag, cement kiln dust, or soluble silicates such as potassium or sodium silicate. The setting agent is typically Portland cement or lime, although other suitable materials are available. Proprietary additives have been developed by several vendors designed specifically to result in the immobilization of various organic contaminants. The final product can be monolithic or granular in appearance.

Several companies have claimed success in applying their silicate based process to a wide range of organic wastes, including PCBs. Site-specific testing using actual contaminated New Bedford Harbor sediments will be necessary to determine which, if any, of these processes could be successfully used on this project.

It is assumed that the selected method for removal of sediments from the Harbor and Bay will produce a waste stream with a low (15 percent to 25 percent) solids content. Most solidification processes can handle a dilute solids stream such as this; however, it would be more cost effective to apply a dewatering step as an initial pretreatment measure. This would reduce both the amount of required additives and the final volume of treated waste. Dewatering processes are evaluated elsewhere in this report.

Final disposal of the treated end product will also be necessary. The actual handling and disposition of the final product will depend primarily on the demonstrated effectiveness of solidification in immobilizing the contaminants of concern and on institutional constraints.

Two possible applications are envisioned for solidification in the treatment of New Bedford Harbor sediments. The process could be used as the primary treatment technology for all of the waste constituents present in the sediments, or it could be used as a support process for immobilization of metals following the application of another technology for destruction or detoxification of organic contaminants.

As the primary treatment technology, solidification would be used to immobilize and incorporate all of the waste contaminants within the final, solidified mass. The precise process and types of additives cannot be selected until extensive testing of the available processes is conducted on actual New Bedford Harbor sediments; however, a general discussion of how solidification would be applied at the New Bedford Harbor site can be presented. For the purposes of this section, it is assumed that sediments will be removed from the harbor and treated by dewatering operations prior to application of the solidification process.

The primary process components of the solidification process are metering and adding solidification agents, blending in a batch mixing plant, and discharging to forms for setting and curing.

Since the actual volume of sediments to be treated has not yet been established, and could potentially range form 20,000 to 2,000,000 cubic yards, generalizations regarding on-site operations and equipment are difficult. It is expected, however, that either mobile or semi-permanent batch mixing plants would be set up on site. Bulk storage tanks and/or silos would be installed for storage of solidification additives. The waste stream would be delivered directly from the dewatering operation to the mixing plant. Solidification agents would then be measured and added to the waste stream. Carefully controlled blending of the sediments with the solidification agents would occur within the mixing plant, after which the final product would be discharged for placement into forms for setting and curing. Cured blocks of treated sediment would be ready for transport to the final disposal site within one to three days. Alternatively, the blended material could be discharged directly into trucks for transport to a local disposal site for placement and curing.

As a support process, solidification would be particularly useful for fixation of metals following treatment of the sediments for PCBs and other organics by a separate process. For instance, if incineration is chosen as the preferred destruction technology for PCBs in the sediments, the residual solids would still be likely to contain unacceptable levels of metals. Solidification has been well demonstrated as an effective treatment process for metals. It is anticipated that incineration followed by solidification would result in a completely innocuous end product for ultimate disposal.

Application of solidification as a support process would be similar to its use as a primary treatment technology. The principal differences would be that the waste stream would be the treated solid effluent from the PCB destruction process, and that the types of solidification additives would most likely be different.

6.3.2 Effectiveness

Reliability. It is anticipated that solidification will achieve a permanent reduction in the mobility of the contaminants present in the sediments. The extent to which mobility will be reduced is dependent on the type of solidification process used, and may vary for the different types of contaminants. Demonstration of the effectiveness in achieving this response objective will require bench and pilot scale testing. The long-term stability of the treated waste is relatively undocumented for PCBs and other organics. In the absence of valid performance data, a testing program would be necessary to monitor for any deterioration in the effectiveness of the immobilization of these contaminants.

In regard to the immobilization of metals, the long-term effectiveness of solidification is reasonably well documented. Vendors have subjected samples of treated sludges containing high levels of metals to the EPA's Multiple Extraction Procedure (MEP), a test designed to simulate 1,000 years of leaching under acidic conditions, without exceeding maximum allowable concentrations in the extract. The reliability of the process when used in support of a separate technology for PCB destruction would therefore be considered good.

Protection of Public Health. The potential for adverse health effects from both short- and long-term exposure will be substantially reduced by solidification of the sediments. In terms of exposure to PCBs and organics, a detailed discussion of the actual human health risks from exposure to the treated sediments must wait until the health risk assessment and bench and/or pilot testing results are available. For metals, it is expected that bench testing will demonstrate that treatment by solidification will comply with all ARARs.

An additional public health concern is worker exposure during the solidification process. The major routes of exposure would be through direct contact and vapor inhalation. It is not expected that dust control will present a problem, due to the relatively high moisture content of the material as it is being handled. Potential worker exposure can be controlled through careful planning and the implementation of strict health and safety procedures during the work. Continuous air quality monitoring would be required to demonstrate that there was no impact to potential off-site receptors.

Protection of the Environment. The benefits to the environment from treatment of the sediments by solidification will be the same as for the other detoxification/destruction technologies being evaluated in that the contaminants are being removed from the areas that they have impacted. The extent to which the contaminants will be effectively isolated from the environment by treatment of the sediments will be determined by the results of bench testing. The selection of the ultimate repository for the treated sediment will be affected by the results of these tests as well.

Unless solidification can be conclusively demonstrated to completely prevent leaching and/or re-mobilization of contaminants from the treated sediments for an indefinite period of time, disposal of the solidified end product will have to be at an engineered, environmentally acceptable site. The combination of solidification and proper disposal, however, would provide for effective and permanent isolation of the contaminants from the environment.

6.3.3 Implementation

This section will address factors concerning the actual implementation of solidification at New Bedford Harbor. The evaluation criteria are listed below along with a brief discussion of each.

Technical Feasibility. It is technically feasible to implement solidification at New Bedford Harbor. The solidification process is compatible with other anticipated elements of the remedial action. The physical characteristics of the sediments do not present any insurmountable difficulties to the application of solidification. It should be possible to select a process that will effectively immobilize the types of contaminants present in the sediments. If used as a support process, solidification would be compatible with other detoxification/destruction technologies that might be implemented.

Demonstrated Performance. Solidification has been well demonstrated in the field. The equipment used in the process is well proven and reliable. Downtime is expected to be minimal.

With batch mixing plant operation, process monitoring is relatively easy and quality control is good. Bench tests will be necessary to demonstrate the effectiveness of solidification on New Bedford Harbor sediments and to select the particular process with the best performance on the contaminants of concern. A pilot test would be beneficial to develop site-specific production techniques and process parameters.

Support Requirements. Dewatering would be a needed pre-treatment process, primarily for volume reduction, and to reduce the amounts of additives required. Post-treatment would involve the disposal of the treated end product. Selection of an appropriate final disposal site will have to take into consideration the bench test results and institutional constraints.

Availability. Required equipment for solidification is readily available. The necessary materials are also generally available, although the required quantities will result in the need for bulk delivery and on-site storage facilities. Bulk deliveries could be by rail or by truck at New Bedford Harbor.

Installation. Site preparation and set-up time for the solidification process for full scale operation is estimated to be six to eight weeks. Space requirements are estimated at approximately ten acres per batch mixing plant, including space for curing of solidified material. Pretreatment activities, such as dewatering operations, would require additional space. Space limitations will be an important consideration during development and evaluation of remedial alternatives, and may preclude the use of this technology for treatment of large volumes of sediment.

Monitoring and Maintenance. Process monitoring is primarily in the areas of metering of materials entering the batch mixing plant and mixing time. Periodic quality control sampling of both the influent stream and the treated end product would also be conducted. Mixing equipment will require periodic maintenance. It is anticipated that multiple mixing plants would be used on the site, so maintenance could be performed on one unit without halting site operations.

Permitting. Solidification would be considered an on-site remedial action and, as such, would not require actual permits. It would be necessary, however, to demonstrate substantial compliance with applicable federal, state, and local rules and regulations. The actual impact of this requirement will be evaluated during the detailed evaluation of alternatives.

Legal Constraints. Implementation of solidification will require a substantial operating area; therefore, property acquisition will be necessary.

Relatively little opposition is anticipated to the use of this process from either governmental agencies or citizens' groups in comparison to other destruction/detoxification technologies (i.e., incineration).

Impacts on Historical and Critical Resources. The solidification process as it would be applied at the New Bedford Harbor site is not expected to have any impact on historical and critical resources.

6.3.4 Costs

Predicting the cost of solidification of New Bedford Harbor sediments is difficult, due to the lack of any similar past applications. The cost of applying the technology in conventional situations, such as solidifying wastewater treatment plant sludge, is well established and generally runs on the order of $20 to $60 per cubic yard, depending on the physical and chemical characteristics of the waste. The conditions at New Bedford Harbor, however, are more complex in the process and logistics of applying the technology. The cost estimates presented here are based on a limited amount of information, most of which was provided by vendors. Revisions may be required as additional data becomes available.

Capital Costs: Most of the vendors contacted gave cost estimates in the form of unit price ranges. These estimated unit process cover the total cost of the solidification process, including equipment, materials, labor, maintenance, and overhead and profit. Many vendors have specially designed mobile mixing plants for which they provide as part of their on-site services, with the cost of the equipment included in the unit price estimate. One vendor did provide a capital cost. This capital cost, which is approximately $220,000, will be used for preliminary cost projections.

Operation and Maintenance Costs: Operation and maintenance costs constitute the major portion of the cost to implement solidification. This category includes the cost of labor and materials, equipment maintenance, testing and analysis, project administration, and miscellaneous expenses.

Materials cost constitutes the major portion of the cost of solidification. Based on information provided by one vendor, Portland cement would be added to the sediments at a rate of approximately 0.5 tons/cu.yd., and the proprietary additive would also be used at approximately 0.5 tons/cy.yd. Using $75/ton for Portland cement and $50/ton for the proprietary additive, the total materials cost would be approximately $62.50/cu.yd.

Labor costs can be estimated based on the following assumptions:

- o capacity of batch mixing is 40 cu yd./hr.
- o labor requirements per mixing plant are 15 people
- o average labor cost including overhead is $30/hr.

These assumptions result in a labor cost of $11.25/cu.yd.

The remaining elements of this cost category (i.e., maintenance, testing, administration, miscellaneous) will be estimated at 15 percent of materials and labor.

Adding all of these elements together, it is estimated that the operation and maintenance costs for solidification will be approximately $85/cu.yd. for an operation involving a single batch mixing plant. In the event that multiple mixing plants are used on-site, some economy of scale could be expected. For purposes of this cost projection, it is estimated that unit operation costs will decrease by approximately 5 percent for each additional batch mixing plant. Table 6-3 summarizes cost estimating information for solidification. Figure 6-3 presents the total cost of solidification operations over a range of volume of sediment requiring treatment.

TABLE 6-3
SOLIDIFICATION COST ESTIMATE

CLEANUP GOAL (PPM)	VOLUME OF SEDIMENT AT 50% SOLIDS REQUIRING TREATMENT (CU.YD)	# OF MIXING UNITS	CAPITAL COST OF MIXING UNITS	OTHER CAPITAL COSTS (30% OF MIXING UNIT COST)	OPERATING ($/CU.YD)	TOTAL OPERATING COST	TOTAL COST	UNIT COST ($/CU.YD)
5,000	24,000	1	220,000	66,000	85	2,040,000	2,330,000	97.1
500	161,000	2	440,000	132,000	81	13,000,000	13,600,000	84.5
100	440,000	2	440,000	132,000	81	35,600,000	36,200,000	82.3
50	639,000	3	660,000	198,000	77	49,200,000	50,100,000	78.4
10	1,300,000	4	880,000	264,000	73	94,900,000	96,000,000	73.8
1	4,270,000	4	880,000	264,000	73	312,000,000	313,000,000	73.3
ND	5,660,000	4	880,000	264,000	73	413,000,000	414,000,000	73.1

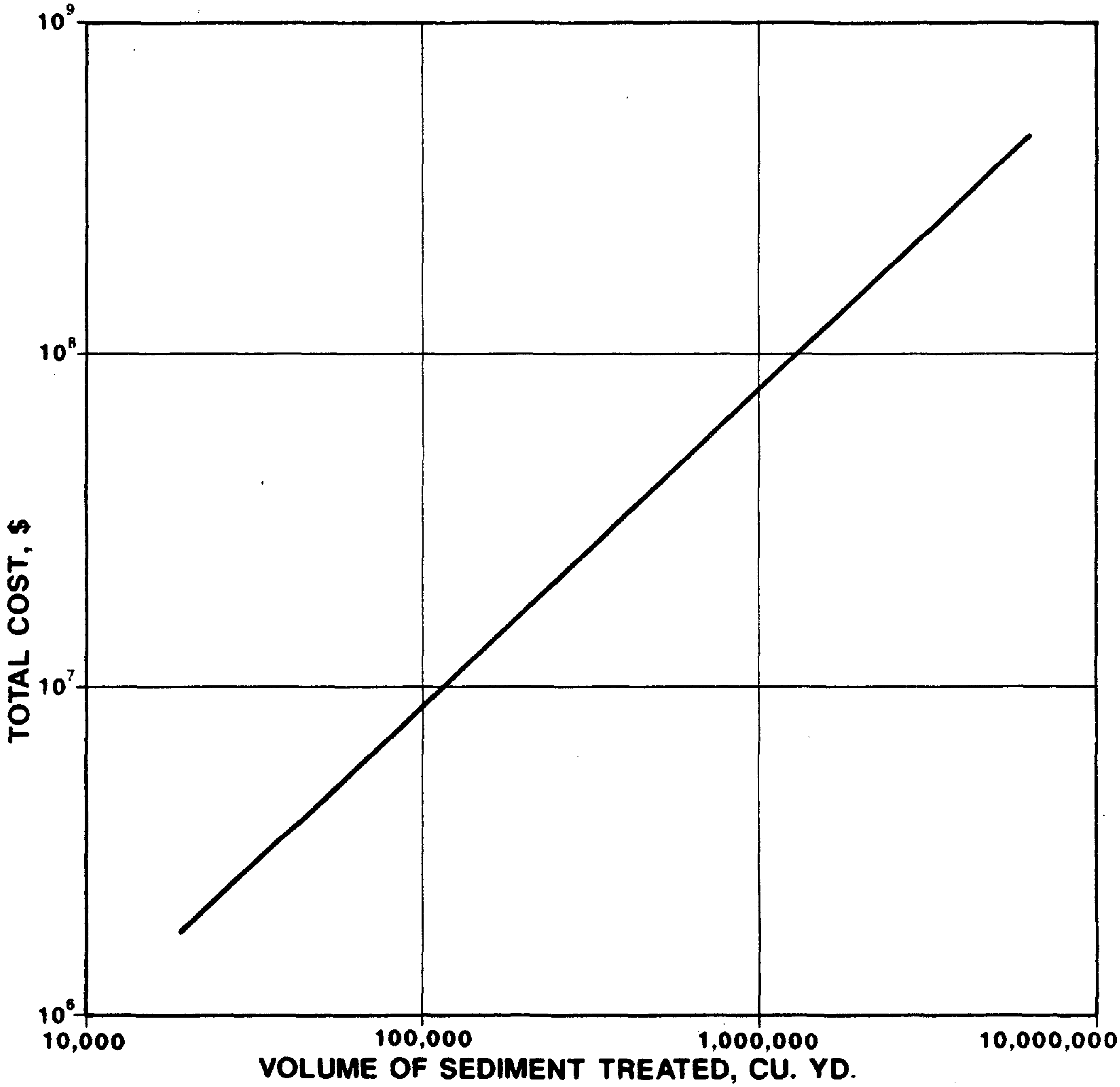

FIGURE 6-3
SOLIDIFICATION TREATMENT COST VS. VOLUME TREATED

E.C.JORDAN CO.

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Sensitivity Analysis: The costs presented in this section are approximate and are based on a limited amount of information. It is likely that one or more of the estimated costs will vary substantially from the actual cost. It is therefore necessary to perform a sensitivity analysis on the cost element to determine the potential impact on the total cost of variances in the cost of individual cost elements.

The following elements have been selected as having the greatest potential for variability: volume of cement, volume of proprietary additive, cost of proprietary additive, labor rate, capital cost. The effects of any element varying by +50 percent to -30 percent are presented in Table 6-4.

6.3.5 Summary

Solidification is a proven technology for substantially reducing the mobility and toxicity of inorganic contaminants. The technology is not well proven for organics, although several demonstration projects are currently under way, including a project being performed as part of the SITE program. Space requirements are substantial, which may be an important consideration at New Bedford Harbor. If the effectiveness of solidification for immobilizing PCBs can be demonstrated for actual New Bedford Harbor sediments, it has the potential for being a cost-effective permanent treatment technology, with an

TABLE 6-4
SENSITIVITY ANALYSIS ON SOLIDIFICATION COST ESTIMATE ELEMENTS

ESTIMATED ELEMENT	ESTIMATED VALUE	-30/+50 RANGE	EFFECT ON TOTAL ESTIMATED UNIT PRICE
Volume of Cement	0.5 ton/cu.yd.	0.35-0.75 ton/cu.yd.	- $11.3/cu.yd., +$18.8/cu.yd.
Volume of Proprietary Additive	0.5 ton/cu.yd.	0.35-0.75 ton/cu.yd.	- $7.5/cu.yd., +12.5/cu.yd.
Cost of Proprietary Additive	$50/ton	$35-$75/ton	- $7.9/cu.yd., +$16.9/cu.yd.
Labor Rate	$30/hr.	$21-$45/hr.	- $7.9/cu.yd., +$16.9/cu.yd.
Capital Cost	$288,000/unit	$202,000-$432,000/unit	- $3.6/cu.yd., +$6.0/cu.yd. @24,000 cu.yd. total
			- $0.1/cu.yd., +$0.1/cu.yd. @5,660,000 cu.yd. total

estimated cost ranging from $73.1/cu.yd. to $97.1/cu.yd. In the event that solidification is used as a support technology for immobilizing metals, it is estimated that the implementation cost would range from $20/cu.yd. to $60/cu.yd.

Based on this evaluation, solidification is recommended for consideration as a treatment technology during the development of remedial alternatives for the New Bedford Harbor site. It is also recommended, however, that bench scale and/or pilot scale tests be conducted to verify the applicability of the process to the actual conditions at New Bedford Harbor.

6.4 VITRIFICATION

This section discusses the feasibility of treating the sediments at New Bedford Harbor by heating them into a molten state and cooling the melt to form a vitrified product. Several technologies are available which can heat silicate based material to the melting point, and thereby destroy organics and encapsulate inorganics into a glass matrix which has a very low potential for leaching. These processes have been modified to handle contaminated soils and are being marketed for hazardous waste remedial action. This section discusses three of these technologies which have been suggested for application at New Bedford Harbor: a modified process for processing minerals into high purity glass; a combustion device which uses a glass bath to distribute heat and encapsulate inerts in the feed stream; and a modified in situ vitrification process.

6.4.1 Description

Three types of vitrification are evaluated in this report.

Geotech Process - The first process is a continuous flow melt process which is modified from the silica materials processing industry. This process has been used to produce high-purity glasses and fibers and is now being applied to solid hazardous wastes. Information describing this process was received from Geotech Development Corporation (Geotech, 1987).

The Geotech process involves introducing a relatively dry feed into a nine-foot-diameter melting pot where temperature is maintained by three electrodes submerged in the melt. The melt is maintained at a temperature of greater than 2500°F. Off gases from the electric melting furnace are collected in an overhead hood and transferred to a baghouse. A pouring orifice at the base of the melting pot provides a continuous stream of molten material which solidifies as a dense glass. A similar conversion from glass bath process to waste destruction has been pursued by Penberthy Electromelt (Penberthy, 1987).

Westinghouse Electric Pyrolyzer - The electric pyrolyzer developed by Westinghouse uses an electrically heated glass bath to provide heat for thermal destruction of hazardous organics (Westinghouse, 1987). The electric pyrolyzer resembles the glass bath processes described above, but was designed for hazardous waste processing and, therefore, includes greater control and safety equipment.

The electric pyrolyzer feeds waste into a molten glass bath maintained at 3000°F. The primary chamber is operated with low levels of oxygen resulting in pyrolytic conditions. Off gases pass into a cooling and gas clean-up system including a cyclone, a baghouse, and an acid gas scrubber. Molten material is tapped from the reactor and quenched by water. The cooled residue is a dense, glass-like material which displays low leaching potential.

Modified In Situ Vitrification - A system for in situ vitrification of contaminated soils has been developed by Battelle Pacific Northwest Laboratories (Buelt, 1986). This process could be modified for onshore application to dredged sediments at New Bedford Harbor. Onshore application would involve placing the dredged sediments into a large container and inserting metal electrodes into the material. These electrodes are constructed out of molybdenum and placed approximately 15 feet apart. Each electrode extends approximately twelve feet into the contaminated material. An electric current is applied to the electrodes and heat is given off along a conductive path of graphite and glass frit placed on the surface of the material. The heat raises the surrounding sediment to temperatures in excess of 3600°F and creates a melt which slowly moves through the material. Organic materials are consumed by pyrolysis as the melt expands to include all of the material between and around the electrodes. The entire process requires 150 to 200 hours.

Volatilized gases migrate to the surface where they combust with oxygen. The products of combustion are collected in a stainless steel hood which is placed over the area being vitrified. This hood directs the gaseous effluents to an off gas treatment system which includes an acid scrubbing system followed by HEPA filters. The large scale equipment has been described by Buelt and Carter (Buelt, 1986).

This technology has been applied to relatively dry soils (<20 percent moisture) for radioactive waste treatment. To apply the technology at New Bedford Harbor, the melt would either be induced at the site of ultimate disposal, or the resulting 200-ton glass block would have to be blasted into pieces for transport to a disposal site.

All three technologies have an advantage over incineration due to the ability to bind inorganics into a glass residue which has a low probability of leaching. Each of the applications may require modification to improve the handling of off-gases. All three have been demonstrated on the pilot scale for some applications, but none are being used on the full scale. A large glass bath is capable of handling up to 100 tons/day of feed, so that multiple units may be required for larger applications. None of the processes is designed to handle high moisture contents and the use of electricity as a heat source will result in high costs to volatilize excess moisture. All of the processes operate with high energy requirements (~4 MW for a large unit) and would require significant planning to ensure power availability and install electrical equipment.

The following sections present a detailed evaluation of the three vitrification processes with specific attention to New Bedford Harbor conditions.

6.4.2 Effectiveness

Reliability. Vitrification would provide a method to permanently reduce the toxicity of all organic contaminants and immobilize the inorganic contaminants found in the sediments. Each of the three systems discussed in this section would produce a glassy melt which would immobilize inorganic constituents. The long-term effects of disposing of the vitrified sediment would be minimal due to the low leaching potential of the glass.

Public Health. Vitrification of sediment would eliminate long-term health effects associated with exposure to hazardous organics and inorganics in New Bedford Harbor. A short-term risk would be associated with the operation of the hazardous waste processing train at New Bedford. This risk would be associated with the potential for process upsets and emissions resulting from insufficient process control. If operated incorrectly, thermal processes which operate in the pyrolytic mode exhibit a tendency to produce products of incomplete combustion, some of which may be hazardous if emitted into the atmosphere. The potential for system upsets and emissions may be minimized by proper process design and control measures. Bench scale testing of the in situ process showed no detectable levels of PCBs in the vitrified product (Battelle, 1986).

The processes proposed for New Bedford Harbor could be optimized by appropriate use of off gas controls. For processes which are treating hazardous compounds, controls include an after burner or other secondary chamber which increases the time-temperature relationship for combustion gases. Other appropriate controls include scrubber systems to control HCL emissions and particulate control devices such as baghouses or venturi scrubbers. Several of the processes which are based on glass making technologies do not include all of these control measures and would require development prior to implementation.

The *in situ vitrification process operates over a wide* temperature range. The melt conditions are a function of the medium being vitrified, and the process does not have controls to ensure adequate thermal conditions. This process is capable of producing products of incomplete combustion which pass into the off gas control train. In bench scale applications, this train has been outfitted with a carbon adsorption filter to trap residual organics in the off gases. This additional step would likely be required for full scale operation as well.

Proper control measures would result in the vitrification process being a highly effective means of destroying PCBs and immobilizing metals.

Environment. Vitrification would destroy or immobilize virtually all of the organics in sediments removed from the harbor. Metals would be immobilized and would therefore pose a very low long-term risk to the environment.

Potential adverse environmental effects from the improper operation of the process would result in release of low levels of products of incomplete combustion.

Vitrified residues resulting from this process could be used in an environmentally safe manner as construction materials or road base material, safely disposed of in a municipal landfill, or returned to the harbor.

6.4.3 Implementation

This section discusses the issues involved in the engineering implementation of the vitrification technology.

Technology Feasibility. Vitrification is theoretically feasible and has been demonstrated as a process for handling soils, ashes, and a variety of other materials. The high temperatures are sufficient to destroy all organics and produce a melt which will cool into a glass which immobilizes metals. The process of producing glass from sediment is well proven and can easily be developed for application at New Bedford Harbor.

Concerns about vitrification include choosing the appropriate off gas handling equipment, and handling sediments with a high moisture content. Appropriate off gas handling equipment can be applied using technologies used in hazardous waste incineration. These have not been widely applied to glass making technology but could be adapted without extensive effort.

A glass furnace is not a particularly efficient method to evaporate moisture. Predrying the sediment would improve the performance of the systems. For the in situ process, excess moisture could have significant effects on the performance of the process. High moisture content slows the progression of the molten zone and results in longer processing times and higher processing costs. Dewatering processes which would reduce the moisture content to less than 20 percent should be investigated prior to implementing this technology.

Demonstrated Performance. Vitrification is based on the well established technology of processing silicates into glass. These processes have seen limited application on hazardous wastes, but are currently being marketed for that purpose. None of these systems have been permitted for RCRA or TSCA applications. The Westinghouse system was developed for application to hazardous materials and is in the process of undergoing pilot performance testing. The in situ process has been demonstrated successfully for nuclear waste materials on the full scale and for PCBs materials on the bench scale. Down time estimates are not available since extended full scale operation has not been achieved.

Support Requirements. Mechanical dewatering followed by vacuum dewatering or thermal drying would be necessary as a pretreatment for process feeds. Scrubber effluents would require neutralization prior to discharge or disposal.

Availability. Any unit which would be used at New Bedford Harbor would need to be capable of handling 100 tons/day of sediment. These units would need to be fabricated, and would require 6 months or more to prepare. These systems could be constructed on a flat level area, requiring approximately 10,000 ft^2 for each unit.

Installation. Vitrification processes are powered by electricity and have high power requirements when compared to other treatment processes. A typical full scale, 100 ton/day system requires 3 to 4 MW of power. If several of these units were to be used at New Bedford for a large volume cleanup, a significant investment of time and resources would be required to coordinate and deliver the necessary power. The ability of the power network in New Bedford to deliver these levels has not been addressed in this report.

Time. Time requirements for construction and implementation of molten glass bath technologies are similar to those for incineration. Time requirements in situ vitrification are presented in Table 6-5.

Safety. Vitrification systems do not pose any significant safety hazards when operated by trained personnel in a properly designed and controlled facility.

TABLE 6-5

TIME REQUIREMENTS FOR
CONSTRUCTION AND IMPLEMENTATION OF IN SITU
VITRIFICATION

Site Preparation	3 months
Mobilization	1 month
Shakedown	1 month
Treatment	Approximately 1 hour/ton
Demobilization	1 month

Monitoring and Maintenance Requirements. Vitrification systems require continuous monitoring of a variety of process parameters to control and maintain combustion conditions. These measurements are used to adjust power requirements and off gas equipment operating conditions.

Regular maintenance must be conducted on these systems. Refractory in the ceramic lined glass baths must be replaced every three to five years. In situ vitrification experiences occasional problems with oxidation of the electrodes which must be monitored. New electrodes must be used for each new batch of sediment.

The air pollution control systems for controlling emissions are complex and require continuous monitoring and maintenance. If carbon adsorption units are used for the in situ process, these units will need to be monitored to avoid carbon exhaustion.

Permitting. A systematic method for permitting vitrification processes has not been established under RCRA or TSCA. Permits are not required for treatment on Superfund sites, but it is reasonable to assume that the technical requirements for TSCA incinerators would need to be met for emissions. Demonstrating these requirements and other regulating requirements will require six to twelve months.

Legal Constraints. Acquisition of land and zoning will be addressed in the evaluation of alternatives. A disposal site for vitrified sediment must be designated. A public education and information campaign in conjunction with the announcement of the alternative would help to address potential public opposition to this program.

Impacts on Historical and Critical Resources. This area will be addressed in the alternatives evaluation.

6.4.4 Costs

This section presents cost information for implementation of vitrification at New Bedford Harbor. Cost information has been developed using the information obtained from vendors in response to questionnaires.

Capital costs are derived from equipment and system installation costs. These processes require a large amount of electricity. Conversations with utility company representatives in the New Bedford Harbor area revealed the need for extension of power lines into the area and construction of a transformer station at the processing site. These improvements could introduce an added delay of up to one year in the schedule.

Capital costs and operating costs are based on molten glass units capable of processing 100 tons/day and modified in situ units capable of vitrifying 600 tons of sediment slurry in 200 hours. Each system is estimated to incur 20 percent downtime for maintenance. Energy costs are based on 7.4 cents per kilowatt hour, which is the minimum power cost available in the New Bedford area. These costs are summarized in Table 6-6, and presented in graphic form in Figure 6-4.

The principal parameters which will affect process costs are energy costs and moisture content of the feed stream. The performance of in situ vitrification on sediments with high moisture contents has not been demonstrated; therefore, time and energy requirements are estimates. Further information will be available as a result of bench scale testing.

Overall, vitrification costs are higher than incineration costs. The advantages of vitrification include the ability to immobilize inorganics in a non-leachable form. This process is comparable to a combination of incineration/solidification of the residuals.

6.4.5 Summary

Vitrification would permanently reduce the toxicity, mobility, and volume of the contaminated sediments by destroying organics, immobilizing inorganics, and producing a glass-like product. This

TABLE 6-6

COST ESTIMATES FOR VITRIFICATION PROCESSES

	Molten Glass Reactor	Modified In Situ Process
Capital Costs		
Equipment Cost	$3,300,000	$2,342,000
Transformers	$ 600,000	--
Line Extension	$1,000,000	$1,000,000
Mobilization and Demobilization	$ 210,000	$ 750,000
Design and Engineering	$1,000,000	$ 468,000
TOTAL CAPITAL	$6,110,000	$4,560,000
Operations an Maintenance Cost		
Power Required	4000 KW	4000 KW
Operating Period	1 hour	200 hours
Total Mass Treated	5 tons	600 tons
Total Mass Treated/Year	33,000 tons	21,000 tons
Total Energy Required/Year	35,040,000 KWH	28,032,000 KWH
Energy Cost/Year	$2,630,000	$2,102,000
Additional Energy Costs	$1,000,000	$500,000
Maintenance Costs	$500,000	$250,000
Air Pollutants Equipment Operating Costs	$250,000	$250,000
Labor (15 person crew)	$900,000	$900,000
Protective Equipment	$250,000	$250,000
Monitoring	$1,000,000	$1,000,000
Miscellaneous Operations and Maintenance	$1,306,000	$1,200,000
Electrodes		$ 742,000
TOTAL OPERATIONS AND MAINTENANCE	$7,836,000	$7,194,000
Unit Cost Estimate (based on ten years operation)		
Capital	6,110,000	4,560,000
O&M	78,360,000	71,940,000
TOTAL	$84,470,000	$76,500,000
Yards Treated	270,500	172,130
Unit Cost	312	444
Unit Cost with 50% Markup	468	666

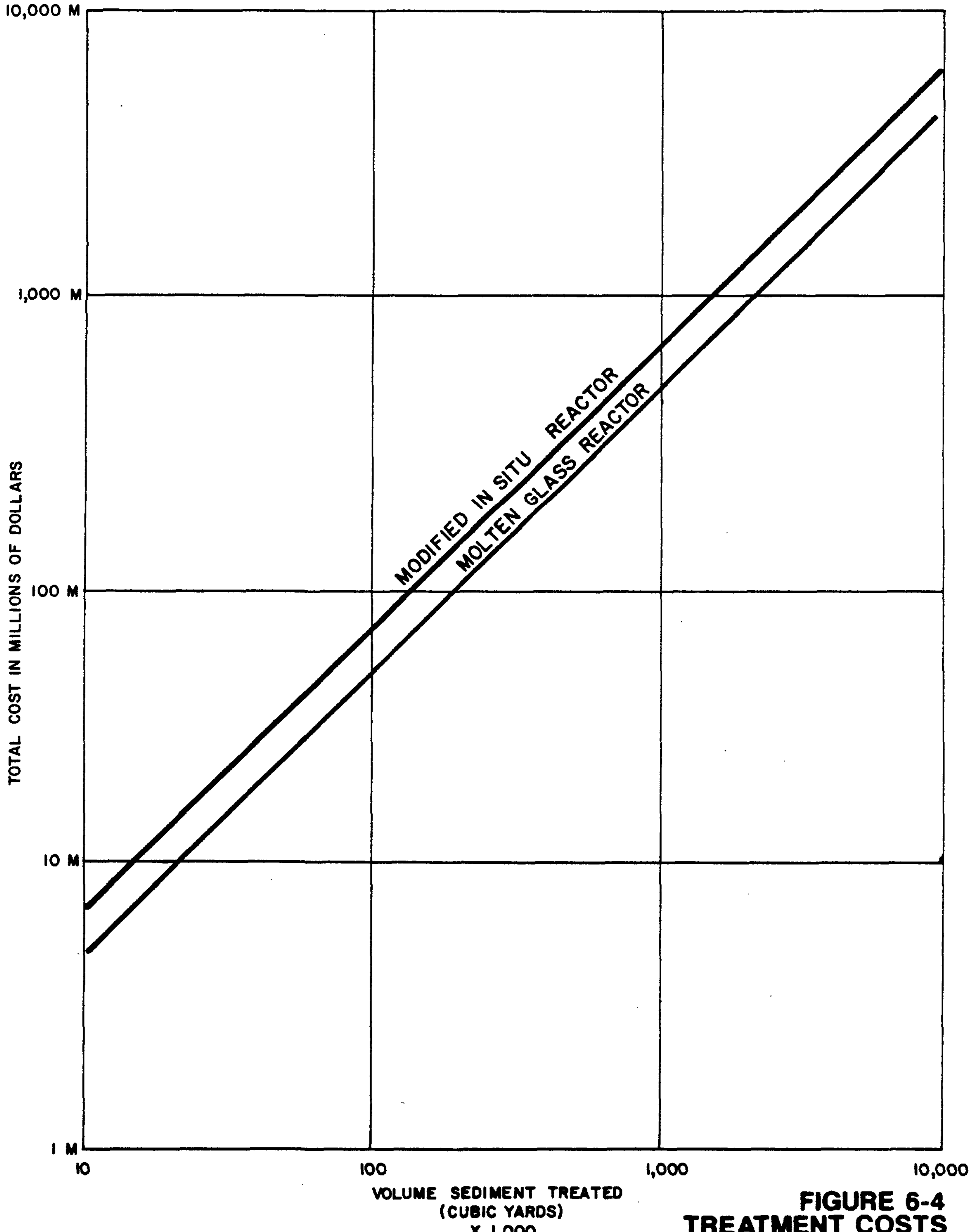


FIGURE 6-4
TREATMENT COSTS FOR VITRIFICATION
NEW BEDFORD HARBOR, MASSACHUSSETS

E.C.JORDAN CO.

4959-21

technology has not been demonstrated for sediments, and significant questions remain in determining operating costs. Vitrification will be retained pending the results of bench testing. The bench test results should provide answers as to the technical feasibility and cost of this process.

6.5 ALKALI METAL DECHLORINATION (KPEG)

KPEG stands for the potassium-polyethylene glycol dechlorination process. The process removes chlorine atoms from PCB molecules leaving a less toxic, biphenyl molecule as a residual.

KPEG is part of a class of processes termed alkali metal dechlorination processes (APEG). Both potassium and sodium have been used as the alkali metal. Alkali metal dechlorination was developed for use in decontaminating PCB-containing transformer oils and has been adapted for use on PCB- and dioxin-contaminated soils.

Galson Research Corp. is presently the major entity pursuing the development of the process.

6.5.1 Description

The KPEG process involves mixing the contaminated sediment with an alkaline reagent consisting of potassium hydroxide in polyethylene glycol. Other solvents (e.g., dimethyl sulfoxide) are sometimes added to the process to increase the rate of the reaction and the rate of transport of PCBs from sediment into reagent. A steam jacket around the reactor heats the reactor to 150°C and volatilizes the water off. The dechlorination reaction then proceeds to completion in one to four hours.

After the reaction is complete, water is added to the reactor to provide cooling and to dissolve excess potassium hydroxide and lead hydroxide salts present. The sediment/reagent/water mixture is then discharged to a belt filter press where the reagent is recovered for recycle. Repeated water addition and subsequent dewatering via the belt filter press is necessary to remove excess reagent still present in the sediment.

After treatment the sediments contain:

- o moisture making up to 50 percent of the residual by weight (this is the expected limit of dewatering which can be achieved by the belt filter press);

- o small amounts of polyethylene glycol and dimethyl sulfoxide (about 1,300 ppm PEG will remain in the sediment after 2 water wash cycles);

- o heavy metals not dissolved in the PEG; and

- o trace amounts of dechlorinated biphenyls.

The reagent and wash water are treated and recycled for reuse in the process.

To ensure that the wash water for the final sediment wash is clean, the water will require carbon adsorption prior to discharge.

Ancillary treatment steps will periodically precipitate metals and remove dechlorinated PCBs from the reagent.

The KPEG process is currently at the bench/pilot scale stage. The largest test to date was performed at the Bengart-Memel site where KPEG decontaminated 50 drums of PCB-contaminated soil to less than 5 ppm PCB (Peterson, 1987). Because KPEG has not yet been used full scale, the process flow diagram, description of process equipment, and costs presented in this evaluation should be considered conceptual.

The effectiveness, cost, and implementation of KPEG depend on the characteristics of the site-specific waste being treated. The effect of the New Bedford Harbor sediments' organic content, particle size distribution, PCB congener distribution and water content will be investigated by bench scale testing.

6.5.2 Effectiveness

KPEG meets the intent of SARA by permanently reducing the toxicity of PCBs via dechlorination. The end product is a biphenyl ether which is not acutely toxic, does not bioaccumulate, and is not mutagenic (as shown by USEPA toxicology testing) (Peterson, 1987).

KPEG has the added advantage that the PCBs are not only dechlorinated; most are also removed from the sediment by the reagent and wash water. The dechlorinated PCBs are subsequently separated for destruction by treating the liquid streams with activated carbon.

KPEG has successfully treated soils in the laboratory to less than 40 ppb PCB. Routinely, KPEG achieves PCB destruction to less than 1 ppm in the laboratory. Pilot testing of KPEG was successful to less than 5 ppm PCBs.

Although some of the metals present in the sediments will also be removed during the KPEG process, the sediment may not pass EP toxicity tests. The sediment could not be returned to the harbor as a non-hazardous waste and would either require metals treatment (e.g., solidification) or disposal in a secure landfill.

Metals and biphenyls removed from the process must be subsequently disposed. The metals can be solidified and landfilled, and the biphenyls will be incinerated during carbon regeneration.

The sediments retain some of the reagents (polyethylene glycol and dimethyl sulfoxide) even after washing with water. The reagents are relatively non-toxic and are not expected to be a serious concern. The level of PEG remaining after two wash cycles is estimated at 1,300 ppm (Peterson, 1987).

6.5.3 Implementation

Technical Feasibility. The alkali metal dechlorination processes are well demonstrated for use on PCB soils. However there has been only limited success of KPEG on soils and sediments.

Level of Development. In the laboratory KPEG performs well on soils where conditions can be controlled and soil moisture is eliminated. Larger scale tests show mixed results:

- o Alkali metal dechlorination application to on-site soils was not effective when the soil was moist (Iaconianni, 1985).

- o At the Shenandoah Stables site moisture in excess of four percent was found to deactivate the KPEG reagent and reduce its ability to destroy halo-organic compounds (des Rosiers, 1986).

- o The largest successful soil test to date is a pilot scale cleanup of PCB-contaminated soil achieved at the Bengart-Memel scrapyard in Buffalo, New York. PCB concentrations were reduced to less than 5 ppm (Rogers, et. al., 1986).

Support Requirements. Support processes are necessary to make KPEG work on a large scale. These processes include:

- o dewatering via a belt filter press and volatilizing remaining water from the sediment;

- o reagent removal from the treated soil;

- o wash water treatment to remove contaminants;

- o reagent treatment to remove dechlorinated biphenyls, other organics and metals;

- o carbon regeneration; and

- o treatment to fix metals or sediment disposal in a secure landfill.

Dewatering: KPEG will not dechlorinate PCBs in the presence of water. Wet sediments must be dewatered to the extent possible prior to KPEG treatment. The initial step in the KPEG process (after dewatering) is to heat the sediment to 150°C. Water vapor is removed as steam, thus enabling the reaction to proceed.

Reagent Removal: Fine grained materials affect the process by making it difficult to separate the reagents from the sediments following treatment. This is a major obstacle to using KPEG at New Bedford Harbor. A belt filter press could be used to overcome this problem. By alternately pressing the reagents/wash water from the sediments and adding fresh wash water, the majority of the solvent is theoretically removed from the sediment. Galson projects that two wash water cycles will reduce the PEG concentration in the sediment to 1,200 ppm.

Reagent Treatment: A carbon adsorption unit will periodically remove dechlorinated biphenyls and other organic compounds from the reagent. Metals will be removed by precipitation if they accumulate to levels which inhibit the reaction.

Water Treatment: The water vaporized during the initial heating of the reactor will be condensed, then treated with carbon to remove any PCBs or organic compounds which volatilize with the water. This clean water will be the final wash water for the process.

Carbon Regeneration: A commercial carbon facility will regenerate carbon off-site.

Sediment Metals Treatment: Solidification of the sediments and disposal in a secure location are discussed elsewhere in this report.

Installation. The KPEG technology is still at the bench/pilot scale; full scale treatment units are not available at this time. The full scale process will require special equipment to handle the hot corrosive reagent. Galson expects to have one full scale unit available in 1988; more could be constructed within 6 to 12 months of decision to use KPEG at New Bedford Harbor.

Mobilization at the site after equipment is constructed will take 4 to 12 months, depending on the volume of sediment to be treated.

Permitting. KPEG would be an on-site remedial action and would be exempt from permitting requirements. However, air emissions, water discharges, and residual solvent in the treated sediments must still meet the applicable regulatory requirements. These requirements will be addressed in the detailed evaluation of alternatives.

Institutional Constraints. Land to set up and operate KPEG will be required. Public concern over sediment treatment using KPEG would most likely result from a concern for the environmental discharges (i.e., air emissions, water discharges and residual solvent in treated sediments) from the process. An aggressive public education program for the dredging and disposal of treated sediments could help to address these concerns.

Impacts on Historical and Cultural Resources: The KPEG process is not expected to have any effect on historical and cultural resources.

6.5.4 Costs

Table 6-7 contains a cost estimate for implementing KPEG at New Bedford Harbor. This cost estimate is based on treating 500,000 cubic yards of sediment at 50 percent solids.

TABLE 6-7
COST ESTIMATE FOR KPEG

<u>Capital Costs</u>	
Equipment	$10,800,000
Mobilization/Demobilization	560,000
Engineering	1,000,000
Permitting/Administration	2,000,000
Site Preparation	1,000,000
TOTAL CAPITAL COSTS	$15,360,000
<u>OPERATING COSTS</u>	
Maintenance	$11,860,000
Labor	9,880,000
Protective Equipment	1,710,000
Fuel	42,090,000
Other Utilities	1,370,000
Monitoring	9,150,000
Water Treatment	1,025,000
Reagents	2,500,000
Miscellaneous	2,000,000
TOTAL OPERATING COSTS	$81,585,000
TOTAL CAPITAL AND OPERATING COSTS	$94,445,000
UNIT COST	$193/yd.

Note: These estimates are based on treating a 500,000 cubic yard volume.

Most of the cost information was provided in response to a questionnaire from Galson Research Corp.

For a 500,000 cubic yard cleanup, Galson would use three batch reactors capable of treating 22 cubic yards of sediment per batch. The cleanup would take about 3½ years.

Sensitivity Analysis

The amount of dewatering achieved prior to treatment affects the cost of the KPEG dechlorination. Water is boiled off during the first stage of the process. Thus, the higher the water content in the sediments to be treated, the greater the fuel cost for treatment.

A graph showing how cost for KPEG treatment varies with moisture content is presented in Figure 6-5.

6.5.5 Summary

KPEG is not a proven process. Bench and pilot scale test results at other sites indicate that KPEG may work at New Bedford Harbor. Because KPEG is not proven on the type of waste present at New Bedford (estuarine fine grained sediments) the use of KPEG cannot be recommended without bench or pilot scale testing on the site specific New Bedford Harbor sediments. KPEG permanently and

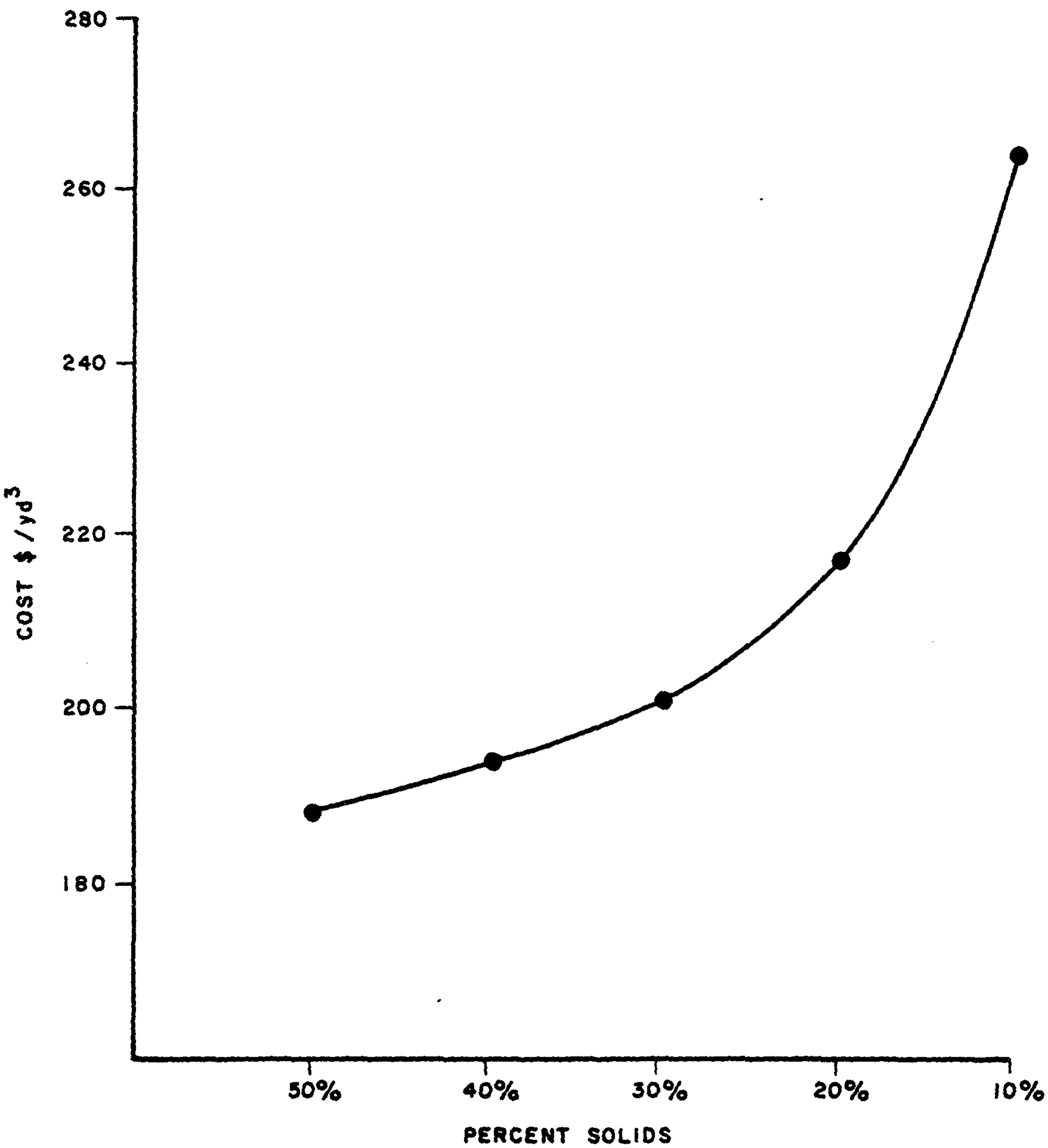


FIGURE 6-5
KPEG TREATMENT COSTS
vs. SOLIDS CONTENT

significantly reduces the toxicity of PCB wastes by dechlorinating the PCBs, thus meeting the requirements of SARA.

KPEG will be carried into the development of alternatives pending the results of bench scale testing during the fall of 1987.

6.6 INCINERATION

Several of the thermal treatment technologies which passed initial screening are being considered together under the heading incineration. The technologies discussed in this section include infrared, rotary kiln, and fluidized bed incineration systems. Each of these systems use a different approach to achieve similar results. The primary differences among the systems are in materials handling and hardware design. These differences will be discussed in this section, but for the purpose of determining effectiveness, implementability, and costs, these systems will be considered together as a group.

Information for the detailed evaluation of incineration was gathered from a number of sources. Compared to other treatment technologies considered in this evaluation, incineration is relatively well proven. This study relied on published handbooks, articles, and vendor information to develop the background data for incineration. In addition, several vendors responded to a detailed questionnaire which asked a series of site specific questions. Responses to these questionnaires are combined with the background data to develop the detailed evaluation profile presented in this section.

6.6.1 Description

Three types of incineration systems are discussed for application at New Bedford Harbor. Each of these systems has a waste feed system, and a combustion zone followed by air pollution control equipment. A process flow diagram for incineration is presented in Figure 6-6. A comparison of the three processes follows.

Waste Feed Mechanism. The infrared system was designed to decontaminate soils, sludges, and activated carbon. The system feeds sediment through a hopper into a wire mesh conveyor belt which conveys the sediment through the primary combustion chamber. This woven belt is designed to withstand the operation temperatures within the chamber. With fine grained material, some of the sediment may sift through the belt into the bottom of the combustion chamber where it will have to be mechanically removed on an intermittent basis. The sediment will be loaded onto the belt in a three inch depth. The system may only accept particles less than six inches in diameter. Auxiliary fuel oil may be sprayed on the sediment to provide energy for complete combustion.

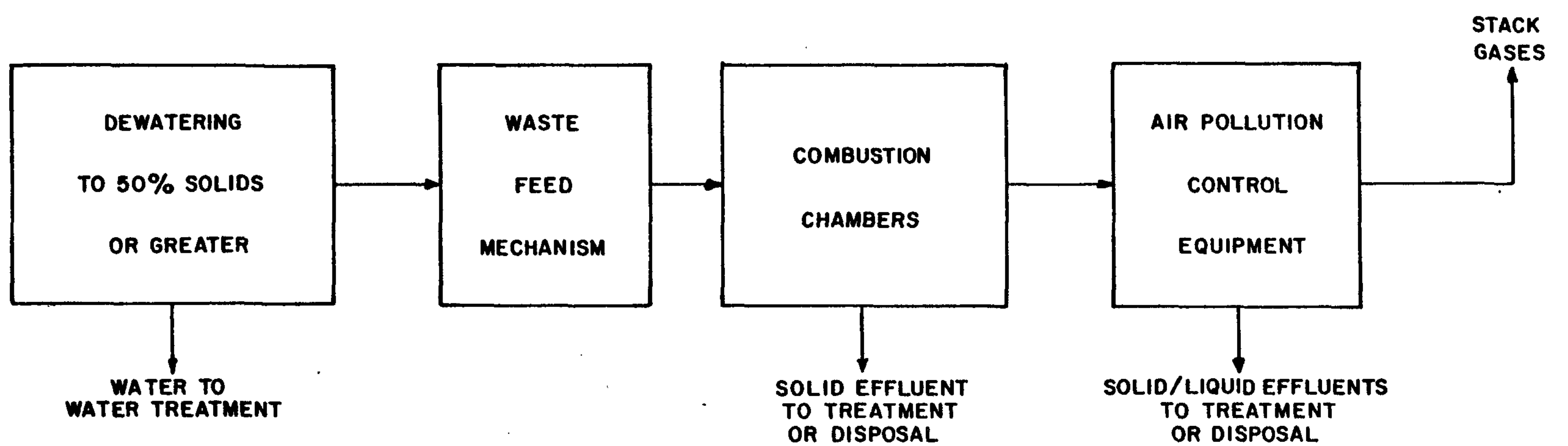


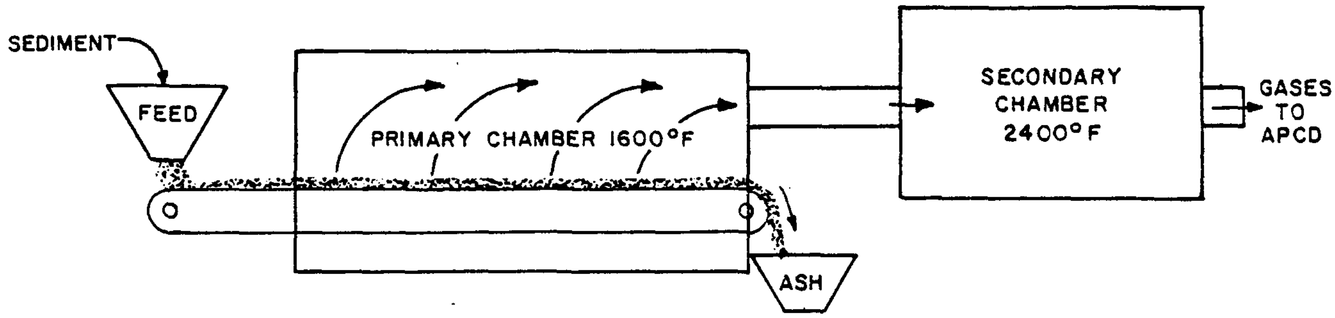
FIGURE 6-6
PROCESS FLOW DIAGRAM FOR INCINERATION

The rotary kiln process is capable of handling the widest variety of feed streams. The rotary kiln incineration system feeds sediment from a hopper into a rotating cylindrical combustion chamber. The kiln system can accept a wide range of particle sizes up to 1 foot in diameter. Larger particles are acceptable provided that they do not damage the kiln refractory. Any other hazardous materials generated on-site during the cleanup (i.e., laboratory supplies, protective clothing, etc.) could be packaged in plastic containers and fed to the rotary kiln process.

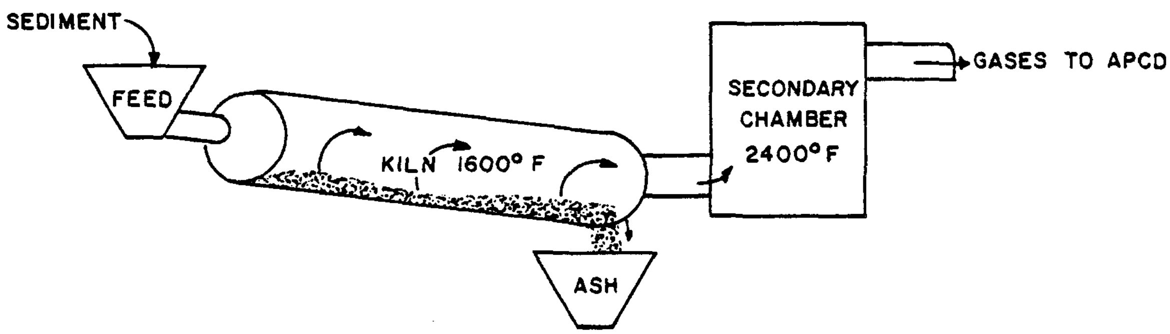
The fluidized bed process has been developed to handle hazardous sludges, pulverized fuels, and waste streams with small particle sizes. The feed is introduced to the combustion chamber using an augered screw feed. Particle size is limited by the screw feed mechanism and the need to maintain a floating bed in the combustion chamber. Maximum acceptable particle size is one inch in diameter.

All three of the waste feed systems would be feasible for treatment of New Bedford Harbor sediments. It is likely that particle size will be uniform and relatively fine. Large particles will be screened out prior to the mechanical dewatering step.

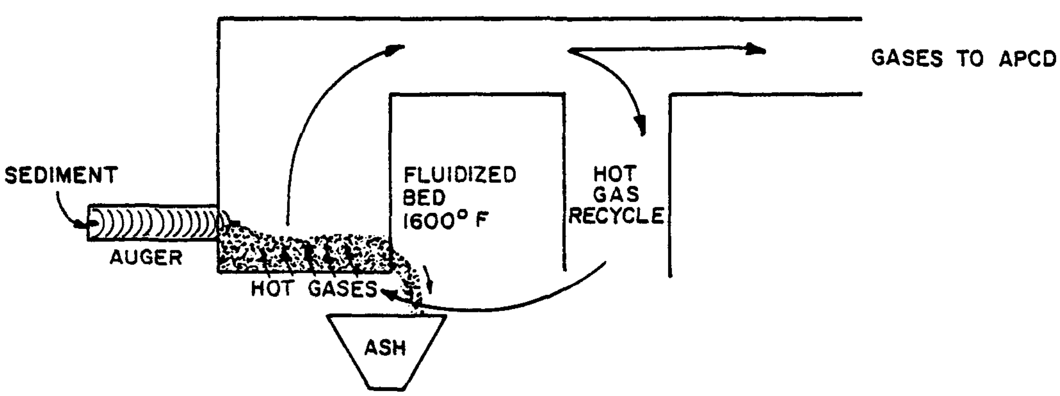
Combustion Chambers. A diagram of the combustion chambers for each incineration process is presented in Figure 6-7.



A) INFRARED INCINERATOR



B) ROTARY KILN INCINERATOR



C) FLUIDIZED BED INCINERATOR

FIGURE 6-7
COMPARISON OF INCINERATION COMBUSTION CHAMBERS
NEW BEDFORD HARBOR, MASSACHUSETTS

The infrared incinerator employs a two stage combustion process. A conveyor belt carries the sediment through the primary combustion chamber. This long horizontal chamber is maintained at a temperature of 1600°-1800°F, sufficient to volatilize any organics. Solids remain in the chamber approximately 30 minutes. Heat in the primary chamber is derived from two sources: infrared heating elements on the chamber walls; and by the combustion of fuel oil which has been sprayed on the sediment in the waste feed step. Combustion air flows through the chamber, carrying volatilized gases into the secondary chamber. In the secondary chamber, additional heat is added to the gases using a natural gas or fuel oil burner. Combustion air is added to improve combustion efficiency. The gases are heated to 2400°F for over 2 seconds in the secondary chamber, and flow into the air pollution control system.

The rotary kiln incineration also consists of a primary and secondary combustion chamber. The primary chamber is a rotating cylinder which tumbles the waste to provide uniform heating and volatilization. Temperatures are maintained at 1600-1800°F using a fuel oil burner in one end of the kiln. Solids residence times range from 15 to 45 minutes and can be varied by controlling the inclination and rotational speed of the kiln. Combustion gases exit the kiln and pass into a secondary chamber which is fired with a natural gas or fuel oil burner. The gases are mixed with additional combustion air and raised to 2400°F for 2 seconds before exiting the chamber into the air pollution control system.

Fluidized bed incineration systems have a combustion chamber with jets of hot air forced upward through a bed of granular waste material. The waste is maintained at a temperature of 1500-1600°F by the addition of auxiliary fuel. Combustion air is added to hot air jets. The hot bed of waste material ensures adequate residence time and turbulence to destroy PCBs at a relatively low temperature. As waste flows into the bed from the waste feed mechanism, solid material is removed from the bottom of the bed. Hot gases and particulate flow up out of the suspended bed and are ducted into the air pollution control equipment.

Air Pollution Control Equipment. Air pollution control equipment is necessary to meet the emissions limits for HCl and particulates. Both the infrared and rotary kiln systems generally use a combination of a packed tower to control HCl followed by a wet venturi scrubber to control particulates. For a fixed facility, a wet electrostatic precipitator may be used for particulates. This equipment is sufficient to achieve regulatory compliance if operated correctly.

The fluidized bed process can achieve HCl control by introducing a caustic component (lime is often used) into the reactor bed. With the HCl removed in the solids effluent, the air pollution control equipment can be limited to particulate control. Electrostatic precipitators and baghouses are appropriate.

Process Effluents. Incineration systems produce three types of effluents: combustion gases, treated solids, and scrubber water and particulates. The combustion gases, which are treated to remove HCl and particulates, are released through the stack requiring no further treatment. The treated sediment exits the primary combustion chamber as a sterile solid effluent. The air pollution control devices have an effluent stream composed of water from the wet scrubbers and/or particulates. Each of the effluent streams must be treated separately.

The decontaminated solids will contain metals at levels near the concentrations in the untreated sediment. These metals may have been oxidized as a result of the high temperatures and presence of excess air in the combustion chamber. As a result, the solid effluent may have hazardous characteristics as defined by the EP Toxicity Test. Assuming that this is true, two options exist for disposal of these solids. One option is to dispose of them in a RCRA-approved landfill. The other option is to fix the metals in the sediments by adding a fixation agent and disposing of the fixed sediments. If the solid effluent does not fail the EP Toxicity Test, it may be disposed of without treatment after delisting.

Effluents from the air pollution control devices include particulate catch from Electrostatic Precipitators (ESPs) or baghouses and scrubber water. If the particulates are caught in the dry form they may be treated with the solid stream described above. Metals tend to partition in higher concentrations in the particulates. Since the particulates may have a higher metals content than the sterile sediment, separate EP Toxicity Testing is recommended.

Liquid effluent from the scrubber system will contain HCl. This stream is usually neutralized using a solution of NaOH, which precipitates as a salt. The scrubber water blowdown stream is an aqueous solution of NaCl with high suspended solids. This stream will contain some metals as a result of entrapped particulates. The scrubber water steam is a low volume stream and could easily be treated in the water treatment facility designed to handle water from the dredging and dewatering operations.

Other Design Considerations. The design of the incineration system and the site layout will depend on the volume and duration of the cleanup. If incineration is limited to Hot Spot sediments, mobile incineration systems are available which could handle the job in a reasonable time frame (1-3 years). On the other end of the spectrum, incineration of all contaminated sediments would require a number of units dedicated to the site for the design life of the system. Figure 6-8 presents the relationship between

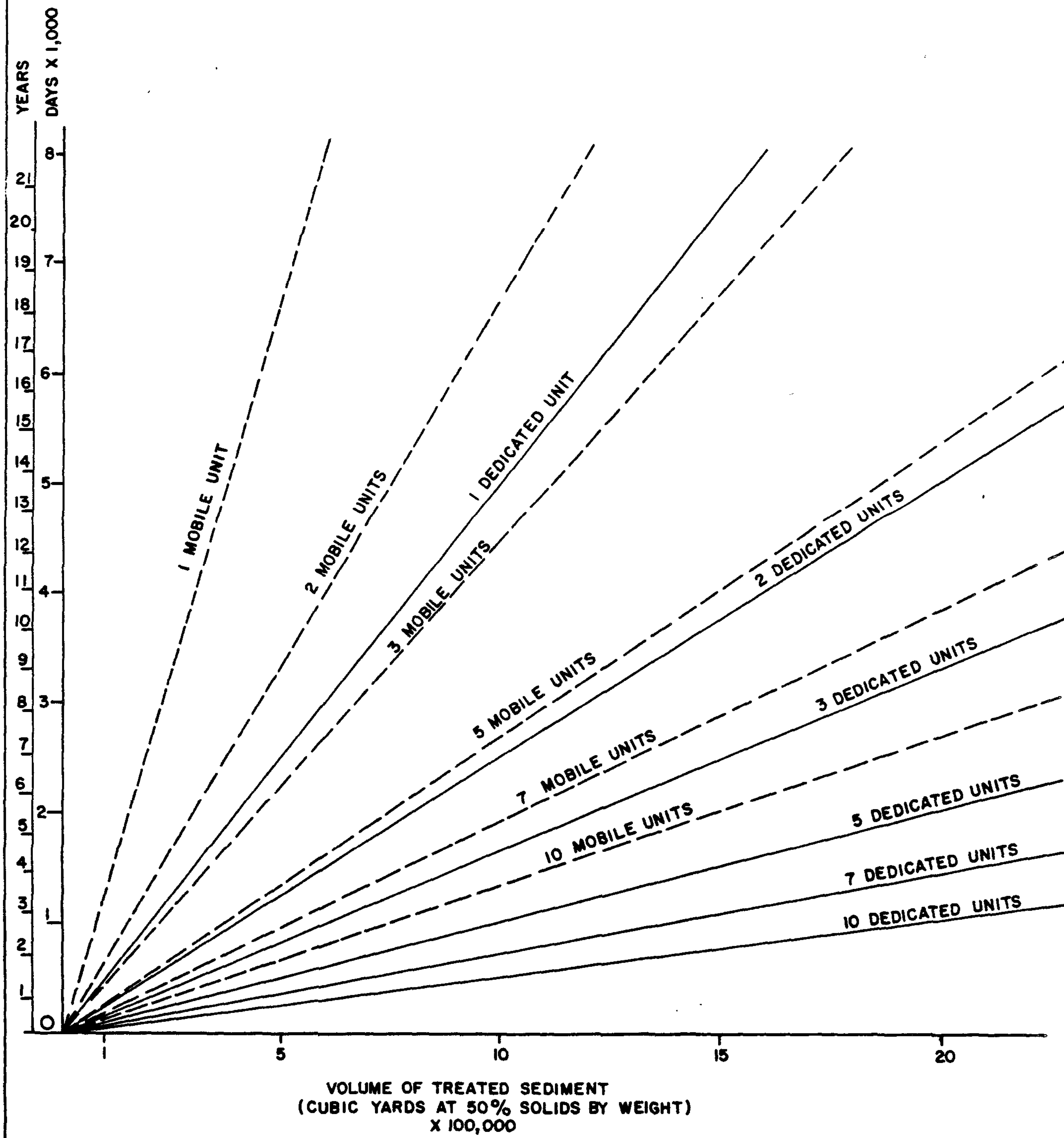


FIGURE 6-8
TREATMENT TIME REQUIRED FOR VARIOUS COMBINATIONS OF INCINERATORS NEW BEDFORD HARBOR, MASSACHUSETTS

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clean-up time, clean-up volume and incineration capacity. Two sets of curves have been developed. The first set is for large scale incineration units which would be constructed on-site and dismantled following the project. A throughput of 200 tons/day dry solids has been chosen to represent this group. The second group of curves represents mobile scale units which could be erected on-site. These units are available with throughputs in the 75 tons/day solids range. Each set of curves shows the relationship between clean-up volume and time for different numbers of units.

Site layout will also be affected by the volume and time frame for the clean-up activities. If multiple incineration units are used, the space requirements will increase. Figure 6-9 shows the relationship between the number of incineration units used and the required site area. Several considerations were used in developing these curves. For the mobile units, two acres were required to set up the first unit and associated control equipment. For each additional unit, one acre was allotted. For dedicated units, three acres were required for the first unit and three quarters of an acre for each additional combustion chamber. These area requirements are based on the assumption that if the facility was designed as a permanent dedicated facility, common air pollution control equipment and common operating equipment would be used.

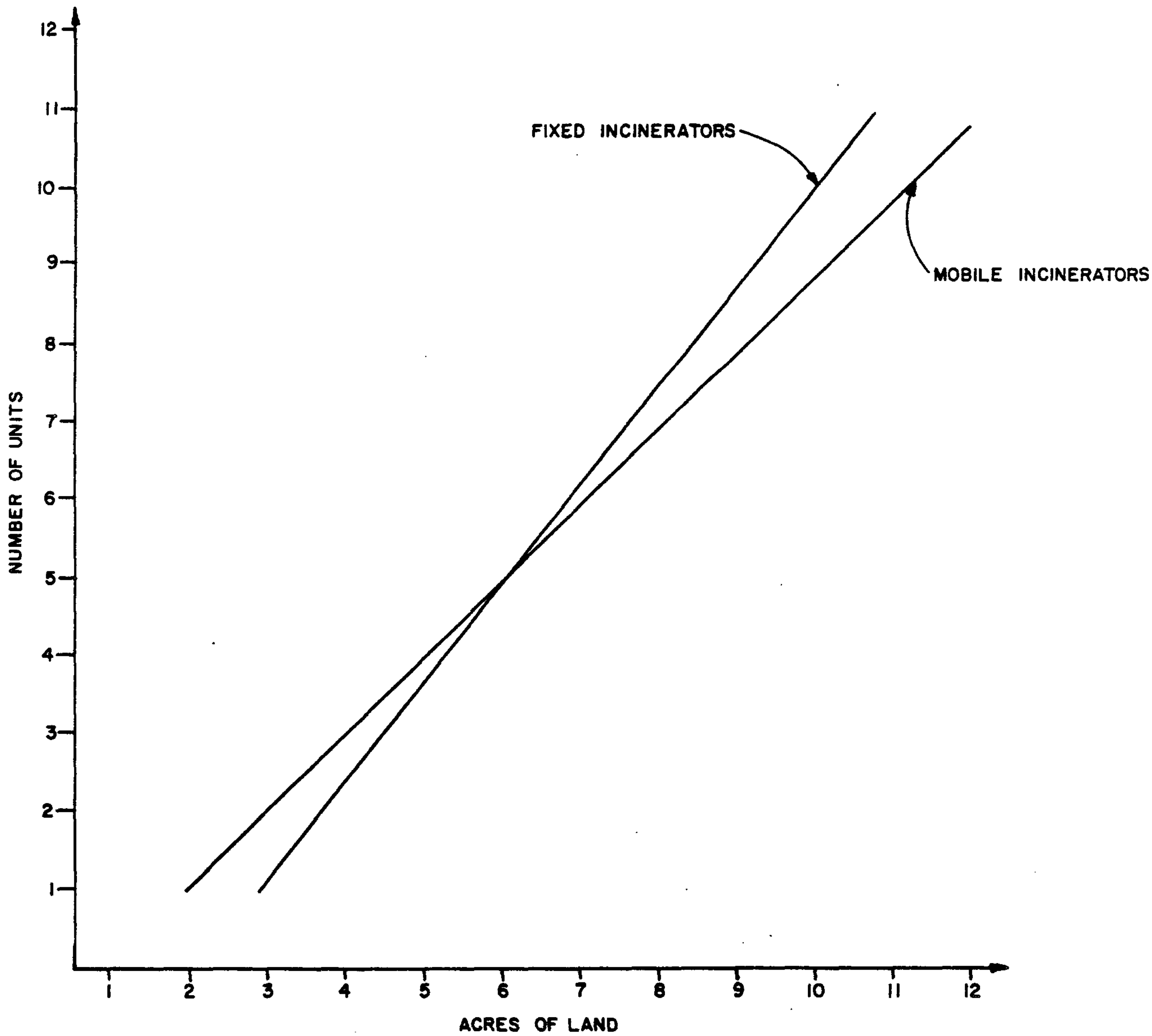

FIGURE 6-9
AREA REQUIREMENTS FOR INCINERATION
NEW BEDFORD HARBOR MASSACHUSETTS

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The primary design considerations for incineration have been presented in the preceding paragraphs. The next section discusses site specific aspects of this technology as they relate to the NCP criteria for detailed evaluation.

For the purposes of evaluation, all of the incineration processes - infrared, rotary kiln and fluidized bed - will be considered together. If differences in the processes affect the evaluation, these differences will be noted in the discussion. Some of the criteria will not be applied during this evaluation of technologies. These criteria will be referred to as not applicable in the appropriate section.

6.6.2 Effectiveness

This section discusses the effectiveness of incineration in achieving the stated goals of destroying PCBs and detoxifying metals in the sediments of New Bedford Harbor. The effectiveness of the process is a measure of the protection provided to human health and the environment, in terms of beneficial and adverse effects.

Reliability - Incineration has been demonstrated to be a very reliable method of permanently reducing the toxicity of organic contaminants including volatiles, semi-volatiles, PAHs, PCBs, PCDDs, and PCDFs. Incineration is the most widely practiced and permitted method of destroying organic hazardous wastes. Each of the three systems discussed in this section has been successfully demonstrated on PCB-contaminated soils and sludges.

These systems are not effective in detoxifying metal bearing hazardous wastes. During the process of incineration, metals are frequently oxidized. For the metals of concern at New Bedford Harbor, these oxidized forms are likely to be more mobile in the environment and, therefore, more accessible to biota. Post treatment may be acceptable for dealing with this enhanced mobility. Appropriate post treatments would either reduce the metals to a less mobile state or immobilize the metals by binding them in a solid matrix. These options are discussed in the section on solidification.

The long term effects of incineration on the New Bedford environment include the permanent destruction of organics found in the sediments which are incinerated. Sediments containing metals would need to undergo a post treatment in addition to incineration to minimize long term effects.

Public Health - Incineration of sediments would eliminate adverse long term effects due to human exposure to contaminated sediments. A short term risk would be posed by the operation of an incinerator near populated areas. This risk is a result of the potential for process upsets which might result in poor combustion conditions in the incinerator. These conditions could lead to the release of low levels of hazardous organics into the atmosphere. The possibility of system failure can be minimized by proper process controls as discussed later in this section.

All of the incineration systems proposed for New Bedford Harbor have demonstrated compliance with federal performance standards for PCB incinerators. These standards include the following limits:

- o particulate emissions not to exceed 0.08 grains/dscf;

- o HCl emissions not to exceed 4 lbs/hr or 1 percent of feed rate, whichever is greater;

- o combustion efficiency maintained above 99.9 percent; and

- o PCB destruction and removal efficiency of 99.9999 percent.

Any system constructed at New Bedford Harbor would have to demonstrate performance during a trial burn prior to full scale operation.

Combination of incineration with appropriate post treatment steps for incinerated sediment and water treatment would meet or exceed all ARARs governing protection of human health.

Environment - Incineration would remove and destroy 99.9999 percent of the PCBs and other hazardous organics in the sediments chosen for treatment. The remaining 0.0001 percent of PCBs would be equivalent to 1 pound of PCBs released for every million pounds destroyed. The result of this treatment would be a significant reduction in available PCBs in the New Bedford Harbor environment. In full scale incineration tests, levels of additional products of incomplete combustion have been measured. Emissions of these compounds are roughly equivalent to the levels of PCB emissions.

Potential adverse effects as a result of implementing incineration include the following:

- releases of low levels of products of incomplete combustion during process upsets;
- increase in mobility of heavy metal compounds;
- release of particulate matter containing heavy metals;

- risks associated with disposal of treated sediments containing heavy metals; and

- any adverse effects resulting from removal, transportation, construction, and disposal activities.

These adverse effects can be minimized through the use of appropriate air pollution control equipment, proper process controls, and selected post treatment steps for process effluents. With these controls on adverse effects, this technology is capable of delivering significant benefits to the environment and achieving all state and federal ARARs.

6.6.3 Implementation

This section discusses issues involved in the implementation of incineration technology. A variety of engineering feasibility issues are discussed in detail.

Technical Feasibility - Incineration is technically feasible and proven for the destruction of all organic species over a wide variety of concentrations. Incineration has limited effectiveness on inorganic species. Incineration systems were originally designed to handle the destruction of wastes which have some energy content; the sediments of New Bedford Harbor are not expected to have significant energy content. This limitation can be overcome by using auxiliary fuels to achieve the necessary temperatures. The use of auxiliary fuel does not alter the effectiveness of incineration, but does result in a higher cost. This cost can be minimized by dewatering the sediments prior to treatment.

The fine grained sediments may result in the need for modified particulate control devices to handle high particulate loading. These modifications are well within the capabilities of the technology.

In general, incineration has been well demonstrated under similar conditions, and the process can be modified to handle the New Bedford Harbor sediments successfully.

Demonstrated Performance - Incineration systems have been field demonstrated for sediments, PCBs, high moisture content waste streams, and fine grained waste streams. Typical down time estimates for incineration systems are 20 to 30 percent for a system operating 24 hours/day, 7 days/week. This time is required for systems maintenance and inspections.

Support Requirements. The incineration process requires a pretreatment step to dewater sediments and post treatment for the ash, scrubber water, and gaseous effluents. These treatment steps would be necessary to comply with the response objectives and institutional constraints.

Prior to passing sediments through the incinerator, the dewatering step is necessary to remove water from the slurry. Heat required to evaporate the water in the combustion chamber represents a large fraction of the total heat necessary to incinerate the sediments. Reducing the amount of water in the slurry will have two benefits. First, the fuel saved by not evaporating the water represents a direct savings in operating cost. Second, the time required to process the sediments is reduced, resulting in higher throughputs and less total operating time.

For these reasons, a dewatering step precedes incineration. This step will likely require gravitational settling followed by mechanical dewatering. For the purpose of this evaluation, a dewatering step involving mechanical dewatering is assumed and the process is evaluated under water feed conditions of 50 percent solids and 50 percent water by weight. Dewatering will be further discussed in Section 7.1.

As a result of dewatering, an aqueous stream will be produced with PCB concentrations which are higher than allowable effluent guidelines (1 ppb). This effluent will require treatment to remove PCBs and possibly heavy metals. Water treatment is discussed in Section 7.2.

Availability. Mobile units capable of treating 75 tons of sediment per day are currently available. Approximately 10 infrared incinerators, 5 rotary kilns and 2 to 3 fluidized bed units will be available in 1990. One of these units can be mobilized on-site in a two month period.

Fabrication of larger units, dedicated to the New Bedford site, would require six months to two years depending on the number of units required, the type of unit, and market conditions. These larger units would be capable of handling 200 tons of sediment per day.

Area requirements for incineration systems were presented in Figure 6-9.

Installation. Time requirements for installation of incineration are presented in Table 6-8. The system can be installed on a flat, vacant area with sufficient space.

Time. Time requirements for construction and demobilization are presented in Table 6-8. Time requirements for a number of volume scenarios are presented in Figure 6-8.

Safety. Incineration systems do not pose any significant safety hazards when operated by trained personnel in a properly

TABLE 6-8
TIME REQUIREMENTS FOR IMPLEMENTATION OF INCINERATION

	Mobile Unit	Dedicated Unit
Equipment Fabrication	----	6-24 months
Site Preparation	1 month	2-4 months
Mobilization/Construction	2 months	6 months
Shakedown/Test Burn	1 month	2 months
Permit Application	6-12 months	6-12 months
Cleanup	variable	variable
Demobilization	1 month	3 months

Ogden, 1987 and ENSCO, 1987

Note: Some of the activities will proceed concurrently.

controlled facility. Incineration systems are equipped with automatic feed shutoff controls in case of process upsets.

Monitoring and Maintenance Requirements. Incineration systems require sophisticated monitoring instrumentation to control the combustion process. Monitoring instrumentation provides continuous data on the following parameters:

- fuel feed rates and pressures;
- waste feed rates;
- temperatures of primary and secondary combustion chambers;
- operating conditions of air pollution control equipment;
- combustion gas concentrations (O_2, CO_2, CO, total hydrocarbons); and
- combustion air flow rates.

This data is used to optimize the combustion process and provides an indication of the combustion efficiency.

Typical maintenance includes regular inspections during operation and periodic shutdowns to perform preventive mechanical maintenance. Fans, pumps, and compressors require regular maintenance. Moving parts which operate in the combustion zone are subject to degradation as a result of heat stress. Refractory must be replaced as a part of regular maintenance. Air pollution control devices are complex and require maintenance. Maintenance costs and time requirements are generally higher for the infrared incinerators as a result of wear on moving conveyor parts in the combustion chamber.

Permitting. Permits are not required for treatment on Superfund sites, but it is reasonable to assume that the technical requirements for TSCA incinerators would need to be met for emissions. Demonstrating these requirements and other applicable regulations will require six to twelve months.

Legal Constraints. Sufficient land must be available to set up process equipment. Acquisition of land and zoning will be addressed during the evaluation of remedial alternatives. Significant public opposition frequently accompanies the siting of incineration facilities. An education program in conjunction with the announcement of the alternative would help address this opposition.

Impacts on Historical and Critical Resources. This area will be addressed in the alternatives evaluation.

6.6.4 Costs

This section presents cost information for incineration of New Bedford Harbor sediments. Estimates have been prepared using information received from vendors of incineration technologies. These estimates reflect a range of assumptions. In the following paragraphs, capital, operating, and maintenance costs are discussed. A cost curve (Figure 6-10) is presented for various cleanup volumes at New Bedford Harbor and the sensitivity of these parameters is discussed. Cost information and sources are presented in Table 6-9.

Capital Costs - Capital costs for incineration include mobilization, equipment costs, and site preparation costs. For a mobile incineration unit, mobilization costs range from $300,000 for the Shirco infrared unit to $600,000 for the ENSCO rotary kiln unit. These costs include installation of equipment, utilities, and labor required for mobilization. Equipment costs are not available for mobile units because they are usually employed on a unit cost per ton of processed material.

Capital costs for dedicated incineration units range from $3,000,000 to $5,000,000. These costs are for units capable of

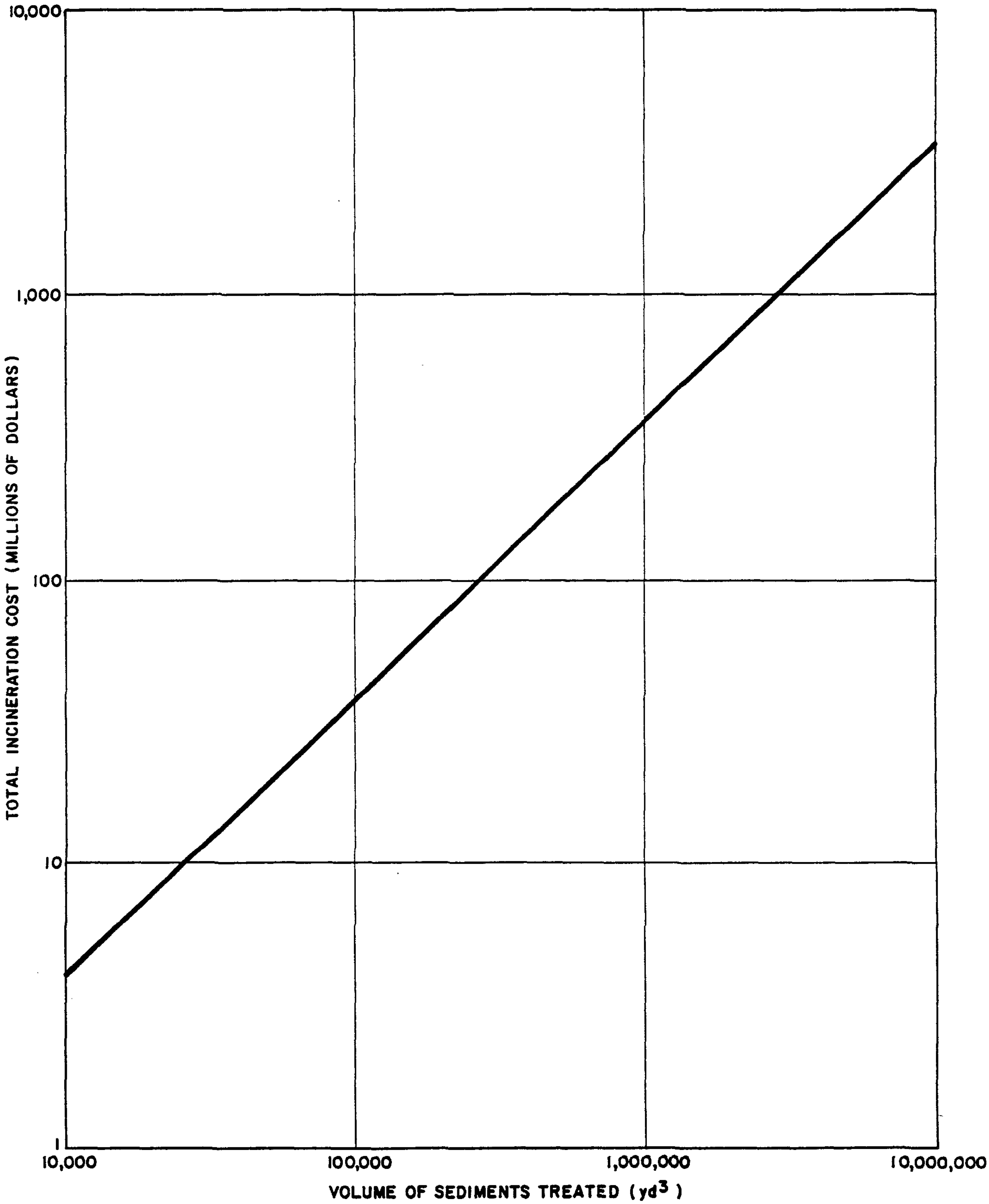

FIGURE 6-10
COST ESTIMATES FOR A RANGE OF CLEANUP VOLUMES USING INCINERATION
NEW BEDFORD HARBOR

TABLE 6-9

COMPARISON OF COST ESTIMATES FOR INCINERATION

Source	Capacity	Capital Cost	Operating Costs	Total Costs Per Ton	Includes Profit? (Y/N)	Total Cost Including 50% Profit/ Contingencies
Ogden Environmental	30 tons/day	--	$66/ton[a]	$246	N	$369/ton
New Bedford Harbor Questionnaire Response	250 tons/day	--	$66/ton[a]	$ 74	N	$111/ton
Ensco New Bedford Harbor Questionnaire Response	100 tons/day	--	$65/ton[a]	$250-400/ton	Y	$325/ton
American Toxic Disposal Inc. Phone Conversation Regarding New Bedford Harbor	500 tons/day	--	--	$250-800/ton	Y	$525/ton
SHIRCO Cost Estimates Provided for Site Program	100 tons/day	2,750,000	$86/ton	$116/ton	N	$174/ton
O.H. Materials Costs Estimates for Operating SHIRCO Incinerator	100 tons/day	--	--	$250-400/ton	Y	$325/ton
Reidel Environmental Cost Estimates for Operating SHIRCO Incinerator	100 tons/day	--	--	$175-225/ton	N	$300/ton
Illinois EPA Cost Bid for Cleanup of State Site	75 tons/day	--	--	$500/ton	Y	$500/ton
Illinois EPA Cost Bid for Cleanup of State Site	75 tons/day	--	--	$250/ton	Y	$250/ton
NUS New Bedford Files Cost Estimate Development for New Bedford Feasibility Study	75 tons/day	$4,599,000	$3,310,400/year	$172/ton[b]	N	$258/ton

[a] Fuel and utility costs only, these costs do not include labor or maintenance.

[b] For ten years of operation and 20% downtime.

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processing approximately 100 tons/day of sediment. These costs include equipment and installation costs. In general, infrared units are less expensive to build than rotary kiln and fluidized bed units.

Indirect capital costs include the work which goes into engineering, permit applications, and administrative costs. These costs will be developed as a part of the alternatives evaluation.

<u>Operation and Maintenance Costs</u> - Operation and maintenance of incineration facilities includes costs associated with fuel, utilities, labor, equipment, supplies, monitoring, and administrative support. Operations crews include a staff of approximately 30 trained operators, maintenance, and monitoring personnel. Standard operations continue 24 hours a day, seven days a week. Typical downtime estimates range from as low as 5 percent for a large scale fluidized bed in continuous operation, to 20 percent for an infrared incinerator. Maintenance costs are higher for the infrared incinerator, up to 20 percent of capital costs per year, due to the high maintenance associated with the conveyor system. Maintenance costs for fluidized bed and rotary kiln units are in the range of 10 percent of capital costs per year.

<u>Estimated Costs</u> - Available data does not provide detailed breakdown of capital, operating, and maintenance costs. A

relatively good agreement can be found for unit costs of incineration processes as indicated in Table 6-9. Using the average of these estimates, a total cost for incineration has been developed for the range of volumes at New Bedford Harbor. These costs are presented in Figure 6-10. The costs are based on incineration only and do not include costs for dredging, dewatering, water treatment, or disposal of effluents. The costs are based on treating sediment with a 50 percent solids content by weight. The unit cost used for this analysis is $325/ton for volumes less than 100,000 yards and $275/ton for volumes greater than 100,000 yards.

This reduction in unit cost for larger volumes is indicated by responses to questionnaires.

Sensitivity - These cost estimates are based on a number of assumptions which could change at the time of construction. Areas which would significantly alter the cost estimates are noted below:

- o Increased moisture content in the waste feed would result in higher costs. Lower moisture content would reduce costs.

- Increased fuel oil costs would result in increased operating costs. Fuel accounts for approximately 30 percent of the unit cost for a long term cleanup.

- Post treatment and effluent disposal costs could significantly increase the cost of this alternative.

- Final costs will depend on the total volume treated, amount of time for the cleanup, and number of units involved in the cleanup.

6.6.5 Summary

Incineration process technology has been well proven for destruction of organics. This process is the most reliable process considered for treating the sediments. Post treatment may be required to treat metals in the sediment. Combined with a solidification step for the ash, incineration provides a permanent reduction in mobility and toxicity of the contaminants. Although the cost for incineration is high, this technology will be carried into the evaluation of alternatives due to the reliable nature of the technology.

6.7 SUPERCRITICAL WATER OXIDATION

This section presents a discussion of the feasibility of treating New Bedford Harbor sediments using supercritical water oxidation. Two processes have been explored which could be used to destroy PCBs in a sediment slurry. The first is a deep shaft wet air oxidation process which has been developed for treatment of municipal wastewater. The second application of this technology involves pumping a slurry at high pressures and temperatures into a reactor where organics are oxidized. Both of these applications of supercritical water oxidation will be discussed in this section.

Information used to evaluate these systems was gathered from two sources. A literature search turned up background information on the process as it has been applied to wastewater and aqueous wastes. Phone calls and detailed questionnaires sent to several companies developing this technology provided a source for much of the material used to evaluate these technologies.

6.7.1 Description

Supercritical water oxidation involves the destruction of organic compounds in an aqueous solution at high temperature and pressure. Above the critical point (705° F, 3,205 psia) water exists as a critical fluid and exhibits characteristics which enhance the oxidation of organic compounds. Supercritical water becomes a non-polar solvent, providing a media in which air and organics can mix, resulting in the oxidation of carbon atoms to CO_2 and hydrogen to H_2O.

Advantages of this process include high theoretical destruction efficiencies and fast reaction rates in solutions containing low concentrations of organics. The process has been demonstrated to achieve destruction rates greater than 99.99 percent for aqueous organics. Typically, little or no fuel is required where sufficient organics are present to supply necessary energy, and either air or oxygen may be used as an oxidant.

The process would require further development for application at New Bedford Harbor. Current applications of subcritical water oxidation include treatment of wastewater and wastewater sludges to reduce COD and destroy dilute organics. The process has been demonstrated on the bench and pilot scale for the destruction of hazardous aqueous and organic streams including PCBs (Staszak et. al., 1987). The major uncertainties associated with treating sediments involve handling large volumes of particulate material under high pressure and temperature. Current designs are intended for use with liquid wastes; conversion to a system which would be capable of handling sediment would require substantial modifications to both pump and reactor components. Additional concerns include the fate of salts in the process train and the success of scaling up to a full scale system.

The following paragraphs describe the process trains which have been proposed for application of supercritical water oxidation at New Bedford Harbor. These descriptions have been extracted from responses to questionnaires (MODAR, 1987; Oxidyne, 1987).

Feed Stream - The feed stream to the reactor will consist of a slurried sediment which has been screened to remove particles greater than 2,000 microns (≈60 mesh). Approximately 25 percent of the Estuary material would require grinding to achieve this level. Depending on the system design, this slurry may contain between 6 percent solids (maximum allowable for deep shaft process) and 40 percent solids. The appropriate solids concentration will be reached by dewatering or adding dilution water to the sediments. Caustic may be added to the feed stream to provide sodium to react with the chlorines associated with PCBs. Fuel oil may be added to the feed to adjust the heating value.

In the Modar process, the feed stream is pumped from atmospheric pressure to pressures above the critical pressure of water (3,205 psia). This pressurized feed is introduced to the reactor along with pressurized air or oxygen in excess of the stoichiometric requirements for oxidation.

In the Oxidyne process, the feed stream is pumped into a deep well which has been drilled to a depth of over 7,000 feet. This well consists of two concentric tubes. Feed enters the inner tube and is pumped to the bottom of the well, where the pressure has reached supercritical levels. This lower part of the well is the reaction zone.

Reaction Zone - In the reaction zone, the more readily oxidizable compounds react with excess oxygen and emits heat, which raises the temperature of the mixture into the supercritical range (>705°F). At this temperature oxidation proceeds rapidly, and high destruction is achieved. Salts and inert particulate matter form a second phase which is insoluble in supercritical water. This phase may be removed either before or after the post reactor separation stage. The MODAR process removes the metals and inerts from the reactor, and reduces the need for post treatment.

In the Oxidyne process, the material leaving the reaction zone flows up the outside of the well and serves to heat the waste feed flowing through the inner tube. All phases of the mixture pass from supercritical to subcritical in a continuous letdown of temperature and pressure.

Post Reactor Separation - After leaving the reactor, the oxidized mixture enters a separator where pressure is released, allowing the gaseous, liquid, and solid phases to form. These phases may be separated. This letdown of pressure is accomplished in stages during the Modar process and continuously during the Oxidyne process.

The process effluents include: a gaseous stream composed of unreacted oxygen, nitrogen, carbon dioxide and trace amounts of carbon monoxide; an aqeuous stream composed of water, some dissolved salts and metals and very low levels of organics; and a slurried inert stream containing most of the solid matter and some water. Most of the metals are expected to end up in the inert stream and are likely to be in an oxidized state.

Both the water and inert effluents may require post treatment. Metals may require removal from the water to achieve effluent standards. The inert stream may also need to be treated for metals, using solidification or other chemical immobilization techniques.

The processes also may be optimized for New Bedford Harbor by the use of recycle streams, multiple reactors, pressure letdown stages and other modifications. More detailed descriptions of these processes may be found in the references.

<u>Other Design Considerations</u> - In addition to the process equipment described above, the operation of a supercritical water oxidation process would likely require a small scale oxygen plant to produce

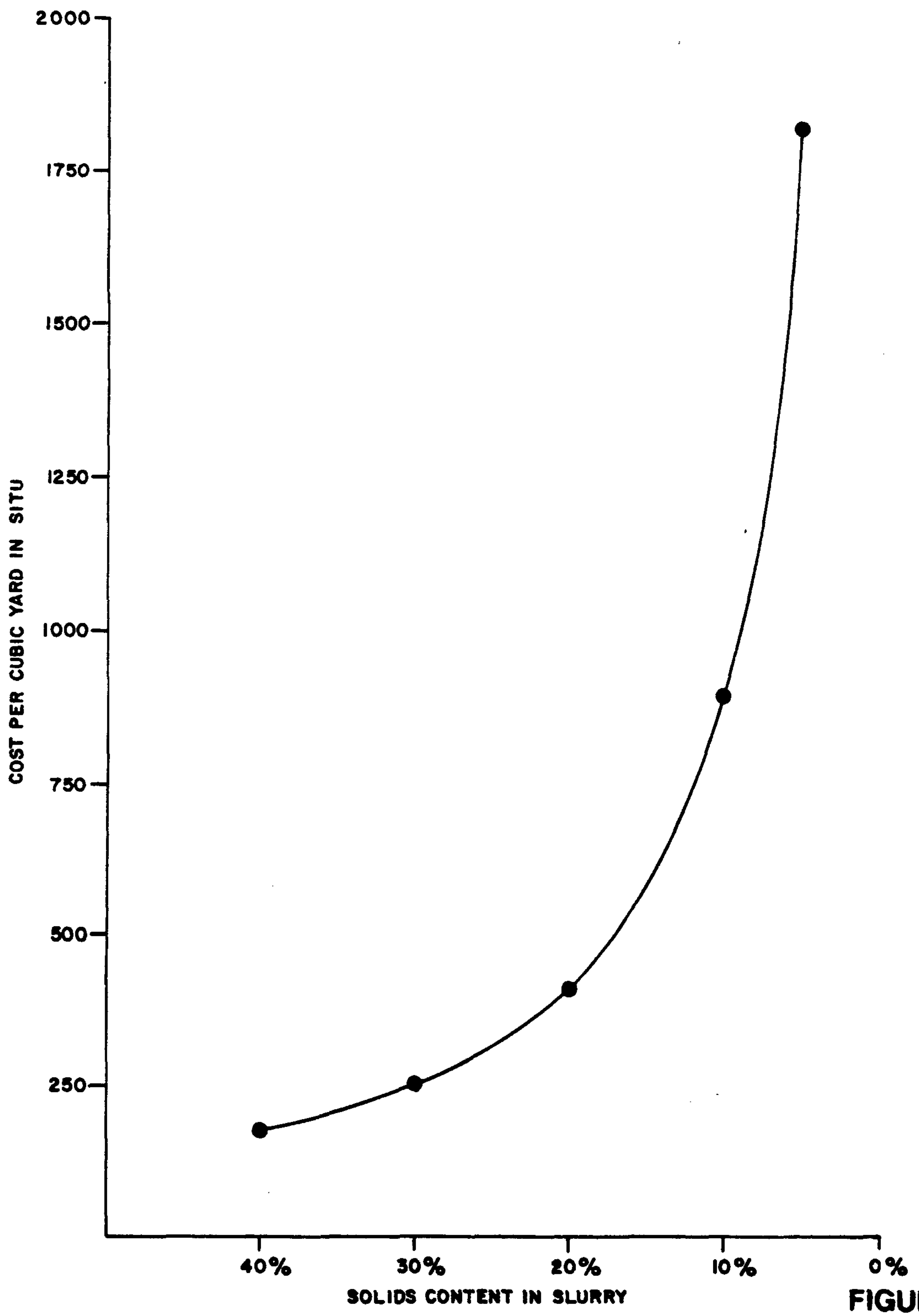

FIGURE 6-12
UNIT COST FOR SEDIMENT TREATMENT USING SUPERCRITICAL WATER OXIDATION
NEW BEDFORD HARBOR MASSACHUSETTS

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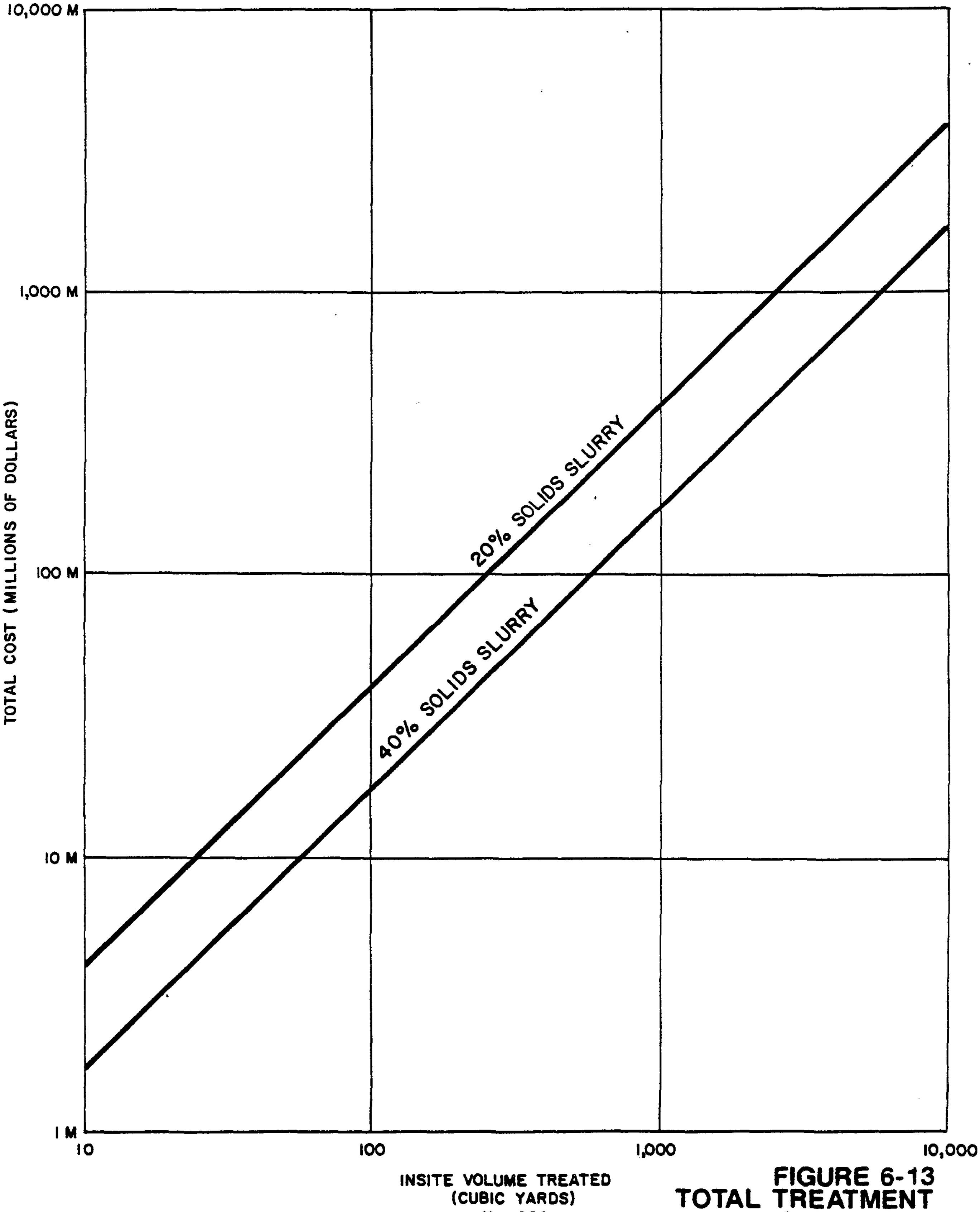


FIGURE 6-13
TOTAL TREATMENT COSTS FOR SUPERCRITICAL WATER OXIDATION
NEW BEDFORD HARBOR, MASSACHUSETTS

an oxygen rich stream. Suggested process rates range from 200 to 1,000 gpm of feed. This process would require approximately two acres for equipment and an operations center, not including pre- or post-treatment. Concrete pads would be required for process equipment and storage tanks. Utility requirements include provisions for up to 10 MW electrical power and minor cooling water needs.

Additional design and construction considerations are presented in the following paragraphs. The remainder of this section presents the detailed evaluation of supercritical water oxidation using the evaluation criteria specified in the NCP.

6.7.2 Effectiveness

This section discusses the effectiveness of supercritical water oxidation in achieving the stated goals of destroying PCBs and detoxifying metals in the sediments of New Bedford Harbor. The effectiveness of a process is a measure of the protection provided to human health and the environment, in terms of beneficial and adverse effects.

Reliability. If operated effectively, supercritical water oxidation would achieve a very high destruction efficiency for PCBs and other organic materials. Combined with post-treatment steps to detoxify metals, this process could achieve a permanent reduction in toxicity and mobility of all contaminants. Demonstrated levels of PCB destruction meet or exceed the suggested goals of this study.

Appropriate metals treatment steps include the use of a water treatment to reduce levels in the aqueous effluent stream, and the use of solidification or immobilization to treat the slurried inert stream. These processes are described elsewhere in this report.

The successful implementation of supercritical water oxidation would provide permanent long-term benefits to the New Bedford Harbor environment associated with the elimination of PCBs. Additional metals treatment would further reduce the long-term environmental effects.

Public Health. The application of this process would eliminate adverse long-term effects resulting from human exposure to contaminated sediments. The implementation of this process would result in a slight short-term risk as a result of the potential for process upsets which might result in low level releases to the environment. The possibility of system upset can be minimized through proper monitoring and controls.

The systems proposed for this cleanup would be able to meet the proposed allowable effluent level of 1 ppb PCBs in the water effluent. Similar levels would be achieved in the inert stream. Metals could also be reduced below effluent standards with proper treatment of water and inert streams. These combined technologies would meet or exceed all ARARs governing protection of human health.

Environment. Supercritical water oxidation would destroy in excess of 99.999 percent of the organic constituents in the sediments. These destruction rates have been demonstrated for organic liquids, but not for soils at the pilot scale (Staszak, et. al., 1987). The result of this destruction would be a significant reduction in the available PCBs in the New Bedford Harbor environment.

Potential adverse effects as a result of implementing this process include:

- release of contaminants during process upsets;
- risks associated with the management of sediment containing heavy metals; and
- any adverse effects resulting from removal, transportation, construction, and disposal activities.

These adverse effects can be minimized through proper design, appropriate post treatment, and monitoring. With appropriate controls in place, this technology is capable of delivering significant benefits to the environment and reducing PCBs and metals beyond the limits imposed by state and federal ARARs.

6.7.3 Implementation

This section discusses a variety of engineering considerations involved in successful implementation of supercritical water oxidation.

Technical Feasibility. Supercritical water oxidation is technically feasible and proven for the destruction of organics, including PCBs, in wastewater and organic wastes (Modell, 1985). This process has not been used to treat sediments or soils on a large scale. Small scale experiments have encountered difficulties resulting from excessive pump wear (Killilea, 1986); erosion of reactor materials by Cl ions (Randhava, 1987); and limitations on solids in the feed. To overcome these problems would require significant modification. In addition to these materials handling problems, a reliable system for removing inerts at high pressure has not been demonstrated.

Deep shaft water oxidation has not been demonstrated at supercritical temperatures or pressures. Subcritical operating conditions are not sufficient for high efficiency destruction of halogenated aromatics such as PCBs (Smith et. al., 1986a). The technical feasibility of well installation and operation at subcritical conditions has been demonstrated, but control of a supercritical reactor and processing of sediment slurries would require further development. The technical feasibility of drilling a ten-inch hole and installing 7,000 feet of concentric pipe has been demonstrated in the oil industry. Site-specific aspects of the well installation have not been addressed in this study. This issue would require further consideration prior to recommending the Oxidyne process.

In summary, these processes are in the developmental stage and face significant design modifications before full scale implementation of a sediment processing system can be achieved.

Demonstrated Performance. As stated in the last section, the MODAR process has been demonstrated successfully on the pilot scale for PCB destruction in an organic waste stream. Solids handling problems have been significant during bench testing. The Oxidyne process has not been demonstrated under supercritical operating conditions and is still in the design phase. Current designs for the supercritical operation have limited solids handling capabilities (Smith, 1986b).

Downtime is difficult to estimate for an unproven process. Estimates of 30 percent for the first year and 15 percent for succeeding years were assumed for schedule and cost estimates.

Support Requirements. Effluent streams would require treatment for metals removal or fixation. Feed streams would require screening and grinding to achieve small particle sizes.

Availability. The MODAR unit would require fabrication, taking 8 to 12 months for delivery. The Oxidyne process would require drilling a 7,000-foot well and installing the reactor. Each of the systems could be installed using two acres of land with access to appropriate utilities.

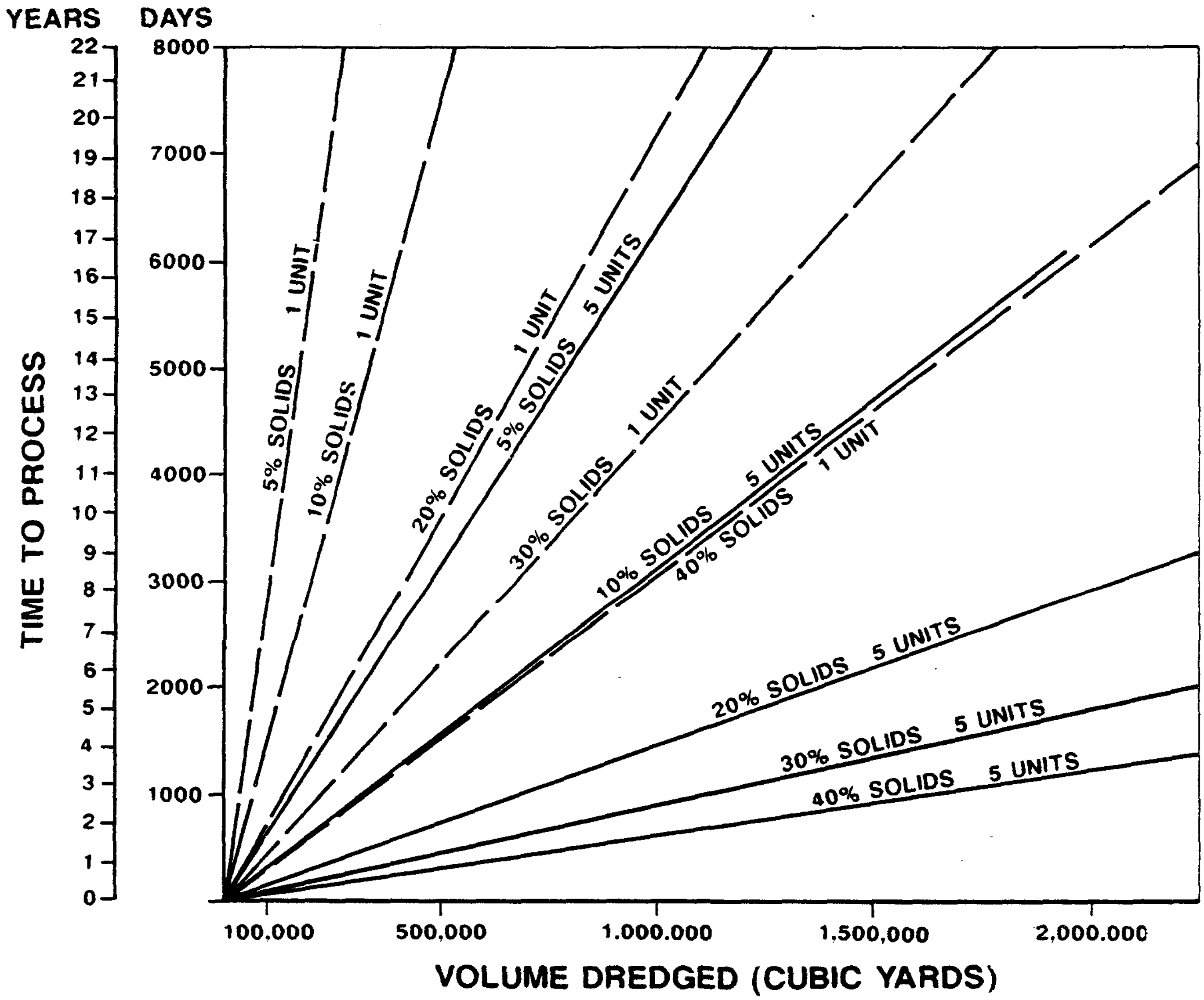
Time. Time requirements for mobilization and demobilization are presented in Table 6-10. Time requirements for treating sediments are a function of the process flowrate. Treatment time for a range of volumes at a number of solids contents which are proposed for the supercritical water oxidation process are presented in Figure 6-11.

Safety. High pressure systems must be fitted with proper monitoring and control instrumentation to avoid dangerous situations that may develop during process upset. Releases to the environment must be avoided by providing automatic feed shutoff systems. Crucial equipment such as pumps and compressors must be

TABLE 6-10
TIME REQUIREMENTS FOR IMPLEMENTATION OF SUPERCRITICAL WATER OXIDATION[1]

Equipment Fabrication	9-12 months
Site Preparation	2-4 weeks
Construction	8-12 weeks
Shakedown	4-8 weeks
Cleanup	Variable
Demobilization	8-12 weeks

1. (MODAR, 1987)



UNIT = PROCESS TREATMENT UNIT

FIGURE 6-11
TREATMENT TIMES FOR SUPERCRITICAL WATER OXIDATION

4959-24

designed with backup systems to minimize upset in case of equipment failure.

Installation. The MODAR system could be installed on a flat level area in two to three months. The Oxidyne system would require a geologic assessment to determine the conditions and method for drilling and placing the vertical reactor. Quality control during installation would be extremely important to ensure the integrity and uniformity of the reactor.

Monitoring and Maintenance Requirements. These systems would require sophisticated monitoring instrumentation to control the process operating conditions. Feed rate and quality, reactor conditions, and effluent quality would require continuous monitoring. The potential for breaches in the integrity of the vertical reactor would require a system for monitoring the conditions in the reactor and detecting leaks into the surrounding rock.

Permitting. Experimental research permits have been granted to MODAR for pilot testing on hazardous waste streams. To date, no permit procedure has been established under RCRA for supercritical water oxidation processes. Discharge permits would be required for effluent streams and performance testing would likely be required prior to implementation.

Permit acquisition time is generally a function of the review period required by regulatory officials. Six to twelve months should be assumed for scheduling purposes.

Legal Constraints. Land acquisition and zoning will be addressed during the evaluation of alternatives.

Impacts on Historical and Cultural Resources. This area will be discussed following development of alternatives.

6.7.4 Costs

Cost information has been developed for implementation of the MODAR supercritical water oxidation process at New Bedford Harbor. Capital, operations, and maintenance costs are presented for a unit capable of processing 550 cubic yards per day of sediment at 40 percent solids content. These costs are shown in Table 6-11.

Values for the cost estimate were taken from the questionnaire submitted by MODAR. Where ranges were given, the high end of the range was used. Utility and fuel costs were calculated using power requirements submitted by MODAR and local utility rates. Additional cost items were added for personal protective equipment and miscellaneous operating and maintenance expenses.

TABLE 6-11
COST ESTIMATE FOR SUPERCRITICAL WATER OXIDATION

CAPITAL COSTS	
Equipment	$20,000,000
Mobilization/Demobilization	500,000
Engineering	1,000,000
Permitting/Administration	2,000,000
Electrical Line and Transformer Installation	1,500,000
TOTAL CAPITAL COSTS	$25,000,000
OPERATING COST Annual, Assume 7010 Hours of Operation (161,000 yd^3 processed)	
Maintenance	$ 1,000,000
Labor (17 man crew)	1,020,000
Protective Equipment	250,000
Fuel (@#16/yd^3)	2,580,000
Electricity (7400 kW @ 7.5¢/kWh)	3,900,000
Other Utilities and Expendable Supplies	1,000,000
Monitoring	1,000,000
Preprocessing	800,000
Miscellaneous Operating and Maintenance Expenses	1,900,000
TOTAL OPERATING COSTS PER YEAR	$13,450,000

NOTE: These estimates are based on information from vendor responses to questionnaires. These values are derived for a unit which could process 550 cubic yards of 40 percent solids content sediment per day.

Sensitivity Analysis. The primary variable that must be considered during the cost sensitivity analysis of supercritical water oxidation is the allowable solids concentration in the feed stream. To compare these costs, a unit cost was developed for a series of scenarios. The unit cost is the cost for treating one yard of sediment as measured in place under a series of solids contents. Since a lower solids content would require the processing of greater slurry volumes, the unit cost increases. These costs, presented in Figure 6-12, were developed by assuming the equipment processed 550 cubic yards/day and operated for 10 years with 20 percent downtime. A profit margin of 50 percent was added to each unit cost. Lower solids contents in the slurry will result in a significant increase in processing cost. Since supercritical water oxidation has not been demonstrated at a solids content of 40 percent, and problems have been encountered during sediment treatment testing, the issue of solids content in the process slurry presents a major source of uncertainty.

The unit costs developed above were used to project total treatment costs over a range of treatment volumes. These costs are presented for a 40 percent solids slurry and a 20 percent solids slurry in Figure 6-13.

6.7.5 Summary

Supercritical water oxidation processes will be removed from further consideration at New Bedford Harbor. At this time, the process has not demonstrated feasible operations for sediments on even the bench scale. Rather, significant problems have been illuminated during small scale testing. Furthermore, at solids concentrations which could reasonably be handled at high pressures (20 percent solids or less), the costs of processing sediment are significantly greater than incineration. Since incineration achieves the same benefits at lower costs, and is more reliable, supercritical water oxidation will be dropped from further consideration.

7.0 TREATMENT TECHNOLOGIES - WATER

This section discusses the dewatering and water treatment technology options available for dewatering the dredged sediment slurry generated from sediment removal activities at New Bedford Harbor, and treating the dewatering and other process effluents. Sediment dewatering and water treatment are necessary support activities for treatment and disposal actions.

Sediment dewatering provides a number of benefits to potential response actions. Dewatering removes water from the sediment slurry and thereby reduces the volume of sediment to be treated or disposed. This reduces the time required to dispose of or treat the sediments, the volume of any sediment disposal facility, and potentially the capacity of any treatment process equipment. Dewatering also reduces the energy requirements of any thermal treatment processes, or other processes requiring a reduced moisture content feed stream, since much of the water associated with the sediments is removed from the slurry. However, sediment dewatering produces an effluent containing PCBs and toxic metals. This wastewater stream requires treatment to reduce the PCBs and toxic metals to concentrations that comply with applicable effluent limits for these contaminants before the effluent is discharged to the environment. The discharge limit in current wastewater discharge permits for PCBs at New Bedford Harbor is 1.0

ppb. A discussion of the dewatering and water treatment support functions follows.

7.1 DEWATERING

7.1.1 Description

A list of technologies that are used to dewater dredged sediment slurries and that may be applicable to dewatering New Bedford Harbor sediments follows. A brief description of each technology is presented, together with a discussion of the appropriateness and applicability of each to the specific task of dewatering sediments dredged from New Bedford Harbor. Cost information is being developed for those technologies found to be appropriate and applicable to dewatering New Bedford Harbor sediment.

Mechanical (Active) Dewatering Technologies	Passive Dewatering Technologies
Belt filter press	Progressive trenching
Centrifugal dewatering	Underdrainage
Gravity thickening	
Plate and frame filter press	
Vacuum filtration	

Mechanical (Active) Dewatering Technologies

Belt Filter Press

Belt filter pressing of sediments is likely the most appropriate and applicable mechanical dewatering technology for New Bedford Harbor sediments. Belt filter press dewatering of river sediments and coal tailings, which has dewatering characteristics similar to those of New Bedford Harbor sediments, has been successfully demonstrated. Also, belt filter presses have been used successfully and dependably to dewater industrial and municipal wastewater treatment facility sludges for years (Rexnord, 1986).

The belt filter press can process sediment slurries that vary widely in solids composition (1 to 40 percent solids by weight). However, sediment cake dryness achieved typically increases with increasing sediment solids feed concentration. Belt filter presses have achieved greater than 50 percent solids by weight in wastewater sludge, coal tailings, and river sediment dewatering applications. Typical solids feed concentrations for these applications range from 10 to 20 percent solids by weight. Typical throughputs for these applications are 25 dry tons per hour of solids feed for a 2.5-meter wide full-size press normally specified for such applications. Typical solids capture rates are a minimum of 95 percent for these solids feed streams with the majority of the 5 percent solids (or less) loss captured in the belt wash water. The combined effluents (gravity drain and belt press filtrates and belt wash water) from the press typically contain less than 2 percent solids by weight (20,000 mg/ℓ) (USEPA, 1980; Rexnord, 1983; Rexnord, 1986).

A belt filter press specified for this application likely would consist of three dewatering stages. The first dewatering stage would possibly be a thickening drum screen section used to increase the solids content of the slurry feed. Bench testing results may suggest that the feed slurry solids should be increased using a thickening drum screen section to achieve an optimum sediment cake dryness from the press. The thickening drum screen separates some filtrate from the slurry solids by gravity before the slurry passes to the second dewatering stage.

The second dewatering stage consists of a gravity drain section which is essentially a conveyor belt where filtrate again separates by gravity from the slurry solids. Slurry leaving the gravity drain section may have a solids content of approximately 30 percent, depending on the slurry feed concentration (USEPA, 1980; Rexnord, 1986).

The third dewatering stage is the actual belt filter press section. The belt filter section consists of two endless filter belts that run over drive and guide rollers at each end like conveyor belts. The upper belt is the press belt and the lower belt is the filter belt. The upper side of the filter belt is supported against the press belt by several rollers. The press belt runs in the same direction and at the same speed as the filter belt. The drive rollers of the press and filter belts are coupled. The press belt can be pressed against the filter belt by a pressure roller system whose roller positions can be adjusted to maximize the static and shear pressures applied. The slurry to be dewatered is fed on the upper face of the filter belt and is dewatered between the belts. After passing through the pressure zone, further slurry dewatering in a reasonable time cannot be achieved by applying only static pressures. The supporting rollers of the filter belt and the pressure rollers of the press belt are adjusted so that the belts and the slurry between them form an S-shaped curve, which imposes shear forces that cause further dewatering. After dewatering in the shear zone, the dried sediment cake is removed by a scraper (USEPA, 1980).

Belt filter presses do not need vacuum systems and do not have the solids pickup problems experienced with rotary vacuum filters. The belt filter press system includes auxiliaries such as polymer preparation and injection equipment. Hard-to-dewater slurries can be handled more readily with a belt filter press and high dewatered cake solids permit thermal detoxification or destruction of contaminants in the dried slurry using a minimum of auxiliary fuel. Also, a large filtration area can be installed in a minimum of floor area. Belt filter presses have the further advantage of handling occasional debris up to 1½-inch in cross section. The presses operate continuously and operating experience with the press demonstrates that downtime for maintenance and operational reasons is minimal (USEPA, 1980; Rexnord, 1986).

Centrifugation

Centrifugation is a physical separation process in which the components of a fluid mixture are separated mechanically, based on their density, by rapidly rotating the mass of fluid within a rigid vessel. Centrifugal forces in centrifugation are similar to gravitational forces in sedimentation except that centrifugal forces are thousands of times stronger than gravitational forces (USEPA, 1986).

Centrifugal dewatering or centrifugation of sediments is not an appropriate or applicable mechanical dewatering technology for New Bedford Harbor sediments for a number of significant reasons. Slurry streams dewatered by centrifuge achieve only 15 to 40 percent solids content, and 80 to 95 percent solids capture with conditioning chemicals addition (USEPA, 1986). These solids contents and capture rates do not compare well with those for a belt filter press, and the solids contents achieved are not compatible with pretreatment requirements for some detoxification and destruction treatment technologies. In addition, centrifuge wear is a significant operating and maintenance problem, and centrifuges are also energy-intensive (USEPA, 1980). Since centrifugation is not considered appropriate or applicable to dewatering New Bedford Harbor sediments, bench testing of the technology will not be undertaken and costs will not be developed.

Gravity Thickening

Gravity thickening is used to produce an effluent, or in the present case a seawater supernatant, having a reduced suspended solids concentration while thickening the solids removed into a smaller slurry volume (Weber, 1972). Removing the seawater supernatant reduces the slurry volume requiring disposal or further treatment. Gravity thickening takes advantage of the difference in specific gravity between the solids and water to accomplish separation of the two materials (USEPA, 1980).

Gravity thickening is appropriate and applicable to dewatering New Bedford Harbor sediments, specifically as applied in the dredged sediment containment area. The sediment containment area receives and stores the sediment slurry for settling and treatment as it is pumped from the dredging operation. Supernatant from the containment area can be pumped from the relatively clear clarification zone to a surge pond and then to the water treatment system where PCB and metal contaminant concentrations are reduced before the supernatant is returned to the harbor.

Settling tests conducted by the USACE using representative samples of New Bedford Harbor sediments indicate that gravity thickening or settling without chemical addition concentrates the sediments to approximately 25 percent solids by weight (USACE, 1987). A portable dredge can be used to pump the thickened sediment slurry from the containment area to the dewatering pretreatment process.

Containment area costs will be refined when the containment structure design information is available from the USACE. The information should be available following USACE's completing the design for constructing the pilot confined aquatic disposal (CAD) facility as part of USACE's pilot dredging program.

Plate and Frame Filter Press

The plate and frame filter press or recessed plate press is a conventional method used to dewater slurries and wastewater sludges. This press consists of a series of parallel vertical plates, covered on both sides with a monofilament filter media, which are held rigidly in a frame and which are pressed together between a fixed and moving end. The slurry is fed into the press under pressure and passes through feed holes in trays along the length of the press. Water in the slurry passes through the filter media covering the plates, while the solids are retained and form a cake on the filter media surface. When filtrate drainage from the press ceases, slurry feed to the press is stopped and dewatering is completed. The press closing gear is then operated to open the press and the individual plates are moved in turn over a gap between the plates and the moving end to allow the filter cakes to fall out. When all the cakes have been released, the complete pack of plates is then pushed back by the moving end and closed to begin the next dewatering cycle (Weber, 1972; USEPA, 1980).

Plate and frame filter pressing is a semi-continuous process but it effectively dewaters hard-to-handle slurries. Filter pressing can be used where a large filtration area is required in a minimum floor area. Pressure plate warpage has been a major problem with the press and plate gasket deterioration (sometimes caused by plate warpage) has been a maintenance problem (USEPA, 1980).

Plate and frame filter press dewatering is appropriate and applicable to dewatering New Bedford Harbor sediments. Advances in working pressures have improved filter cake solids contents to greater than 50 percent. Filter presses offer the advantages of high (greater than 50 percent) solids concentrations, improved solids capture rates, improved filtrate clarity, and reduced chemical consumption (USEPA, 1980). Results from bench testing, if bench testing is performed for the technology, may be used to develop filter press capital, operation and maintenance costs, present worth costs, and cost sensitivity analyses for the range of sediment volumes to be dewatered under identified clean-up scenarios.

Vacuum Filtration

A rotary vacuum filter consists of a cylindrical drum rotating partially submerged (20 to 40 percent) in a vat or pan of conditioned slurry. The drum is divided radially into several sections, which are connected through internal piping to ports in a valve body (plate) at the hub. This plate rotates in contact with a fixed valve plate with similar ports, which are connected to a vacuum supply, a compressed air supply, and an atmospheric vent. As the drum rotates each section is connected to the appropriate service. In the pickup or form section, vacuum is applied to draw liquid through the filter covering (media) and form a cake of partially dewatered slurry. As the drum rotates the cake leaves the slurry while suction is maintained to promote further cake dewatering. A scraper blade is often provided to assist cake removal if the cake tends to adhere to the media.

Vacuum filter solids capture typically ranges from 85 to 99.5 percent and cake solids content typically ranges from 20 to 40 percent depending on feed type, solids concentration, chemical conditioning, machine operation, and management. Typical solids loadings are 5 to 15 pounds dry solids/hr/ft^2 and are a function of feed solids concentrations, chemical preconditioning, and subsequent processing requirements. Operation is sensitive to the type of slurry and conditioning procedures. Chemical conditioning costs can be extremely large if a slurry is difficult to dewater.

Vacuum filtration may be appropriate and applicable to dewatering New Bedford Harbor sediments. Bench testing may be required to develop site-specific sediment cake solids contents, solids capture, slurry throughput rates, capital, operation, and maintenance costs for the range of sediment volumes to be dewatered under identified clean-up scenarios.

Passive Dewatering Technologies

Progressive Trenching

Progressive trenching is a passive dewatering technology that consists of allowing evaporative forces to dry fine-grained dredged material into a crust. Effective surface drainage by rapidly removing precipitation and preventing ponding of surface water accelerates the evaporative drying. Lowering the internal water table of the dredged material results in further consolidation. The most efficient method of promoting effective surface drainage is by constructing drainage trenches in the dredged material containment area. To promote continuing surface drainage as drying occurs, site drainage trenches require progressive deepening as the water table falls and the surface crust becomes thicker, which is the origin of the name "progressive trenching" for the concept (USACE, 1978).

Minimizing volatilization of PCBs during the New Bedford Harbor remedial action is a priority of primary concern. Measures to minimize PCB volatilization during any removal, treatment, and disposal activities will be incorporated. Dewatering processes may be contained in buildings or other suitable enclosures to minimize PCB volatilization.

Progressive trenching is an evaporative drying process and clearly can not be applied in an enclosure. Further, land requirements for applying progressive trenching are substantial (on the order of tens to hundreds of acres), and drying times to achieve solids contents that ultimately may not be adequate for detoxification/destruction treatment processes are on the order of hundreds of days to years (USACE, 1978). For these reasons progressive trenching is not appropriate or applicable to dewatering New Bedford Harbor sediments.

Underdrainage

Underdrainage is a passive dewatering method that consists of placing collector pipes in either a naturally occurring or artificially placed pervious layer before dredged material is applied. Free water in the dredged material migrates into the pervious underdrainage layer and is removed through a collector pipe system. Research by the USACE identified four dewatering and densification mechanisms for dredged material using pervious underdrainage layers as follows.

- Gravity underdrainage. This technique consists of providing free drainage at the base of the dredged material. Downward flow of water from the dredged material into the underdrainage layer takes place by gravity.

- Vacuum-assisted underdrainage. This technique is similar to gravity underdrainage, but a partial vacuum is maintained in the underdrainage layer by vacuum pumping to assist drainage.

- Seepage consolidation. This technique incorporates ponded water on the dredged material surface and underdrainage at the base of the dredged material. Downward seepage gradients act as a consolidating force, causing dredged material densification.

- Vacuum-assisted seepage consolidation. This technique combines the effects of seepage consolidation with those of an induced partial vacuum in the underdrainage layer (USACE, 1978).

Underdrainage is similar to progressive trenching in its need for substantial land requirements (on the order of tens to hundreds of acres) and extended drying times (on the order of years) (USACE, 1978). Also, these drying times may not achieve solids contents required by subsequent detoxification/destruction treatment processes. Underdrainage is not considered appropriate or applicable to dewatering New Bedford Harbor sediments due to these excessive requirements involved in applying the technology to the New Bedford Harbor case.

7.1.2 Effectiveness

Dewatering technologies are support technologies to the detoxification/destruction treatment technologies and are not themselves intended to be effective at removing or reducing the risk of PCB and toxic metals exposure to public health and the environment. However, four dewatering technologies (i.e., belt filter press, gravity thickening, plate and frame filter press, and vacuum filtration) have been found in this detailed evaluation of technologies to be applicable and appropriate to dewatering New Bedford Harbor sediments. Each of these dewatering technologies has been proven effective and has been used successfully and dependably for years to dewater industrial and municipal wastewater treatment facility sludges.

The effectiveness of these dewatering technologies is discussed further in Section 7.1.3. Issues relating to public health and the environment will be discussed during the detailed evaluation of remedial alternatives.

7.1.3 Implementation

Four sediment dewatering technologies have been evaluated as appropriate and applicable for use at New Bedford Harbor: belt filter press; gravity thickening; plate and frame filter press; and vacuum filter. For the purpose of determining their implementability these technologies will be discussed together in the remaining detailed screening sections.

Technical Feasibility. Solids dewatering is technically feasible and has been demonstrated for each of the four applicable technologies. All four dewatering technologies have been successfully applied for years at municipal and industrial wastewater treatment facilities. The technologies are used to dewater fine-grained wastewater sludges, which have similar physical characteristics to those of sediments, prior to sludge treatment or disposal. Substantial sludge volume reductions are achieved using the technologies; this results in significant sludge treatment and disposal cost savings from handling the reduced sludge volumes.

Level of Development. Each of the dewatering technologies has been demonstrated to operate dependably and with a reasonable amount of downtime for maintenance. Bench test results will also demonstrate the effectiveness as well as performance of each dewatering technology in dewatering New Bedford Harbor sediments.

Support Requirements. Any of the dewatering technologies will require screening of the sediment feed material to remove potentially troublesome large objects and debris collected along with the sediments during dredging operations. This debris screening and removal activity would likely occur as dewatering feed sediments are removed from the dredge spoils containment area by portable dredging equipment and pumped to a headbox, or other sediment equalizing containment, ahead of the sediment dewatering process. Provisions for treating and disposing of the debris through detoxification and destruction treatment processes, or disposing of the debris untreated, will be needed.

Any of the dewatering technologies will also require chemical addition (including polymer) systems to optimize sediment dewatering effectiveness. Provisions will also be needed to store dewatered sediment cake in an enclosed facility to minimize volatilization and protect the dewatered sediment from precipitation until the dewatered cake can be processed through detoxification and destruction treatment technologies. Also, seawater effluents from any of the dewatering technologies selected will require treatment to reduce PCB and metals concentrations in the effluents to acceptable levels before the effluent is discharged to the environment. Water treatment as a support technology will be provided and is discussed later in Section 7.2.

Availability. Delivery time for any of the mechanical dewatering technology units selected for use at New Bedford Harbor are reasonable (six months to two years) and depend on the quantity and type of units required.

Area requirements also depend on the type and quantity of units selected and the dewatered sediment storage capacity required. Specifically, the gravity settling containment area requires several acres (on the order of tens) depending on the containment capacity needed for the range of sediment volumes to be dewatered under identified clean-up scenarios. Area required for any of the mechanical dewatering technologies and dewatered sediment storage is less than that needed for the containment area(s), but depends on the type and quantity of units selected and sediment volumes processed.

Installation. These dewatering systems and containment may be housed in buildings or other suitable enclosures to contain and minimize PCB volatilization to the environment. These systems can be installed or constructed on flat, vacant areas with sufficient space.

Time. Time requirements for installing the mechanical dewatering systems and for constructing containment areas for a range of sediment volumes to be dewatered under identified clean-up scenarios are reasonable (six months to two years) and depend on the type and quantity of units selected.

Safety. None of the dewatering technologies or containment areas pose any significant safety hazards when operated by trained personnel in a properly designed and controlled facility. Appropriate protection will be worn by dewatering system operating personnel and PCB releases to the environment shall be minimal and should pose no hazard to public health or the environment.

Monitoring and Maintenance Requirements. Mechanical dewatering technologies require monitoring instrumentation to control the dewatering process and provide data at a minimum on sediment slurry feed rate and consistency, and chemical/polymer feed rates. These data are used to assist in achieving optimum sediment cake solids. The containment areas will also require monitoring of chemical/polymer feed rates and slurry levels within the containment area(s).

Typical equipment maintenance includes regular inspections during operation and periodic shutdowns to perform preventive mechanical maintenance. Pumps require regular maintenance and moving parts require periodic lubrication.

Permitting. No permitting is presently anticipated for containment area(s) dewatering or mechanical dewatering systems' operations. Permitting will be required for the water treatment discharge supporting the dewatering operation. This will be discussed in the water treatment technologies section that follows.

Legal Constraints. Sufficient land must be available to construct containment areas and a mechanical dewatering system. Land acquisition and zoning will be addressed during the evaluation of alternatives.

Impacts on Historical and Cultural Resources. This subject will be addressed in the alternatives evaluation.

7.1.4 Costs

This section presents cost information for dredged sediment containment and dewatering of New Bedford Harbor sediments. Containment area cost estimates have been prepared using a design report prepared in 1980 by Malcolm Pirnie, Inc. Consulting

Engineers for the New York State Department of Environmental Conservation concerning a Hudson River PCB Dredging and Reclamation Program. Dewatering cost estimates have been prepared using information received from vendors of dewatering technologies. These estimates reflect a range of assumptions. A cost curve is presented for containment and dewatering operations. Capital and operating and maintenance costs are discussed in the following paragraphs.

Costs for dewatering were calculated for a worst case scenario in which it is required that remedial action (i.e., dredging, dewatering, etc.) be conducted in the shortest time possible. Hence, equipment capacities and containment volumes were sized to accommodate the maximum production rates of the dredges and the time required to complete the dredging operations. This batch mode of operation may be preferable to minimize risks to public health and the environment by minimizing the time to implement remedial action. During the detailed evaluation of remedial alternatives, a continuous mode of operation will be considered relative to costs and potential impacts on public health and the environment.

<u>Containment Area and Surge Pond Costs</u>. Capital costs for containment, dewatering, and water treatment at New Bedford Harbor are based on processing the sediments and water associated with removing three selected volumes of in-place sediments, i.e.,

20,000, 200,000, and 2,000,000 yd^3 of in-place material. Dredged sediments are assumed to be delivered to the containment area(s) as a slurry at approximately 14 percent solids by weight. The material then separates from seawater and settles to a consistency of approximately 25 percent solids.

The containment areas for the three clean-up scenarios were sized on a worst-case basis; that is, sized to hold the entire dredge spoils volume (delivered at approximately 14 percent solids) produced by a small dredge, since this dredge produces the greatest volume of spoils of those considered. A containment area constructed with a 20-ft depth is assumed (a small portable dredge to deliver sediments to the dewatering area can operate in this depth range) and the land requirements to contain the entire volume of spoils produced was then computed.

In the cases of the two larger clean-up volumes (200,000 and 2,000,000 yd^3) unreasonable land requirements are needed to contain the spoils (59 and 590 acres). To reduce the containment area(s) land requirements to more reasonable levels, and at the same time reduce the capacities of the dewatering, water treatment, and destruction/detoxification equipment that will also be required, the 200,000 yd^3 cleanup was assumed to occur over three years and the 2,000,000 yd^3 cleanup over 10 years. These clean-up duration assumptions reduced the required containment area(s) for these volumes to 20 and 59 acres which would be reused each year of dredging duration. These containment land requirements remain substantial but clearly represent an improvement over the case of containing and treating the entire clean-up volume at once.

Any number of assumptions may be made concerning the time required to perform the cleanup. The sensitivity of the many parameters affected by the time required to perform the cleanup may be better assessed during the evaluation of alternatives. Optimization or linear programming techniques may then be used to refine the sensitivities of individual treatment processes to varying times of performing the cleanup.

Capital costs for constructing containment area(s) and a surge pond were developed to accommodate two containment scenarios. The first scenario includes the cost for containment area(s) and surge pond buildings with air collection and distribution systems to contain and minimize airborne PCB release, if PCB volatilization to the atmosphere is considered a significant problem that must be addressed. The second scenario does not include the cost of buildings, but only the cost of constructing the containment area(s) and surge pond.

Capital costs for constructing containment area(s) and a surge pond were developed directly from costs for these structures prepared by Malcolm Pirnie, Inc. Consulting Engineers presented in their 1980 Hudson River PCB Dredging and Reclamation Program design report (Malcolm Pirie, Inc., 1980). The Malcom Pirnie capital costs for these structures apparently do not include any provision for engineering and construction services or contingencies. No provision for these items was added in developing New Bedford Harbor containment area and surge pond costs. The six-tenths exponent rule for estimating costs of varying equipment capacities was used to develop costs for varying capacity containment areas, and the Engineering News Record's Construction Cost Index (ENR CCI) was used to update the Malcolm Pirnie 1980 costs to first quarter 1987 dollars. The surge pond to hold containment decant water, belt filter press filtrate, and destruction/detoxification process effluents ahead of the water treatment system is kept constant in size for three clean-up scenarios at 2.4 acres (56,000 yd^3 or 11.3 million gallon capacity).

Capital and operation and maintenance (O&M) costs for containment area(s) and a surge pond are presented in Table 7-1 along with applicable containment and surge pond design information. A cost curve is presented in Figure 7-1 for containment area and surge pond operations. As can be seen from the table, the cost for buildings constructed over such large areas is the major component of containment area and surge pond capital costs, and causes these costs to become excessive and unreasonable. Operation and

TABLE 7-1
DREDGE SPOILS, CONTAINMENT AREA, AND SURGE POND COSTS
(thousands of first quarter 1987 dollars)

Sediment volume dredged (yd^3 in place)	20,000	200,000	2,000,000
Total dredge spoils volume (10^6 yd^3)	0.2	1.9	19.0
Containment volume required (10^6 yd^3)	0.2	0.63	1.9
Dredging duration (years)	1	3	10
Land required for 20-ft depth containment (acres)	6.2	20	59
Surge pond volume (10^6 yd^3)	.056	.056	.056
Land required for surge pond (acres) (15-ft depth)	2.4	2.4	2.4

Containment and surge pond costs	Capital[1] ($1,000)	O&M[2] ($1,000/yr)	Capital[1] ($1,000)	O&M[2] ($1,000/yr)	Capital[1] ($1,000)	O&M[2] ($1,000/yr)
Containment and surge pond with buildings	9,860	394	24,735	989	66,361	2,654
Containment and surge pond without buildings	870	35	1,316	53	2,151	86

[1] Building cost developed to enclose containment area(s), if required, to minimize PCB volatilization to the atmosphere. Building cost estimates based on $24/ft (1987 dollars).

[2] O&M cost estimated at 4 percent of capital cost.

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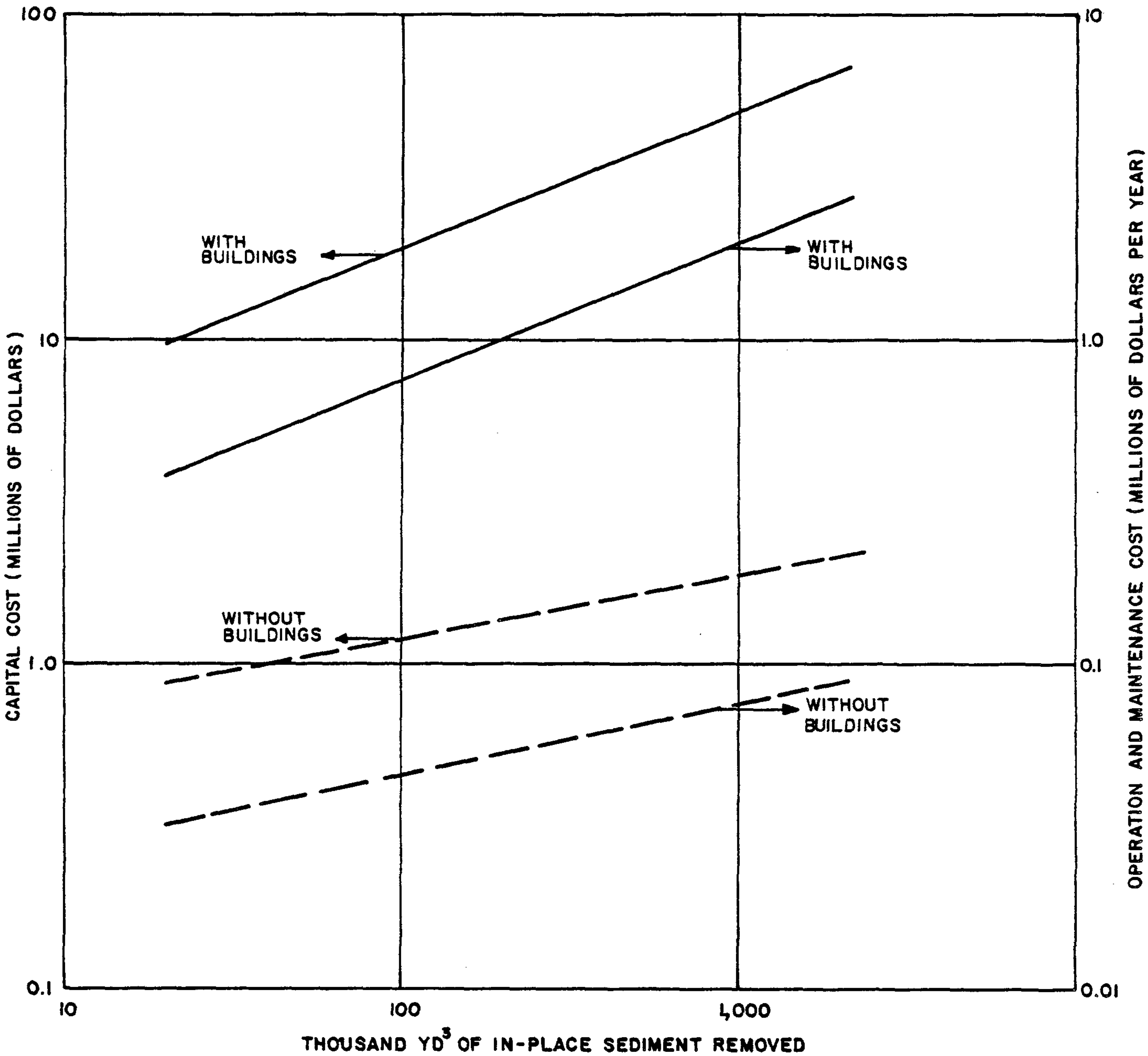


NOTE: O & M COST (MILLION $/YR) MUST BE MULTIPLIED BY YEARS TO PERFOM CLEANUP.

FIGURE 7-1
DREDGE SPOILS CONTAINMENT AREA AND SURGE POND CAPITAL AND OPERATIONS AND MAINTENANCE COSTS

maintenance costs for containment area(s) and a surge pond were estimated at 4 percent of capital costs.

Sediment Dewatering Costs

Capital costs for dewatering New Bedford Harbor sediments are, as stated previously, based on processing sediments associated with removing three selected volumes of in-place sediments, that is, 20,000, 200,000, and 2,000,000 yd^3 of in-place material. Sediments are assumed to be delivered to the dewatering area as a slurry in the range of approximately 25 percent solids by weight. The sediments are then dewatered using one or more belt filter presses to a consistency of approximately 50 percent solids. The dewatered sediments are then stored in a corrugated steel, airplane hanger-type building of similar construction to that used to enclose the containment area(s) and surge pond, except that the dewatered sediment building is equipped with a concrete slab floor with floor drains. Unlike the containment area case, sediment dewatering costs were developed including a building since the dewatered sediments must be protected from precipitation once they have been pressed.

The dewatered sediments are stored prior to treatment based on assuming that the detoxification/destruction equipment throughput capacities will be insufficient to treat the sediments continuously as they are dewatered. This assumption provides conservative, worst case treatment costs that can be refined in the detailed evaluation of remedial alternatives where a continuous treatment operation will be considered.

The belt filter press machine capacity required for the three clean-up scenarios was determined using the same dredging duration assumptions used to size the containment area(s) for these three cases. The 20,000 yd^3 cleanup is assumed to occur in one year, the 200,000 yd^3 cleanup over three years, and the 2,000,000 yd^3 cleanup over 10 years. Sediment dewatering rates are based on using a 2.5m-wide belt filter press having a dewatering capacity of 25 dry tons of sediment/hour. However, a throughput of 20 dry tons of sediment/hour was used to estimate capital and operation and maintenance (O&M) costs.

Capital and O&M costs for belt filter presses and necessary ancillary equipment, including a building to house the dewatering operation, were prepared based on vendor quotations developed for similar applications, and updated to first quarter 1987 dollars using the ENR CCI. Capital and O&M costs for sediment dewatering are presented in Table 7-2 along with applicable dewatering facility design information. As can be seen from the table, the cost for a sediment storage building is, as for the containment area(s) and surge pond, the major component of the dewatering capital cost, and similarly causes these costs to become excessive and unreasonable. Operation and maintenance costs for dewatering

TABLE 7-2
SEDIMENT DEWATERING COSTS
(thousands of 1st Qtr 1987 dollars)

Sediment volume dewatered (yd^3 in place)	20,000	200,000	2,000,000
Total dry tons of sediment to be dewatered	24,500	245,000	2,450,000
Dredging and dewatering duration (years)	1	3	10
Total Dewatered (50% solids) sediment requiring storage (yd^3)	40,000	400,000	4,000,000
Land required for one year of dewatered sediment storage (acres)	2.1	6.9	20.7

	Capital[1] ($1,000)	O&M[2] ($1,000/yr)	Capital[1] ($1,000)	O&M[2] ($1,000/yr)	Capital[1] ($1,000)	O&M[2] ($1,000/yr)
Sediment dewatering cost[1]	1,754	147	1,754	490	4,090	1,470
Sediment storage building cost[2]	3,000	120	9,000	360	27,000	1,080
Total dewatering cost	4,754	267	10,754	850	31,090	2,550

1 Capital cost based on belt filter press throughput of 20 tons dry solids/hr/machine. O&M cost estimated at $6/dry ton of solids dewatered.

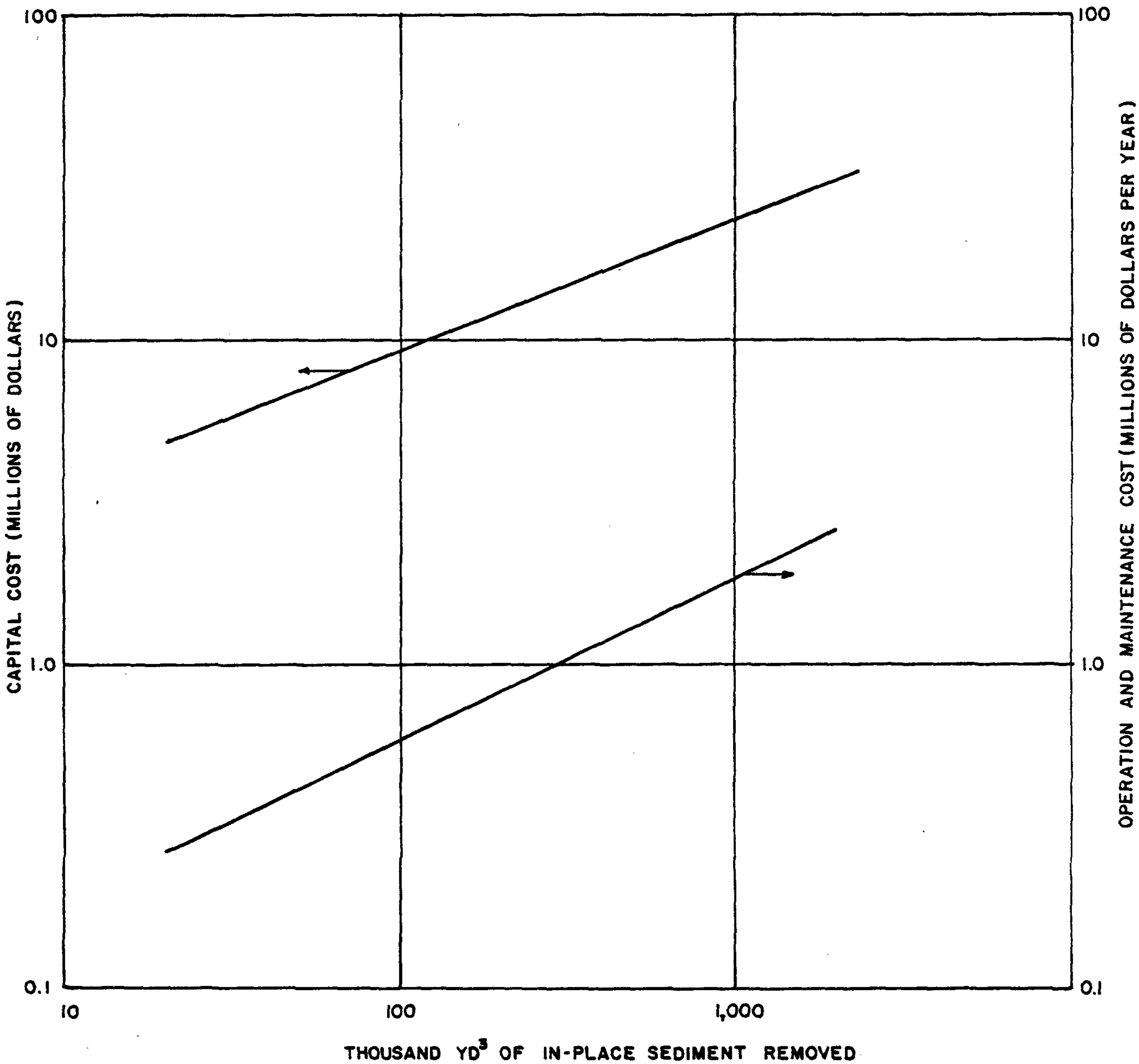
2 Sediment storage building capital cost estimated at $30/ft^2$ (1987 dollars) for 20-ft high steel hanger-type building on a concrete slab with floor drains. Dewatered sediments are piled 12-ft high. O&M cost estimated at 4 percent of building capital cost. Building must be provided for dewatered sediment storage to protect dewatered sediments from precipitation.

the sediments are based on $6.00 per dry ton of sediment dewatered. Operation and maintenance costs for the sediment storage building are estimated at 4 percent of building capital cost. Figure 7-2 presents a cost curve for sediment dewatering operations.

7.1.5 Dewatering Summary

Sediment dewatering is a necessary support activity for removal, treatment, and disposal actions, and provides a number of benefits to potential response actions. The primary benefit of dewatering is the removal of water from the sediment slurry, thereby reducing the volume of sediment to be treated or disposed. This reduction in sediment volume in turn reduces the time required to treat or dispose of the sediments, the volume of any sediment disposed, and potentially the capacity of any treatment process equipment. Dewatering also reduces the energy requirements of any thermal treatment process, or other processes requiring a reduced moisture content feed stream, since much of the water associated with the sediments is removed from the slurry.

Four dewatering technologies (belt filter press, gravity thickening, plate and frame press, and vacuum filtration) have been found in this detailed evaluation of technologies to be applicable and appropriate to dewatering New Bedford Harbor sediments. Each of these dewatering technologies has been proven



NOTE: O & M COST (MILLION $/YR) MUST BE
MULTIPLIED BY YEARS TO PERFOM CLEANUP.

FIGURE 7-2
SEDIMENT DEWATERING
CAPITAL AND OPERATION AND MAINTENANCE COSTS

effective and has been used successfully and dependably to dewater industrial and municipal wastewater treatment facility sludges for years. Belt filter pressing of sediments is likely the most appropriate and applicable dewatering technology for New Bedford Harbor sediments.

Capital and O&M costs for dewatering New Bedford Harbor sediments were developed based on storing and belt filter pressing 20,000, 200,000, and 2,000,000 yd^3 of in-place sediments. Cost curves for storing and belt press dewatering a range of sediment volumes is presented.

7.2 WATER TREATMENT

7.2.1 Description

Water Treatment Technologies Evaluated

A list of technologies that are used to treat wastewater and that were retained for consideration during the initial technology screening follow. Some of these treatment technologies may be applicable to treating the effluents from the sediment dewatering and treatment processes. These effluents require treatment to reduce the PCB and toxic metal concentrations they contain to acceptable levels for discharge to the environment.

A brief description of each technology is presented, together with a discussion of the appropriateness and applicability of each to the specific task of treating effluents from New Bedford Harbor sediment dewatering and treatment processes. Those technologies determined to be appropriate and applicable to treating sediment dewatering and treatment process effluents will then be grouped together in a single process treatment train, and discussed in subsequent sections as a single treatment technology.

The following water treatment processes were retained during initial screening:

- o carbon adsorption;
- o coagulation/Flocculation/Precipitation;
- o ion exchange; and
- o resin adsorption.

Carbon Adsorption

Activated carbon adsorption is used in wastewater treatment to adsorb organic materials. Adsorption is a surface phenomenon in which molecules from a solution are sorbed onto a particular substrate. This treatment technology removes organics from dilute waste streams by adsorbing the compounds onto the large internal surface area of the activated carbon.

One of the most desirable properties of an adsorbent is a high surface-to-volume ratio. Activated carbon (with a surface-to-unit weight ratio ranging from 500 to 1,400 m^2/g) is an effective adsorbent for removing organic compounds. The large surface area and the surface's activity, or affinity for specific organic groups, results from the activation process that produces numerous pores within the carbon particle and creates active sites on the surfaces of the pores. Carbon adsorption has been demonstrated to remove a variety of organics, is one of the most developed and proven technologies for water treatment, and is one of the most frequently applied technologies for removing organics from dilute aqueous solutions (USEPA, 1986a; WPCF, 1977; USEPA, 1980; USEPA, 1986).

In practice, activated carbon typically removes organics from an aqueous stream containing organic material by a combination of adsorbing the less polar molecules, filtering the larger particles, and partially depositing colloidal material on the carbon's exterior surface.

Activated carbon will adsorb most organic compounds to some degree. Factors that affect the adsorption process include the following:

- o carbon pore structure;

- carbon contact time;
- temperature; and
- pH.

A list of compounds that can be successfully removed from waste streams follows:

- organic liquids containing metal and halogen groups;
- organic nitrogen compounds;
- chelated heavy metals; and
- many volatile organics (USEPA, 1986a).

Mixtures of organics in the waste stream may cause significantly reduced adsorption capacity for some compounds due to the preferential adsorption of other compounds by the carbon. Competitive adsorption of organic compounds is extremely complicated and difficult to predict. The effectiveness of activated carbon adsorption in removing an organic material is limited by the following waste characteristics:

- low molecular weights;
- high polarities; and
- high solubility.

For these and other reasons, it is recommended that bench treatability tests be performed on a specific waste. The following waste stream characteristics represent applications for which the activated carbon adsorption process is not recommended:

- o high solids content (greater than 500 mg/l);
- o unassociated metals; and
- o high humidity gas streams (USEPA, 1986a).

Granular activated carbon systems generally consist of vessels in which the carbon is placed, forming a "filter" bed. These systems may include carbon storage vessels and thermal regeneration facilities. Vessels are usually circular for pressure systems or rectangular for gravity flow systems. Once the carbon adsorptive capacity has been fully exhausted, the carbon must be disposed of or regenerated. Usually, multiple carbon columns are used to permit continuous operation. These columns can be operated either in series or parallel. All carbon vessels must be equipped with carbon removal and loading mechanisms to remove spent carbon and add new adsorbent. Flow can be directed either upward or downward through the carbon bed.

Spent carbon will contain all of the waste constituents removed from the waste stream. Small systems (less than 3 million gallons/day (mgd)) usually dispose of spent carbon or regenerate it off-site. Systems greater than approximately 3 to 5 mgd capacity usually provide on-site carbon regeneration for economic reasons.

Thermal regeneration of the spent carbon is the most common method currently used. Other methods of regeneration used are solvent and steam regeneration (USEPA, 1980; USEPA, 1986a). Carbon used to adsorb PCBs or dioxin is not currently regenerated by mobile treatment technology vendors.

The carbon columns are backwashed periodically to remove solids buildup. Surface wash and air scour systems can also be used as part of the backwash cycle. Periodic backwashing of the carbon generates a small amount of wastewater containing high concentrations of organics, requiring treatment before disposal (USEPA, 1980).

Carbon adsorption is appropriate and applicable to treating the effluents from sediment dewatering and treatment processes at New Bedford Harbor to reduce the PCBs and toxic metals concentrations to acceptable levels for discharge to the environment. The USACE is presently performing carbon adsorption bench testing on seawater samples collected from New Bedford Harbor. Bench testing results will be used to develop design information, including optimum carbon contact time, pH, area and organic loading rates, carbon adsorption capital, O&M costs, present worth costs, and cost sensitivity analyses for treating water volumes associated with the range of sediment volumes to be dewatered, and potentially treated, under identified clean-up scenarios.

Coagulation/Flocculation/Precipitation

Coagulation is the first step in the coagulation/flocculation process used to remove colloidal and suspended material from aqueous wastes. The coagulation/flocculation/precipitation process may prove to be a key treatment process in removing PCBs and toxic metals from New Bedford Harbor sediment dewatering and treatment process effluents. This treatment process is particularly effective at removing colloidal and finely divided suspended matter from an aqueous solution. Baker, et. al. (1986) suggest that colloidal-associated contaminants may be the dominant contaminant species in most surface waters. Colloids are intermediate in size between suspended and dissolved solids. Removing colloidal and suspended matter may prove essential in removing PCBs and toxic metals from an aqueous waste stream.

Coagulation is defined as destabilization by particle charge neutralization and initial aggregation of colloidal and finely divided suspended matter by inorganic coagulants. Coagulants are simple electrolytes that are water soluble, low molecular weight inorganic acids, bases, or salts.

The stability of colloidal suspensions occurring in wastewaters is primarily caused by electrostatic repulsive forces among particles. The stability of the suspension is generally a function of the magnitude of the repulsive forces, or particle charge. A colloid is most stable when it possesses the greatest electrical charge and smallest size. Adding coagulant to wastewater increases the electrolyte concentration and floods the solution with an excess of oppositely charged ions, which acts to compress the electrical double layer surrounding each particle in the wastewater. This reduces the repulsive forces among particles, that is, their stability, and promotes coagulation. Iron, aluminum, and calcium salts are the most effective coagulants (WPCF, 1977).

Coagulation can also be enhanced by organic polyelectrolytes (coagulant aids or flocculants), long chain organic molecules that have the properties of polymers and of electrolytes. These coagulant aids promote further agglomeration of coagulated solids through charge neutralization, bridging, or a combination of these, but primarily through interparticle bridging.

Selection of specific coagulants and coagulant aids depends on the characteristics of the solid-liquid system to be separated. Electrolytes and colloids react readily to changes in the wastewater pH. Most negatively charged particles, including the majority of colloids present in wastewaters, coagulate at an optimum pH value of less than 7.0. Salt content and pH affect the surface charges of suspended solids. The signs, magnitudes, and distribution of the surface charges primarily influence the type and quantity of coagulant to be used. Coagulant aids include activated silica, bentonite clay, and polyelectrolytes (WPCF, 1977).

Flocculation is the agglomeration of coagulated colloidal and finely divided suspended material by adding chemical coagulant aids and physically mixing the solution. The flocculation process consists of aggregating suspended coagulated particles to form larger flocs that are readily separated or settled from the aqueous stream by a subsequent process, that is, sedimentation or direct filtration. Colloidal particles that compose the larger flocs may result from the precipitation process, where the chemical precipitation reactions have formed insoluble colloids, or they may already be present in the aqueous waste stream (WPCF, 1977). These colloidal particles will contain PCBs and toxic metals which will be removed from the waste stream in the larger floc particles.

Typically, the chemicals used for flocculation are alum, lime, and polyelectrolytes. These flocculating agents are first rapidly mixed to disperse the agents. Then the solution is slowly and gently mixed to allow larger particles or flocs to form. The solution pH is an important factor in controlling the chemical properties of the flocculating agent and must be monitored (USEPA, 1986a). Flocculent hydroxide colloids are insoluble only at pH values above 7.0 and usually over 9.0. Lime is normally added to raise the pH, as well as to aid in coagulating, flocculating, and precipitating colloids (Nemerow, 1978).

Precipitation is a physical/chemical process in which dissolved chemical species in solution (e.g., toxic metals) react with precipitating chemicals to form insoluble species. Once converted to insoluble form, the colloidal and suspended particles are aggregated to form larger flocs that are easily removed from the waste stream in a subsequent sedimentation or filtration process (USEPA, 1986a).

The chemical equilibrium relationships governing the soluble materials are typically altered in precipitation by adding chemicals. Metals may be precipitated from solution as hydroxides, sulfides, carbonates, or other salts. Hydroxide precipitation with lime is most common; however, sodium sulfide is sometimes used to achieve lower metals concentrations. Other chemicals may need to be added (e.g., lime) to adjust the solution pH since the solubility of metal hydroxides and sulfides is very dependent on pH (USEPA, 1986; USEPA, 1982).

Precipitation is particularly well-suited for treating aqueous waste streams containing heavy metals and suspended solids, and has been used extensively to treat wastewaters containing heavy metals. These heavy metals include arsenic, cadmium, trivalent chromium, copper, lead, manganese, mercury, nickel, and zinc.

Precipitation also acts to remove PCBs that may be associated with suspended solids (USEPA, 1986a).

The coagulation, flocculation, and precipitation processes are appropriate and applicable to treating sediment dewatering and treatment process effluents at New Bedford Harbor to reduce the PCB and toxic metal concentrations to acceptable levels for discharge to the environment. Precipitation and coagulation/ flocculation may possibly be performed simultaneously in a common treatment unit. Bench testing results will be used to develop design and treatability information for representative samples of New Bedford Harbor seawater and dewatering process effluent, including: selection of coagulants, coagulant aids, flocculants, and precipitants, along with dosages for each; optimum pH ranges for the most effective coagulant, flocculant, and precipitant performance; and optimum floc settling times for use in determining sedimentation tank overflow rates. Bench testing results will also be used to refine process capital, O&M costs, present worth costs, and cost sensitivity analyses for treating water volumes associated with the range of sediment volumes to be dewatered, and potentially treated, under identified clean-up scenarios.

Ion Exchange

Ion exchange is a process of exchanging certain anions and cations that are electrostatically attached to a solid resin material for dissolved metal ions of similar charge in an aqueous solution or waste stream. The exchange occurs because the divalent and trivalent metal anions or cations in solution have an increased affinity for the charged sites on the surface of the resins. These resins are originally coated with weakly held monovalent anions or cations such as chloride, hydroxyl, sodium, or hydrogen ions. The exchange process is reversible, which allows for resin regeneration. The ion exchange process was originally developed to reduce hardness in domestic water supplies, but has recently been used to treat wastewaters (USEPA, 1986a).

Currently, the majority of ion exchange resins are constructed of synthetic organic materials. The resins are able to withstand a wide range of temperatures and pH and are capable of specific selectivity if the specific ions have a high exchange capacity. Both dissolved anions and cations can be removed from solution by placing a cation exchange column and anion exchange column in series. Such a system has the capability to remove a wide range of inorganic and some organic dissolved contaminants, depending on the resins selected for use (USEPA, 1986a).

Wastes that are suited to ion exchange include:

- many metallic anions and cations such as $Cr_2O_7^{-2}$, SeO_4^{-2}, AsO_4^{-2}, Ni^{+2}, Cd^{+2}, or Hg^{+2};

- inorganic anions such as halides, sulfates, and cyanides;

- organic acids such as carboxylics, sulfonics, and some phenols; and

- organic bases such as amines.

The upper concentration limits for a waste stream to which ion exchange may be applied are 2,500 mg/l for dissolved ions and 50 mg/l for suspended solids. Higher concentration levels of dissolved ion will result in rapid resin exhaustion accompanied by excessive regeneration costs. High suspended solids concentrations in a waste stream will cause resin columns to clog or plug. The presence of oxidants in the waste stream should also be avoided (USEPA, 1986a).

A concentrated backwash stream results from resin regeneration. The backwash stream will typically require treatment depending on the characteristics of the exchanged waste and regenerants, such as acid, caustic, or brine.

Ion exchange is not an appropriate or applicable technology for treating sediment dewatering and treatment process effluents at New Bedford Harbor since the technology treats only the toxic metals portion of the waste stream. PCBs are nonpolar molecules, and ion exchange will not appreciably remove PCBs from the waste stream and will be ineffective at PCB treatment. The coagulation, flocculation, and precipitation processes, however, will simultaneously remove PCBs and toxic metals from the waste stream. Residual PCBs in the waste stream following these processes will be removed by an appropriate level of activated carbon adsorption treatment to attain a discharge level at New Bedford of 1.0 ppb. Ion exchange is therefore an ineffective and unnecessary treatment technology for New Bedford Harbor process effluents, and as such will not be bench tested, and costs for the technology will not be developed.

Resin Adsorption

Resin adsorption is used for organics removal in a process similar to ion exchange except that the removal mechanism is one of sorption rather than ion exchange. Laboratory studies have shown that phthalate esters, aldehydes and ketones, alcohols, chlorinated aromatics, aromatics, esters, amines, chlorinated alkanes and alkenes, and pesticides are adsorbed by sorptive resins. Resins adsorbed certain amines and aromatics better than activated carbon did (USEPA, 1982a).

Resin adsorption has greatest applicability in the following situations:

- when color due to organic molecules must be removed;
- when solute recovery is practical or thermal regeneration is impractical;
- where selective adsorption is desired; or
- where wastewaters contain high levels of dissolved inorganics.

Polymeric adsorbents are either nonpolar, with an affinity for nonpolar solutes in polar solvents, or of intermediate polarity and capable of sorbing nonpolar solutes from polar solvents and polar solutes from nonpolar solvents. Carbonaceous resins have a chemical composition which is intermediate between polymeric adsorbents and activated carbon and are available in a range of surface polarities (USEPA, 1982a).

Resin adsorption is not economically competitive with carbon for high volume, high concentration, or mixed constituent wastes. However, because of selectivity, rapid adsorption kinetics, and chemical regenerability, resin adsorption offers the potential for treating a range of organic waste streams. As with activated carbon, spent adsorbent, if not reused, requires disposal by incineration or land disposal, if permitted (USEPA, 1980a).

Resin adsorption is not widely used compared to more common treatment technologies, such as carbon adsorption, due to difficulties in selecting the appropriate adsorbent/regenerant combination for a particular waste stream. This sorption technology has not been developed sufficiently and, in particular, its effectiveness at removing PCBs from marine sediment dewatering filtrate has not been demonstrated to date; therefore, the technology cannot be actively considered for use at New Bedford Harbor. For these reasons, resin adsorption presently is not considered appropriate or applicable for treating effluents from sediment dewatering and treatment processes at New Bedford Harbor.

7.2.2 Effectiveness

The water treatment technologies determined to be appropriate and applicable for treating sediment dewatering and treatment process effluents at New Bedford Harbor are coagulation/flocculation/precipitation and carbon adsorption. Support technologies to these water treatment technologies to be included in the water treatment process train are sedimentation and dual media filtration, which will follow coagulation/flocculation/precipitation and precede carbon adsorption. These two support technologies, which will assist suspended solids removal and increase the effectiveness of the PCBs and toxic metals removal process, are briefly discussed below.

Sedimentation or clarification involves a relatively long period of quiescence in a basin where settleable solids fall out of suspension by gravity, ordinarily after a chemical coagulant has been added. The solids are mechanically collected on the tank or basin bottom and are pumped to a thickening or dewatering operation as a sludge underflow.

Granular media filtration involves passing water through a filter media bed where the solids contained in the process stream deposit on the filter bed. Gravity dual media filtration is one of the most economical forms of granular media filtration. Dual media filtration uses both sand and anthracite coal media, with anthracite being placed on top of the sand.

The pressure drop across the filter bed eventually becomes excessive and the bed's ability to remove suspended solids is impaired. The filter bed is cleaned by backwashing, or reversing the flow through the bed so that the flow enters at the filter bottom and overflows at the bed top. Backwashing fluidizes the filter bed, allowing the bed to release accumulated solids through shearing and scouring actions. Backwash water and the associated solids can then be returned to the head of the treatment process.

These support technologies, together with the coagulation/flocculation/precipitation and carbon adsorption technologies, compose the water treatment technology process train that will be used to reduce the PCB and toxic metal concentrations to acceptable levels for discharge to the environment. These technologies will be discussed as a single water treatment technology in this and subsequent sections.

This section discusses the effectiveness of water treatment in achieving the stated goals of destroying PCBs and detoxifying metals in New Bedford Harbor sediment dewatering and treatment process effluents. The effectiveness of the process is measured in terms of its beneficial and adverse effects in providing protection to human health and the environment.

Reliability. The preceding water treatment process has been demonstrated to be a reliable method for permanently reducing the volume of aqueous wastes contaminated with PCBs and toxic metals. This water treatment process achieves this reduction by removing wastes from the waste stream and concentrating them for destruction or detoxification in post-treatment processes.

The reliability of this water treatment process and its components has been successfully demonstrated at industrial and municipal wastewater treatment facilities. Likely post-treatments for the concentrated PCB and toxic metal wastes produced by the water treatment process include incineration to destroy PCBs concentrated in the flocculation/precipitation sludges, and thermal regeneration of the spent activated carbon to destroy PCBs adsorbed to the carbon and prepare the carbon for reuse. The water treatment process effectiveness can be maintained for any reasonable period, for example, up to 20 years, selected for performing a cleanup of the New Bedford Harbor site. Some form of fixation technology (e.g., solidification) will likely be required to immobilize the toxic metals contained in the incinerated sludge ash and dewatered sediment.

Public Health. Water treatment of sediment dewatering and treatment process effluents will eliminate the potential for adverse short- and long-term effects from human exposure to contaminated clean-up process effluents that will be discharged to the environment. Water treatment will remove PCBs and toxic metals from these effluents and thereby eliminate any potential threat to human health and the environment associated with return of process effluents to the New Bedford Harbor environment.

Environment. Water treatment for the clean-up process effluents will remove PCBs in the effluent system discharged to the New Bedford environment to or below a 1.0 ppb concentration level. This is the equivalent of returning, at most, 1 pound of PCBs to the environment for every billion pounds of seawater and process effluent treated. This treatment will result in a significant reduction in available PCBs and other hazardous organics, as well as in available toxic metals, in the New Bedford Harbor environment.

Potential adverse effects resulting from implementing water treatment include the following:

- o releases of low levels of PCBs and toxic metals during contaminated materials handling (e.g., sediments, spent carbon) and treatment process spills or upsets;

- o releases of low levels of PCBs as volatilization losses from the treatment process enclosures, ducting, and piping; and

- o any adverse effects resulting from removal, transportation, construction, and residue disposal activities.

These adverse effects can be minimized through the use of proper process controls, appropriate air pollution control equipment, appropriately selected post-treatment for process effluents, and appropriately selected materials handling and treatment process equipment. With these controls on adverse effects, this water treatment technology is capable of providing significant benefits to the environment and achieving or exceeding all federal and state ARARs governing protection of the environment.

7.2.3 Implementation

This section discusses issues concerning the implementation of water treatment technology. As mentioned previously, the water treatment process train that is proposed to be used to reduce the PCB and toxic metal concentrations to levels acceptable for discharge consists of the following technologies: coagulation/flocculation/precipitation, sedimentation, filtration, and carbon adsorption. These technologies are discussed as a single water treatment technology in this section. A discussion of a variety of engineering feasibility issues follows.

Technical Feasibility. The water treatment process proposed to treat sediment dewatering and treatment process effluents at New Bedford Harbor is technically feasible, and each of the component technologies has been successfully demonstrated for years at industrial and municipal wastewater treatment facilities. Some industrial and some municipal wastewaters have waste characteristics, that is, PCB and toxic metal concentrations, similar to those that will be present in sediment dewatering and treatment process effluents at New Bedford Harbor. In addition, the USACE is performing bench tests on samples of New Bedford seawater for the coagulation/flocculation and carbon adsorption treatment technologies. Results of the USACE's bench tests will provide specific data on the technical feasibility of these treatment technologies for treating New Bedford Harbor clean-up process effluents.

<u>Level of Development</u>. As discussed in the preceding Technical Feasibility section, each of the water treatment process component technologies has been successfully applied and demonstrated for years at industrial and municipal wastewater treatment facilities. Each of the water treatment component technologies has been demonstrated to operate dependably and with a reasonable amount of downtime for maintenance. Bench test results to be provided by USACE will also demonstrate the effectiveness and performance of the bench-tested technologies (coagulation/flocculation and carbon adsorption) at treating New Bedford Harbor clean-up process effluents.

<u>Support Requirements</u>. The water treatment process train will require screening of the treatment system influent to remove potentially troublesome objects and debris in the clean-up process stream. The water treatment system will require provisions for adjusting the process stream pH by chemical (acid or base) addition to optimize the process stream treatability and treatment system effectiveness. Sediment dewatering, discussed in Section 7.1, is a necessary pre-treatment requirement for water treatment

since it separates the sediment and water streams for their respective treatments.

Sludge produced by the coagulation/flocculation/precipitation process will require dewatering, separately or combined with the sediment dewatering process, and post-treatment to destroy PCBs and detoxify toxic metals contained in the chemical sludge. As discussed previously, incineration of the chemical sludge to destroy PCBs, followed by fixation of the ash to detoxify and immobilize toxic metals, are examples of appropriate post-treatments needed to treat the chemical sludge.

Spent carbon, used to adsorb PCBs and any other hazardous organics present in the sediment dewatering and process effluents, may require thermal regeneration to regenerate the carbon for reuse. Rotary kilns or multiple hearth furnaces, located on-site or off-site depending on the process economics, are typically used as regeneration furnaces. Exhaust gases from the furnace will require afterburners and scrubbers to treat these furnace emissions. If the spent carbon is not regenerated, it must be disposed of by landfilling, if permissible, or by post-treatment (e.g., incineration) since it contains PCBs and other hazardous organics.

Availability. Deliveries for any of the water treatment technology components composing the process train proposed for use at New Bedford Harbor are reasonable (six months to two years) and depend on the quantity and capacity of units required. Treatment process equipment capacity is available. Water treatment processes typically consist of treatment modules and can be constructed to provide any capacity required. Area requirements also depend on treatment capacity requirements, and can be expected to be on the order of ten acres based on the treatment capacity needed under identified clean-up scenarios (see Table 7-1, Water Treatment Costs).

Installation. The water treatment process technologies are housed in buildings or other suitable enclosures to contain and minimize PCB volatilization to the environment. These technologies can be installed or constructed on flat, vacant areas with sufficient space.

Time. The time required to install a water treatment system to treat process effluents for identified clean-up scenarios is on the order of one to two years.

Safety. The water treatment train proposed for use at New Bedford Harbor does not pose any significant safety hazards when operated by trained personnel in a properly designed and controlled facility. Appropriate protection will be worn by water treatment system operating personnel, and PCB and toxic metal releases to the environment will be minimal and should pose no short- or long-term hazards to public health or the environment.

Monitoring and Maintenance Requirements. The water treatment component technologies require monitoring instrumentation to control the treatment processes and, at a minimum, provide data on process flow rates, chemical/polymer feed rates, and operating equipment pressure differentials. These data are used to assist in achieving optimum treatment results. The treated effluent requires frequent sampling and analysis to verify that permitted discharge levels for PCBs, toxic metals, and any other contaminants of concern in the treated effluent are being met or exceeded.

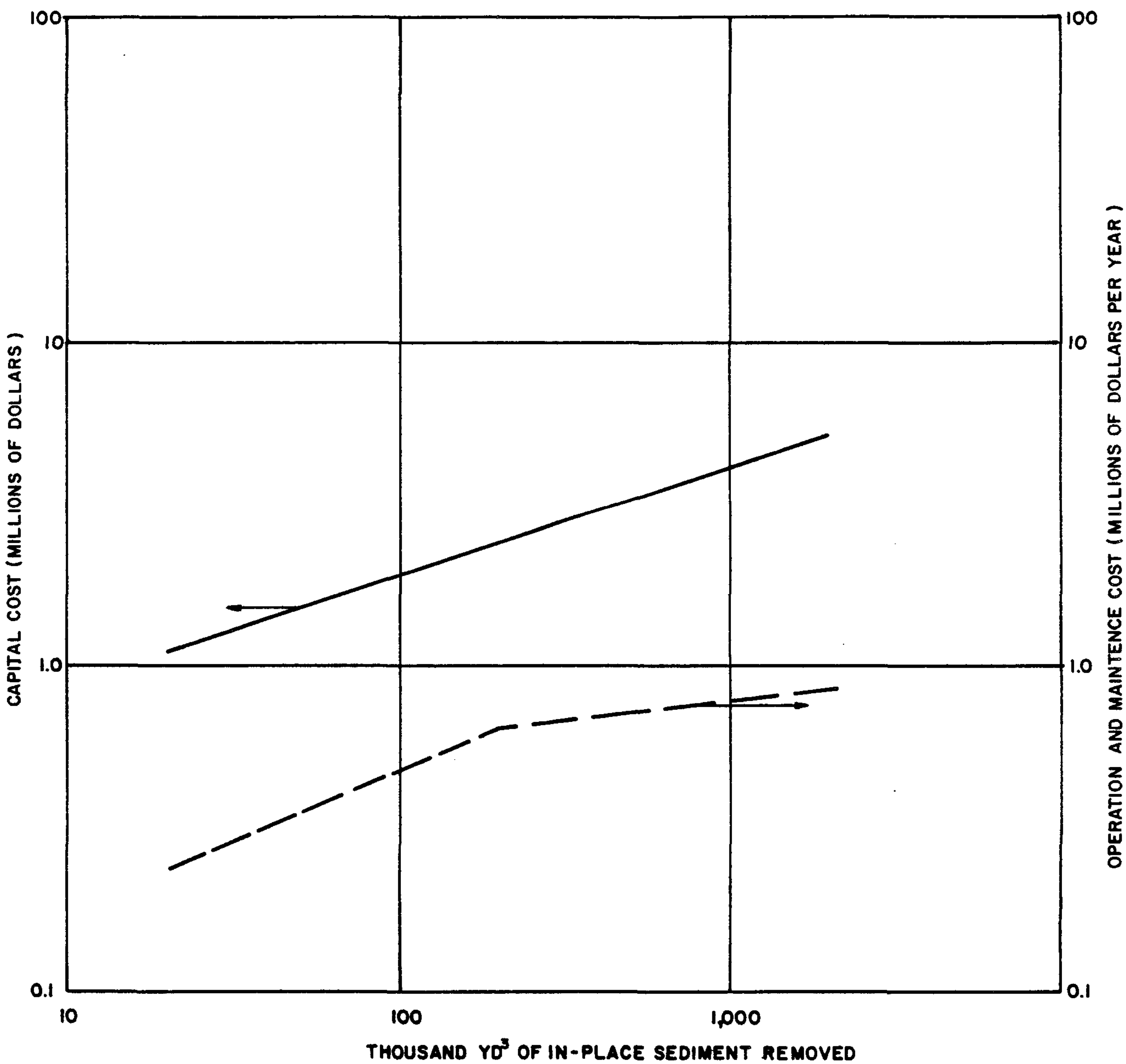
Typical equipment maintenance includes regular inspections during operation and periodic shutdowns to perform preventive mechanical maintenance. Pumps and piping components (e.g., valving) require regular maintenance and moving parts require periodic lubrication.

Permitting. Formal permitting (i.e., a National Pollutant Discharge Elimination System (NPDES) permit and a Massachusetts state discharge permit) likely will not be required for the treated process water discharge returned to New Bedford Harbor. The treated process water discharge will likely be required to meet technical requirements only, such as a 1.0 ppb limit for PCBs, and may include limits on other hazardous organics and toxic metals species, as well as on other conventional and unconventional pollutants (e.g., oil and grease, suspended solids, and chloroform).

Legal Constraints. Sufficient land must be available to construct a water treatment system of the capacity required to treat process effluents for identified clean-up scenarios. Land acquisition and zoning will be addressed during the evaluation of alternatives.

7.2.4 Costs

This section presents water treatment cost information for the following streams associated with removing the three selected volumes (20,000, 200,000, and 2,000,000 yd^3) of in-place sediments: containment area overflow or decant water; belt filter press filtrate; destruction/detoxification process effluents; landfill leachate; and surges. These water treatment cost estimates have been prepared using a USEPA manual ("Innovative and Alternative Technology Assessment Manual," EPA 430/9-78-009, February 1980) produced jointly by EPA's Office of Research and Development and Office of Water and Waste Management. These estimates reflect a range of assumptions. A cost curve (Figure 7-3) is presented for the water treatment operations. Water treatment cost information, along with applicable water treatment design information, is presented in Table 7-3.



NOTE: O & M COSTS (MILLION $/YR) MUST BE MULTIPLIED BY YEARS TO PERFORM CLEANUP.
THE SLOPE CHANGE IN THE O&M COST CURVE INDICATES THE BREAKPOINT AT WHICH CARBON REGENERATION BECOMES COST-EFFECTIVE AND IS INCLUDED, REDUCING CARBON REPLACEMENT COSTS.

FIGURE 7-3
WATER TREATMENT
CAPITAL AND OPERATION AND MAINTENANCE COSTS

4959-21

TABLE 7-3
WATER TREATMENT COSTS
(thousands of First Quarter 1987 dollars)

Sediment volume dewatered (yd^3 in place)	20,000		200,000		2,000,000	
Treatment system design capacity (mgd)[1]	0.17		0.6		1.7	
Treatment period (years) at system design capacity	1		3		10	
Technology	Capital[2] ($1,000)	O&M ($1,000/yr)	Capital[2] ($1,000)	O&M ($1,000/yr)	Capital[2] ($1,000)	O&M ($1,000/yr)
Screening	44	14	100	18	176	23
coagulation/flocculation/precipitation						
lime (adjust pH, precipitation)	23	3	56	11	105	32
alum addition (coag/floc)	59	17	67	35	97	79
ferric chloride (coag/floc)	59	14	67	28	88	62
polymer addition (coag/floc)	23	14	35	21	50	30
total chemical addition	164	48	225	95	340	203
sedimentation	246	7	457	15	843	30
filtration (dual media)	269	14	644	32	1,230	67
activated carbon adsorption	381	157	820	491	1,640	299
(w/regeneration where applicable)	--	--	--	--	984	203
Totals	1,104	240	2,246	651	5,213	825

[1] Treatment system capacity designed to treat a one year volume (365 day operation) from containment and dewatering operations plus an additional 100% of destruction/detoxification process effluents, landfill leachate, and surges.

[2] Capital costs include a 15% allowance for engineering and construction services and a 15% allowance for contingencies.

Costs for water treatment were calculated for a worst case scenario in which it is required that remedial action (i.e., dredging, dewatering, etc.) be conducted in the shortest time possible. Hence, equipment capacities and containment volumes were sized to accommodate the maximum production rates of the dredges and the time required to complete the dredging operations. This batch mode of operation may be preferable to minimize risks to public health and the environment by minimizing the time to implement remedial action. During the detailed evaluation of remedial alternatives, a continuous mode of operation will be considered relative to costs and potential impacts on public health and the environment.

<u>Water Treatment Costs</u>. Capital and O&M costs for treating the waste streams associated with removing the three selected volumes (20,000, 200,000, and 2,000,000 yd^3) of in-place sediments were determined using the same dredging duration assumptions used to size the containment and dewatering facilities for these three cases. The 20,000 yd^3 cleanup is assumed to occur in one year, the 200,000 yd^3 cleanup over three years, and the 2,000,000 yd^3 cleanup over 10 years. The water treatment system capacities to treat the various effluents were determined by assuming the system would treat annually the entire water volume from the containment area and dewatering facility operations and an equal volume of destruction/detoxification process effluents. These waste streams are assumed to be directed to the surge pond where the wastes are

mixed and equalized before being pumped to the treatment system. This assumption effectively doubled the treatment system capacity.

The water treatment capacities determined also assumed the following: 365-day per year operation; standard chemical dosages (coagulation/flocculation/precipitation) per the EPA reference manual since actual chemical dosages are not yet available; sedimentation overflow rate at 350 gal/ft^2/d; sedimentation sludge would be treated in the sediment dewatering facility; 30 minute carbon contact time and 1,800 pounds of carbon required per million gallons treated, since actual carbon contact times and dosages to achieve a 1.0 ppb PCB discharge level are not yet available; and activated carbon regeneration when economically justified (otherwise spent carbon would be disposed of in a destruction/detoxification process). The three resulting water treatment system design capacities follow: 0.17 mgd for the 20,000 yd^3 case; 0.6 mgd for the 200,000 yd^3 case; and 1.7 mgd for the 2,000,000 yd^3 case.

Capital and O&M costs for water treatment system components were developed using the cost curves presented for each technology and updated to first quarter 1987 dollars using the ENR CCI. The costs for the technologies are presented separately and as sums for the process train in Table 7-3, along with applicable water treatment system design information.

The water treatment system component and total capital costs include the construction cost of each component technology, plus an additional 28 percent allowance for non-component costs (i.e., piping, electrical, instrumentation, and site preparation), plus an additional 15 percent of the construction and non-component cost subtotal for engineering and construction supervision and an additional 15 percent of the subtotal for contingencies. However, these water treatment system costs may be understated and may require adjusting by adding a larger (greater than 15 percent) contingencies percentage.

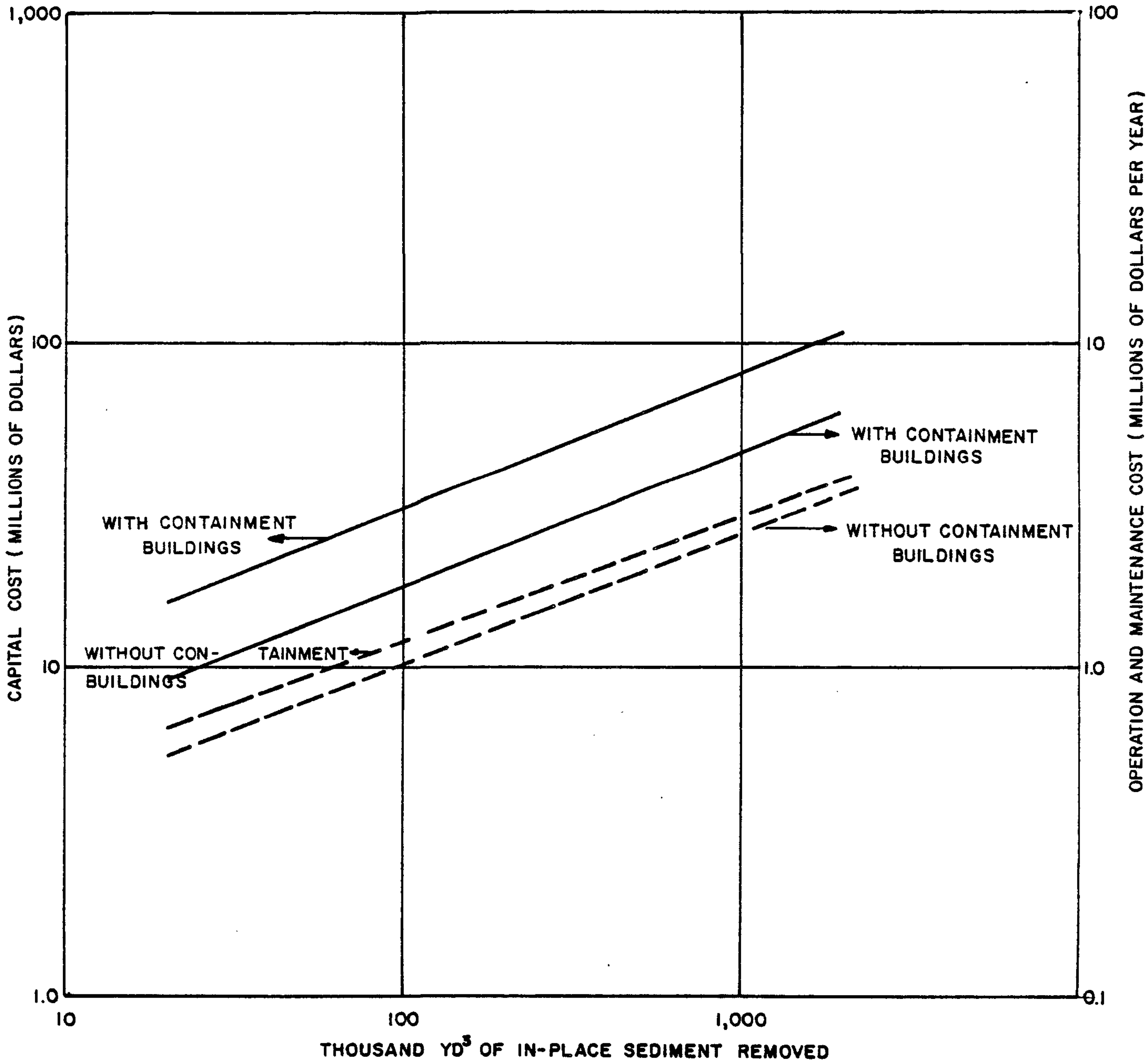
Each of the component technology's construction costs includes a building to enclose the technology, and the sedimentation clarifier is enclosed with a dome. The 2,000,000 yd^3 sediment volume case is the only case of the three considered for which carbon regeneration is economically justified. A cost curve is presented in Figure 7-3 for water treatment system operations. Table 7-4 and Figure 7-4 present a summary of dredged sediment containment, dewatering, and water treatment costs for the three clean-up volumes.

7.2.5 Summary

Water treatment is a necessary support activity for sediment removal, dewatering, treatment, and disposal processes. The primary benefit of water treatment is the permanent reduction it

TABLE 7-4
Dredged Sediment Containment, Dewatering, and Water Treatment Cost Summary

Sediment volume handled (yd^3 in place)	20,000				200,000				2,000,000			
Dredging, dewatering, and water treatment duration (years)	1				3				10			
	w/containment buildings		w/ocontainment buildings		w/containment buildings		w/ocontainment buildings		w/containment buildings		w/ocontainment buildings	
	Capital ($1,000)	O&M ($1,000/yr)	Capital ($1,000)	O&M ($1,000/yr)	Capital ($1,000)	O&M ($1,000/yr)	Capital ($1,000)	O&M ($1,000/yr)	Capital ($1,000)	O&M ($1,000/yr)	Capital ($1,000)	O&M ($1,000/yr)
Containment area and surge pond	9,860	394	870	35	24,735	989	1,316	53	66,361	2,654	2,151	86
Sediment dewatering and storage	4,754	267	4,754	267	10,754	850	10,754	850	31,090	2,550	31,090	2,550
Water treatment	1,104	240	1,104	240	2,246	651	2,246	651	5,213	825	5,213	825
Totals	15,718	901	6,728	542	37,735	2,490	14,316	1,554	102,664	6,029	38,454	3,461



NOTE: O & M COST (MILLION $/YR) MUST BE MULTIPLIED BY YEARS TO PERFOM CLEANUP.

FIGURE 7-4
DREDGED SEDIMENT CONTAINMENT, DEWATERING, AND WATER TREATMENT CAPITAL AND OPERATION AND MAINTENANCE COSTS

provides in the toxicity and mobility of PCBs and toxic metals present in the effluents produced by the remedial processes mentioned. Water treatment achieves this reduction by removing these wastes from the waste stream and concentrating them for destruction and/or detoxification in post-treatment processes.

A water treatment process train has been identified in this detailed evaluation of technologies that is applicable and appropriate to treating remedial process effluents at New Bedford Harbor. The water treatment process train identified consists of the following technologies: coagulation/flocculation/ precipitation, sedimentation, filtration, and carbon adsorption. The sedimentation and filtration support technologies will assist suspended solids removal and increase the effectiveness of the coagulation/flocculation/precipitation and carbon adsorption treatment processes. The component technologies of this water treatment process have been successfully demonstrated for years at industrial and municipal wastewater treatment facilities.

Capital and O&M costs were developed for systems treating New Bedford Harbor remedial process effluents associated with removing three volumes (20,000, 200,000 and 2,000,000 yd^3) of in-place sediments. The costs for these systems were prepared using the same dredging duration assumptions used to size the containment and dewatering facilities for these three cases; the 200,000 yd^3 cleanup occurs over three years; and the 2,000,000 yd^3 cleanup occurs over 10 years. The water treatment system capacities needed to treat the remedial process effluents were determined by assuming the system would treat annually the entire water volume from the contaminant area and dewatering facility operations, plus an equal volume of destruction/detoxification process effluents and landfill leachate. The three resulting water treatment system design capacities follow: 0.17 mgd for the 20,000 yd^3 case; 0.6 mgd for the 200,000 yd^3 case; and 1.7 mgd for the 2,000,000 yd^3 case. The 2,000,000 yd^3 sediment volume case is the only case of the three considered for which carbon regeneration is economically justified, based on the design information available to date.

8.0 DISPOSAL TECHNOLOGIES

8.1 DESCRIPTION

As part of the overall FS process for New Bedford Harbor, numerous disposal technologies have been identified for potential sediment deposition. These disposal technologies have been grouped according to general location and combined with other disposal actions:

- In-harbor sites - located within the confines of the harbor waters.
- Shoreline sites - located along the Estuary/harbor shorelines.
- Upland sites - areas identified for potential development of landfills within ten miles of the harbor.
- Offsite landfills - approved chemical waste landfills.
- Ocean sites - previously identified/utilized ocean dump sites located within the proximity of the harbor.

Contained Aquatic Disposal (CAD) was proposed in the NUS 1984 Draft FS, September 1984, as a technology that would dispose of the sediments within the harbor without irreversibly damaging or destroying the wetland areas along the shoreline. Thus, an alternative was proposed that disposes of the contaminants within the harbor bottom.

Island construction, another disposal scenario that contains the sediments within the harbor, consists of constructing a landfill with the appropriate embankments within the harbor, and depositing the sediments within its confines.

Shoreline disposal involves depositing the contaminated harbor sediments along the eastern or western shoreline in one or more of the previously identified sites. These sites would be constructed of earthen and/or synthetic materials that isolate the contaminants from the harbor waters and environment in a similar fashion as island construction. Fifteen potential shoreline sites have been retained for detailed analysis (NUS, April 1986).

Numerous federal and state agencies, in conjunction with NUS, identified 37 upland disposal sites within a 10-mile radius of the harbor that could potentially be developed as a secure landfill (NUS, June 1984). After preliminary evaluation, six areas were selected for detailed analysis. Three of these sites are woodlands, and the other three include active and inactive gravel pit operations.

Contaminated sediments may be disposed of in off-site approved chemical waste landfills. There are nine EPA/RCRA-permitted landfills currently operating within the United States for the disposal of materials containing PCBs (Environmental Information Ltd., 1986). Of these landfills, the closest one to New Bedford is located in Model City, New York.

The final disposal technology being considered in the detailed screening phase is ocean dumping. Three sites in closest proximity to the New Bedford Harbor site were identified. Although currently closed, the West Island site was retained for detailed screening based on its proximity to the harbor. The other two sites are significantly further away from the harbor.

Liner Systems. Currently, regulations as promulgated under the Hazardous and Solid Waste Amendments of 1984 (HSWA) require all hazardous waste landfills to incorporate liner systems. These liner systems include a minimum of two liners and leachate collection systems above each of these liners, as shown in Figure 8-1 (USEPA, 1985).

The HSWA regulations further stipulate the design criteria for these liner systems. The top liner is to be constructed of materials, generally synthetic, compatible with the chemicals being deposited to prevent migration for a period of 30 years. The lower liner consists of two components: an upper section

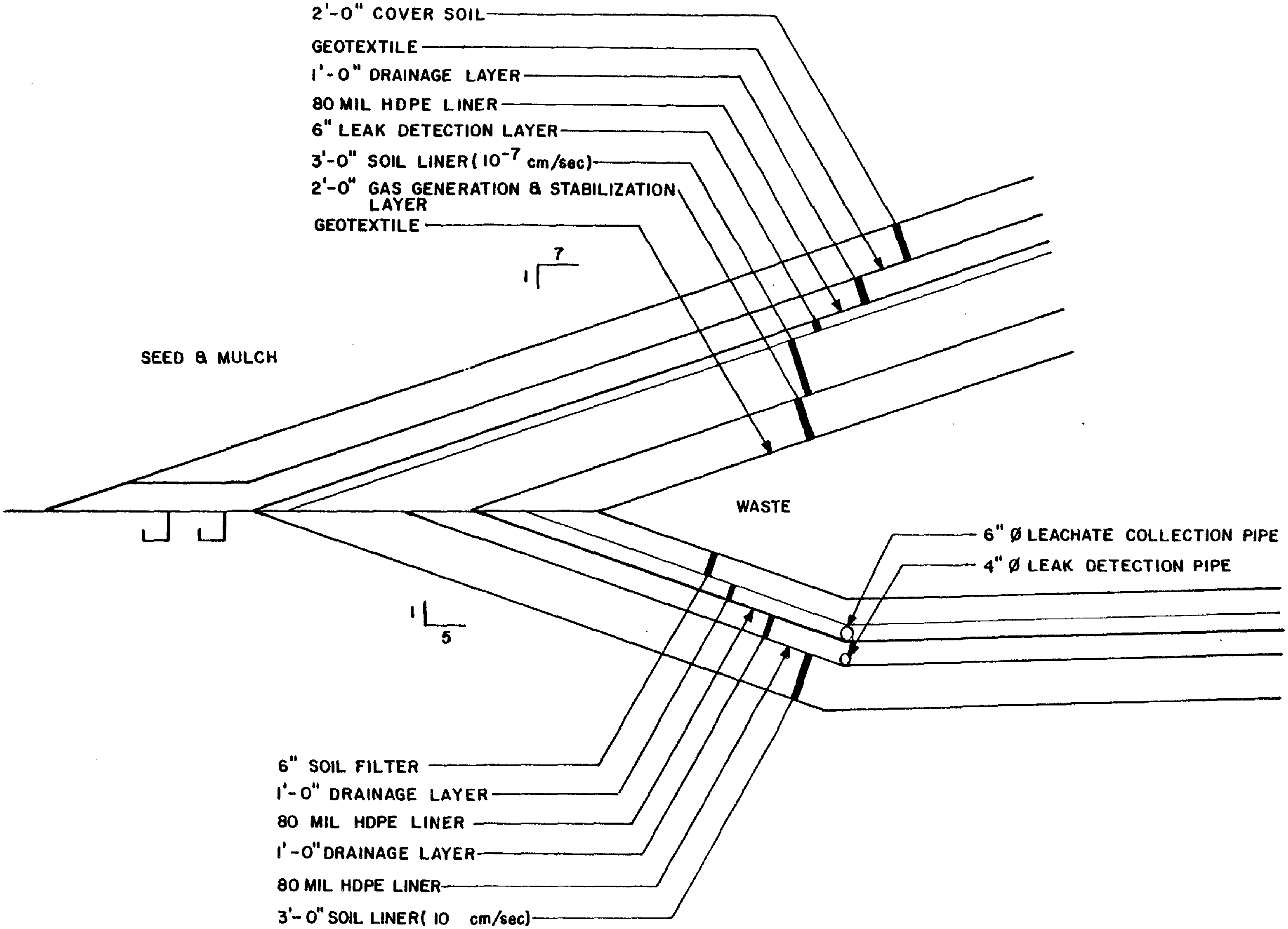


FIGURE 8-1
CROSS-SECTIONAL STRUCTURE OF A RCRA SUBTITLE C FACILITY
NEW BEDFORD HARBOR SITE FEASIBILITY STUDY
NEW BEDFORD, MASSACHUSETTS

similar to the top liner, and a bottom component that should prevent contaminant migration should a breach in liner integrity occur. Often the lower portion is constructed of recompacted soils of low permeability, less than or equal to 1×10^{-7} cm/sec. Above each of the liners a leachate collection and removal system is installed to further reduce the possibility of contaminant release. This system also needs to be constructed of materials that will resist chemical attack.

The USACE is currently evaluating liner materials in Task 12 of their Engineering FS. Additionally, in Task 16, USACE is conducting research on the physical properties of the dredged sediments with respect to liner requirements. Incorporated into this task is a review of stabilizing agents for the deposited sediments to create an impermeable liner.

The actual costs incurred in constructing the previously mentioned liner systems will not be available until the liner studies have been completed. The costs for these liner systems will vary, depending on site type and location, due to placement costs. For example, lining a shoreline disposal site would require dredging the area of deposition prior to liner placement. Leachate collection systems would also most likely need to be more elaborate along the shore than for an upland landfill due to the more active hydraulic environment of a shoreline site. However, estimates for liner costs given the previously mentioned caveats are summarized on Table 8-1 for the shoreline sites given varying construction scenarios. Also listed on this table are the volume requirements for these liner systems and hence storage volume reductions.

The first measure of effectiveness in successfully removing contaminants from the environment is the ability of the disposal technology to utilize the liner systems. Liners are considered a proven method of waste containment at upland landfills, but have not yet been successfully implemented in some of the other disposal scenarios.

The CAD alternative is one such scenario. Constructing a liner system similar to the type described above would be difficult under water, and the leachate collection systems would most likely be inoperable since the system would be submerged. Groundwater hydraulics may cause varying pressures on the cell that would not occur upland. It is possible to cofferdam the separate CAD cells and then dewater them prior to liner placement, but this effort would be very expensive.

The island and shoreline alternatives both would need to be dewatered prior to liner placement, but since the disposed materials would be isolated from the Estuary and groundwater, leachate collection systems could be successfully employed. Pump

TABLE 8-1

NEW BEDFORD HARBOR
LINER/LEACHATE COLLECTION SYSTEM
COST AND VOLUME CORRECTIONS

Site	Surface Area (sq ft)	Approximate Cost ($)	Embankment Length (ft)	Volume @ 5:1 (cu yd)	Corrected Vol. 5:1 (cu yds)	Volume @ 7:1 (cu yd)	Corrected Vol. 7:1 (cu yds)
1	864,611	6,614,274	3,580	267,189	141,868	253,930	138,567
1a	579,798	4,435,455	4,330	150,592	85,303	134,555	81,310
1a (Alt)	579,798	4,435,455	3,620	150,592	85,303	134,555	81,310
1b	925,642	7,081,161	8,550	216,164	127,842	184,497	119,957
1b (Alt)	925,642	7,081,161	8,344	216,164	127,842	184,497	119,957
2	2,160,074	16,524,566	8,006	681,420	359,213	651,768	351,829
3	979,408	7,492,471	4,520	295,781	158,337	279,040	154,168
4	196,172	1,500,716	1,820	45,693	27,053	38,953	25,374
4 (Alt)	233,954	1,789,748	1,875	73,316	38,739	69,983	37,908
5	343,665	2,629,037	2,420	91,431	51,309	92,469	49,077
6	515,860	3,946,329	2,890	148,244	80,801	137,541	78,136
7	982,496	7,516,094	5,230	286,406	155,290	267,036	150,467
8	263,016	2,012,072	2,190	64,969	37,546	56,858	35,526
9	562,360	4,302,054	3,040	163,244	88,648	151,985	85,844
10	1,049,885	8,031,620	4,890	316,402	169,502	298,291	164,993
10a	183,094	1,400,669	1,880	39,961	24,325	32,998	22,591
10a(Alt)	249,211	1,906,464	2,138	72,863	39,464	68,004	38,254
11	635,743	4,863,434	3,863	178,231	98,043	163,923	94,481
12	1,719,776	13,156,286	6,510	552,565	289,447	NA	NA
II	1,280,000	8,283,640	4,800	372,000	199,403	NA	NA
I2	960,000	7,593,920	4,400	262,000	142,922	NA	NA

Notes: Assume the liner system is incorporated into side slope to minimize further volume reduction.
A 2.5:1 slope will not sustain filter sand on HDPE membranes.
A 5:1 slope minimum is necessary.

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systems may be necessary to enhance gravitational flow of leachate, however.

As mentioned previously, liner systems are a demonstrated technology in current upland landfill design. For off-site disposal, liner/leachate collection systems would already be an integral part of the licensed hazardous waste disposal facility.

Ocean disposal does not lend itself well to liner systems. Disposal sites within the ocean environs are not typically physically prepared to contain the wastes. Thus, it is unlikely that lining the ocean site would be a practical application of this technology, especially due to the obstacles associated with submarine construction.

In summary, liner systems are designed to prevent migration of wastes from the disposal site for a minimum of 30 years post-closure. These specifications are based on standard upland landfill designs. Using liner systems on variations of the standard landfill may perform as designed (as island or shoreline disposal sites), but may also be encumbered by problems such as surface or groundwater hydraulics. Implementing liner systems in a sub-aqueous environment would be even more difficult and thus less feasible.

Should the integrity of the liner system be breached within a CAD cell or within the island disposal site, contaminants may migrate into the Estuary or harbor. From there, tidal flow may carry the contaminants to the outer harbor and into the ocean. Recipients of this waste would include the flora and fauna indigenous to the receiving waters.

A breach in containment at a shoreline site could result in all of the effects cited previously. In addition, the potential for public contact exists due to the proximity of the site(s) to residential and commercial properties.

The groundwater movement within the area of the New Bedford Harbor and Acushnet Estuary has not yet been accurately defined, although preliminary data indicates the harbor/Estuary area to be a groundwater discharge zone. The impacts of contaminant migration via groundwater cannot be fully assessed without further study, which is currently in progress.

The potential impact from the release of hazardous wastes at an upland site is location- and geohydrology-dependent. The groundwater in the vicinity of the site would probably be impacted first. Depending on location, this contamination could in turn affect private and/or municipal drinking water aquifers. The towns of Dartmouth, Fairhaven, and Mattapoisett each have municipal wellfields which could be impacted. Leachate escaping from an upland site could also contaminate the local surface water. The City of New Bedford and the Town of Acushnet receive their drinking water from reservoirs. In addition to the municipal water supplies, numerous households obtain their drinking water from private wells. The public could potentially come in contact with the waste directly or via the drinking water. Finally, should there be a breach in containment at an upland site, the local flora and fauna might be impacted.

Another point to be considered in depositing contaminated material at an upland site is that these sites may be situated in a pristine environment. This point needs to be weighed against the advantages, such as land/space availability, and the ability to better control the containment of the waste.

Contaminant release at a licensed off-site facility should be limited due to state-of-the-art construction. This site would also have undergone detailed review and would have met all applicable permitting requirements. If conditions at this site were less than ideal, impacts of contaminant release could be similar to those at an upland site.

Since installation of liner systems would not be feasible at ocean dumping grounds, effects of a contaminant release through the liners would not be applicable. The USACE has investigated other means of containment within ocean environments. One such technique is to cap the dumped sediments in layers (USACE-NY). This method has proven to control the deposited material from migrating from the site.

Contaminant release at an ocean dumping ground could adversely affect the marine flora and fauna, which in turn could impact the local fishing industry (USACE, November 1985).

8.2 EFFECTIVENESS

Reliability

In-Harbor: CAD. In order to effectively contain sediments within a CAD site, proper placement of material into the cells is necessary (NUS, August 1984). Thus far, only limited use has been made of CAD cell disposal, so much information is not yet available. The only successful demonstration of this technology for contaminated dredge spoils has been in Rotterdam, the Netherlands (Volker, Stevin). The USACE is planning a demonstration project to show the effectiveness of this disposal technology within New Bedford Harbor on a pilot-scale level.

In theory, open water sites have fewer transport mechanisms for contaminant migration than the other disposal options cited (Phillips and Malek, 1984). Air is absent, reducing the chance for volatilization. Also, heavy metals will be less likely to go into solution in a saturated environment, since they would not have the opportunity to oxidize. Organic compounds, however, would be more susceptible to migration. They would be more likely to leach off sediments in an aqueous phase, depending on their solubility.

In practice, it may be difficult to place contaminated New Bedford Harbor sediments into cells without overdumping and creating a suspended solids plume, although the use of diffusers at the end of the discharge pipe would significantly reduce resuspension of materials. Once in place, capping the sediments can also be problematic, as the capping material will most likely be heavier than the soft contaminant layer (USACE, 1984). Thus, mixing would occur between the clean and contaminated sediments. Numerous capping layers may be necessary in order to isolate the contaminants.

Failure at the CAD site could be caused by improper placement of material, as discussed above. Failure may also be a result of scouring induced by tidal action, or water-related activity such as boating. Flushing may be a means of contaminant release, both by tidal flushing and/or groundwater movement. Finally, benthic organisms may penetrate the cap, exposing the sediments.

<u>In-Harbor: Island Construction</u>. Island construction is a proven technology for sediment disposal (USACE, 5th-10th Proceedings).

This type of containment has not, however, been utilized much for waste containment. Leachate collection systems may be more difficult to install and maintain, due to high groundwater and surface water levels around the site.

Contaminant transport mechanisms are more varied in an island setting than either open water or upland disposal sites (Phillips and Mallek, 1984). The chance of mobility by means of diffusion and convection would be high in the unsaturated zone and medium in the saturated zone. Transport by volatilization would be high for the applicable contaminants. Bioturbation would vary depending on location and thus species present, and erosion, given adequate rip-rap construction, should be low. Groundwater and tidal hydraulics may also compound the chance of mobility through flushing, although proper installation of liner systems may minimize this effect. The USACE is currently evaluating leaching tests and liners for the shoreline Contained Disposal Facilities (CDF), which would also be applicable to the island scenario.

Failure of island containment sites could occur due to scouring of the embankments by the surface water, although proper use of rip-rap should minimize this. Additionally, tidal flushing may cause liner failure (if a liner system was installed).

Shoreline. Shoreline sites are located in a very active environment with the most available transport routes of the various disposal siting options. Shoreline sites are, however, a proven technology for disposal of "clean" sediments and have also been constructed for contaminated sediments in various locations. Implementation of a double liner/leachate collection system may be difficult due to groundwater and tidal hydraulic flushing. The USACE is evaluating leaching tests for the CDFs to determine liner requirements, as this may be the most likely route of contaminant release.

Secondary uses for CDFs have been identified that include roadway construction and/or development of a recreational park on top of the embankments and cap. These uses would require extensive sediment dewatering with subsequent solidification/stabilization for the additional support required.

Upland Sites. Upland landfills are a proven technology that have in the past been the primary solution for waste disposal. Current landfill requirements dictate a closure system with a minimum design life of 30 years post-closure. A conceivable source of failure would be an inadequate design for deposited sediments, causing leachate breakthrough, although this would be unlikely (within the design life). Other sources of failure would include leachate collection system clogging, incompatibility of the chemicals with the liner systems, or vandalism.

Off-Site Landfills. Off-site disposal facilities are constructed in compliance with current RCRA requirements. They are a proven technology both through design and through monitoring the current use. A breach in containment could be caused by any of the factors discussed for the upland sites. Two other potential causes of failure could be overuse of the landfill, thereby stressing the designed capacity, or deposition of incompatible wastes, resulting in undesirable chemical reactions. Migration of contaminants by means of diffusion into the surrounding media, convection, and erosion should be minimal, would vary for bioturbation depending on species present, and could be extensive for volatile wastes.

Ocean. Ocean dumping has been a common practice in the past and is still an acceptable means of disposing "clean" dredge spoils. Current regulations limit the disposal of contaminated spoils into the ocean due to the lack of control and treatment alternatives available. Capping has been the only measure used to control contaminant migration within the ocean (USACE, May 1984). Transport of contaminants by diffusing through the ocean water medium is high, varies for bioturbation based on the species present, and is average for convective and erosional forces when compared with the other disposal options (Phillips and Mellek, 1984). Cap scouring is very much site-dependent and varies inversely with depth.

To summarize the reliability of the different disposal scenarios, the greatest degree of control in containing wastes is offered by an upland landfill, be it new construction or an existing facility. To offset that advantage is the increased mobility of various contaminants due to oxidation of metals and volatilization of organics when coming from a saturated to unsaturated state. Risk to the environment and public from contaminant release varies depending on the contaminant and location. Shoreline and island sites also carry a high risk to human health and resources, and also offer a lesser degree of control and/or treatment for waste migration. Open water disposal, including both ocean dumping and CAD, offers very limited control for waste migration, but has fewer transport mechanisms for contaminant release. Also, the health and environmental risks associated with contaminant release are lower, due to dilution within the open waters.

Public Health

The various disposal options pose differing potentials for public health risks both during and after implementation. These risks are identified for each of the options that follow. As each of the disposal options will require removal of sediments from the Estuary and harbor, risks associated with that task are not discussed here.

CAD. The CAD cell option will require temporary containment of the contaminated sediments while the cells are prepared for disposal. An opportunity for contact with these sediments exists while in temporary storage. If left exposed to the air, volatilization of PCBs may adversely impact the surrounding community. Since the contaminants would ultimately be buried under the Estuary, further chance of contact is minimal as long as the cell cap remains intact. Groundwater should not be impacted by this alternative since the Estuary/harbor is a groundwater discharge zone. (The groundwater in the vicinity of the Estuary is not used as a drinking water supply.)

Island. The island disposal option may provide the best buffer from public contact since the sediments may be transported directly from the dredging activity to the island containment site within the bounds of the Estuary and harbor (assuming no treatment, dewatering, etc., is to occur). Volatile organic emissions may be an issue during implementation, but since the site would be located in the open water, the emissions would have a greater opportunity to diffuse prior to reaching on-shore human receptors. Groundwater, as discussed previously in the CAD scenario, should not be of concern relative to public health.

Shoreline. The principal routes of exposure for the in-harbor shoreline containment sites are again public contact and volatile air emissions. The chance for public contact can be diminished by securing the area (fence or guards). Air emissions would be a temporary phenomenon since the site would ultimately be capped. Should the risk assessment currently in progress determine the volatile emissions to be a significant hazard, the site could feasibly be enclosed during sediment deposition. Should the groundwater in the vicinity of the site become contaminated (from the disposal of contaminated sediments), it would not have a direct impact on the public since it is not a source of drinking water. Surface water runoff would immediately discharge to the Estuary/harbor and, therefore, not present a route of exposure to the public.

Upland. Direct contact and volatile emissions are the primary routes of exposure for upland disposal sites. Securing the area can mitigate the potential for contact, and, since the sites currently under consideration are well buffered from residents and industry, significant dispersion should take place prior to exposure.

Due to the need for sediment transport to the upland site, the potential for a transportation accident exists. An accident could impact the public in several ways, including direct contact, surface contamination, volatile emissions, PCBs and/or heavy metal particulate plumes, and groundwater/drinking water contamination.

A breach in the landfill containment system may cause ground surface, surface water, and groundwater contamination. Exposure through direct contact and drinking water would thus become possible, as the groundwater in the outlying areas of New Bedford is utilized for drinking.

Off-Site. Routes of contaminant exposure for off-site disposal would be similar to the upland option, except that the mode of transportation would most likely vary and the distance to the destination would be substantially farther. Transferring the contaminated sediments (e.g., rail to truck) increases the potential for spillage and accidents.

Ocean. Assuming the dredged/excavated sediments are transported directly to the dump site, minimal opportunity for direct public contact exists. The dumping activity itself may cause suspension of sediments that may migrate to nearby beaches, affording the chance for contact. The sediment suspension may also create greater uptake by the indigenous fauna, which in turn may be ingested by the local residents.

Environment: Beneficial Effects/Adverse Effects

This section discusses the adverse impacts that the various disposal alternatives could have on the environment.

CAD. CAD is a relatively new method of waste deposition with numerous unknown variables. Groundwater and marine tidal hydraulics may cause the wastes to be leached out of the cells causing them to become bioavailable. Tidal action and the Acushnet River flows could cause scouring of the cap to also expose the wastes to the environment. Benthic organisms could burrow through the cap, thereby causing the same to happen. The USACE is studying these conditions to determine the adequacy of this type of containment (USACE, September 1985).

Deposition of the sediments may cause resuspension and thus their escape into the Estuary and Lower Harbor. Excavating the cells will cause extermination of the benthic organisms, although rehabilitation should occur after the the CAD cells have been closed. Finally, bulking factors will require additional deposition of material off-site and lengthy settling times for the deposited materials.

Island. Construction of an island disposal site will cause loss of the benthic environment at that location. The island will cause a change in the hydraulics of the Estuary and/or harbor which may affect the wetland/floodplain environment. The flood storage capacity of the Estuary and harbor will be decreased by the amount deposited to create the island. A final impact the island construction may have is disrupting the flow of boat traffic in the harbor, depending on the chosen location.

Shoreline. Shoreline disposal of the contaminated harbor sediments would have the following impacts. Deposition would cause loss of a portion of the benthic community. The structure may cause changes in the channel hydraulics, further affecting the marine ecosystem. Any portion of the containment site located within the water and floodplains will cause that amount of decrease in flood storage capacity. Depending on location, the shoreline site may disrupt current or future shoreline commercial and recreational activities. If located within the wetlands or floodplains, it would cause the demise of those aquatic and terrestrial communities. Since the site would be located in a populated harbor area, a chance of public contact is present due to the limited buffer zones. A final adverse impact would be a potential decrease in property values in and around the disposal site.

Upland. A danger of contaminating a pristine environment exists when siting a landfill in an upland location, away from the harbor. Numerous drinking water wells are located in the vicinity of some of the proposed locations for an upland disposal site (NUS, June 1986). Depending upon the extent to which access is restricted, there is a chance for public contact. Since the material is being hauled off-site, there is a potential for a transportation accident. Finally, property values in the vicinity of the landfill may decrease with its construction.

Off-Site. The primary impact from off-site disposal would be the extended distance over which a transportation accident could occur - probably 500 miles. In addition, there could be heavy truck (or rail) traffic, depending on the volume. A final impact that could result from shipping the waste sediments to an approved off-site facility is utilizing much of the scarce PCB storage capacity. This is a matter of "fund balancing," whereby the finite storage capacity may be better suited for many smaller sites rather than one large site.

Ocean. Ocean disposal would have the greatest impact on the marine ecosystem in the area (USACE, 5th-10th Proceedings). Deposition would cause (at least temporarily) loss of the benthic organisms in the area. The dump may cause the ocean bottom to degrade since immobile benthic species would be buried, and other more mobile inhabitants would be forced to move. The new environment may be sufficiently altered to inhibit recolonization. If the contaminants are not sufficiently isolated, upwelling, tidal drift, and/or currents could cause migration of contaminants.

8.3 IMPLEMENTATION

Technical Feasibility. All of the disposal alternatives identified have been previously constructed, but may not have been utilized for contaminated sediments. Thus the technical feasibility of any of these alternatives is not assured.

CAD. The CAD system has thus far only been utilized in the Netherlands for waste disposal (Volker, Stevin). Additional information regarding CAD implementation at New Bedford will be required, including: bulking factors for the New Bedford sediments, the degree of sediment dispersion, and mixing of the cap and waste sediments. The USACE is currently collecting this information as part of their engineering FS.

Island. Island construction is a proven technology for sediment containment. This disposal technology has not, however, been utilized for contaminated sediments where full containment with leachate collection systems is required. The harbor and Estuary hydraulics may also make implementation difficult. Structural stability of the sediments would need to be investigated.

Shoreline. The harbor and Estuary hydraulics could create difficulty in constructing the shoreline disposal site. The flows could be altered and the embankments may become damaged by erosion. Soft sediments have been encountered in some of the identified locations, which may cause some difficulty in constructing a stable embankment. Constructing a lined facility with leachate collection systems may also be difficult to implement. Shoreline disposal sites have been utilized for hazardous waste containment at various locations throughout the country, and could therefore be considered a proven technology (NUS, June 1986; USACE, EM 1110-2-5027).

Upland. Upland sites are proven to be technically feasible as they have been the most common method of waste disposal in the past (USEPA, 1984). Some additional work (e.g., additional fill, liners, or grout curtains and groundwater diversion pumps) may be necessary to isolate the landfill from the shallow aquifers prominent throughout the New Bedford region.

Off-Site. Off-site landfills are a proven technology. Since they are an existing facility, locating a site and dealing with any hydrogeologic problems that may exist would not apply.

Ocean. Ocean dumping has in the past been an accepted means of waste disposal. It has been proven as technically feasible, although current concerns of total containment through capping or other means has not been consistently demonstrated.

Level of Development

The sediment disposal options discussed previously are at various levels of development. CAD has been demonstrated once (in the Netherlands) for containment of contaminated sediments. Island disposal has been used for dredge sediment containment (such that a bird sanctuary and wetlands could be constructed on it, too), but has not been demonstrated for secure containment of hazardous wastes. Shoreline sites, upland landfills, and off-site licensed facilities are well-developed technologies. Ocean disposal is a proven technology that is currently discouraged from use due to environmental constraints.

Support Requirements

CAD. Various requirements will be necessary to support the different disposal alternatives. CAD will require temporary storage of the waste sediments, as well as the capping material. A site also needs to be located for disposal of clean sediments dredged due to a bulking factor (which may be up to 50 percent). Sediment dispersal control will be required during placement of material into the cell to minimize release of resuspended material. A hydraulic diffuser should also be used to reduce upwelling during placement of the 20/80 sediment/water mix.

Island. Island disposal will require sediment dewatering to approximately 50 to 60 percent solids. The leachate must be treated to acceptable water quality standards. Temporary access for construction of the facility must also be obtained.

Shoreline. Shoreline disposal facilities will require similar support as the island scenario, including sediment dewatering and leachate treatment. Additionally, land may need to be acquired from private parties depending on the chosen location(s).

Upland. Upland site waste deposition will require additional dewatering to the extent that the sediments will pass the "paint filter test." The material may also need to be solidifed or stabilized such that it can pass the "compaction test." Land may need to be purchased from private parties. Trucks or some other means of transportation will be required to move the wastes to the landfill. Once there, leachate treatment will be necessary for water run-off and infiltration.

Off-Site. RCRA has specific guidelines for the deposition of materials at licensed hazardous waste facilities. The material must be able to pass the "paint filter test"; therefore, secondary dewatering would be necessary. The material must also have a load-bearing capacity such that it can pass the compaction test. This criterion may require solidification or stabilization of the material. The material will need to be transported to the designated facility, by rail and/or truck. Leachate collection systems will need to be present - this requirement would be consistent with the licensing of the facility, however.

Ocean. Support requirements necessary for ocean dumping consist of a means for transport and deposition of the material in the ocean. Currently, ARARs require complete detoxification of the sediments prior to deposition. This would require extensive treatment which is currently being researched as another task of this FS.

Availability

Implementation of the various disposal alternatives depends upon the availability of land to construct these facilities. The proposed location of the CAD cells is owned by the Massachusetts State government and should therefore not be an obstacle to use. The location for island construction should similarly be owned by the Massachusetts State government, but access to these locations may require town or private permission. Shoreline sites are owned in portion by the Cities of New Bedford, Fairhaven, or Town of Acushnet and/or private entities and the aqueous portion by the Massachusetts State government. Shoreline access may be difficult, depending on the site. Upland sites are owned by either private entities or the local towns. Some upland sites currently do not have ready access. The availability of an off-site licensed facility is a function of space limitations for PCBs disposal. The closest site with available space is located in upstate New York. The West Island Dump site is currently the closest designated ocean dump site to New Bedford Harbor. The site has been closed to further dumping by the USACE and would need to be reopened to accept the wastes.

Installation

The degree of effort required to install the different types of containment sites varies, both with the type and location. CAD construction is somewhat depth-dependent. It should be built such that the cells are constantly submerged throughout the tidal cycle. Adequate time will be required for the deposited material to settle prior to cap placement. An extra site will be needed for placement of "clean sediment" due to the bulking factor (NUS, 6-7/1984). Sediment dispersal control will be required during this work to minimize escape of resuspended sediments.

Island construction will require geotechnical analysis and a topographic survey for design criteria. A barrier will need to be constructed to isolate the disposal site from marine, surface, and groundwater. Access to the construction of the island will be required and could be in the form of barges, temporary bridges, or dikes.

Similar to island construction, shoreline sites will require analysis of the subsurface for geotechnical properties. Topography of the selected site will also be required for design considerations. A barrier will be required to isolate contaminants from the aquatic environment. Finally, some form of access restriction will be required to insure the safety of the public.

Upland sites will require topographic and geophysical surveys for design purposes. Preparation of the site may include grouting of bedrock fractures, clearing the given area of trees, and leveling the site. Barriers to isolate contaminants from the surface and groundwater in the form of liners and leachate collection systems will be required. Fencing or some other means of access restriction will also be necessary to protect the general public.

Installation criteria are not applicable for off-site or ocean disposal.

Time

Insufficient design data is currently available to determine construction time of the CAD, island, or shoreline disposal alternatives. Upland landfills generally would require between 3 and 6 months to construct, site-dependent. Implementation time is not applicable for off-site or ocean disposal.

Since the beneficial effects are a function of containment, this criterion does not apply unless rate of deposition is used.

Safety

Safety involves the health and well-being of the workers during construction and deposition, and the safety of the general public in the vicinity of the site.

Since most of the work for CAD would be done underwater, the only significant opportunity for exposure exists during the temporary storage of the contaminated sediments. At this time the potential for release of volatile emissions exists. Public access to the temporary site needs to be controlled by fencing. If the cells are improperly constructed or filled, contaminants could become resuspended and affect the aquatic community. Should fishing and shellfishing be opened again to the public, such a relase could enter the human food supply.

Island disposal could present short-term releases of volatile emissions prior to cap placement. Due to location, access would be limited. Also, since the island would be located within the confines of the harbor, the sediments would undergo limited over-land transport.

Shoreline sites may exhibit short-term releases of volatile emissions prior to cap placement. Public access needs to be restricted to prevent contact with the contaminated material. The sediments would undergo limited handling. This disposal alternative, although somewhat site-dependent, has less of a buffer zone than the above two alternatives.

More extensive handling of the contaminated sediments may result in a greater chance for volatile emissions in the upland landfill scenario. This handling also encompasses an increased chance of a transportation accident en route to the landfill on roads of varying population densities. The sites identified for upland deposition have adequate buffer zones from the public, although access restrictions would be required.

Safety conditions for off-site licensed disposal facilities would be similar to those for upland disposal. The material may be handled more often due to the potential use of rail service, and transport would occur over significantly greater distances. These licensed disposal facilities would most likely have greater control over access, since they are business enterprises with large volumes of material brought in for deposition. These facilities should also have been built with an adequate buffer zone from the general public.

Ocean disposal involves very limited handling of the material, and unless suspended sediments migrate to the local beaches or waterfront, should provide no means for public contact. Transport of the material will be maintained on the water away from congested urban areas.

Monitoring and Maintenance Requirements

In order to be consistent with TSCA monitoring and maintenance requirements, a minimum of three monitoring wells must be installed per site (or cell) to assess contaminant migration in groundwater, and thus potential discharge into the harbor (USEPA, 1985). Monitoring should be conducted once per month during disposal and once every six months after closure. (Parameters for analysis should include PCBs, pH, specific conductance, chlorinated hydrocarbons, and heavy metals.) Biological monitoring, applicable to CAD, island, shoreline, and ocean disposal, should consist of sediment toxicity tests (tube-dwelling amphipods - *Ampelisca abdita*), water quality tests (mussel transplants - early warning systems), and sperm cell toxicity tests for rapid toxicity information (USACE, 5th-10th Proceedings).

Specific to CAD cells, cap integrity should be monitored by taking core samples at the same intervals as given above. Both island and shoreline disposal sites would require monitoring of the leachate collection system discharges once every month. Off-site licensed facilities would be accountable to RCRA regulations which are similar to TSCA. Since, however, the facility is a business enterprise, it would be responsible for maintenance and monitoring of the facility.

Baseline and trend assessment surveys by EPA, NOAA, and the state for the ocean disposal alternative will be used as reference for determining the impact of disposal on the marine environment. Biological and sediment monitoring would be the same as that used for CAD, island, and shoreline disposal.

Permitting

The CAD, island, and shoreline disposal alternatives are located within the Superfund site boundaries and, as such, are exempt from the permit process. The alternatives must, however, achieve substantial compliance with the technical requirements of the permits.

In order to construct an upland landfill for the harbor sediments, technical requirements of the following permits would need to be met: a RCRA permit for the construction of a hazardous waste facility; an NPDES permit under CWA for treated leachate discharge; a notice of intent in siting a hazardous waste facility and a project notification from EPA-Region I to the DEQE; a surface water discharge permit to the MDWPC; and DOT manifest for waste transport (E.C. Jordan Co., September 1986).

Removing the sediments to a licensed off-site facility will require a permit from the DOT for the transportation to the site.

RCRA manifests will also be necessary when transporting the material to the licensed facility.

Ocean disposal will require permits through the Rivers and Harbors Act (Federal Pollution Control Act, Marine Protection, Research, and Sanctuaries Act), and the USACE for dredge material and ocean dumping permits.

Legal Constraints

Limited legal constraints are envisioned in executing the CAD alternative. Since the site is within the Estuary boundaries, limited opposition is anticipated to be encountered for siting or construction.

Island construction should also be faced with limited opposition in locating the site, as long as the construction would not interfere with the local waterfront activities. Aesthetics of the island may be a point of contention with the local residents. Resistance may also be met when trying to secure access to the island from the mainland.

Shoreline disposal may be faced with opposition for a variety of reasons. Numerous sites have been tentatively identified along the Acushnet Estuary and New Bedford Harbor for sediment disposal. Some of these sites are privately owned and acquisition may be met with resistance. Access could involve still other property owners. Other issues that will arise are wetlands preservation, waterfront usage, current and proposed zoning, and the aesthetics of the disposal site. Concurrent uses of the facility will also be considered (e.g., roadway on the embankment or recreational park on the cap) (Cortell, November 1982; NUS, September 1986).

Opposition is likely in siting an upland landfill. Of prime importance is State acceptance of this alternative (MA.DEQE 1/16/1985). The State's current stance is that the location of an upland landfill needs to be already degraded before they would accept it. Property ownership, access restrictions, and zoning ordinances may further impede development. Some of the designated sites infringe on wetlands, thus creating a further hurdle. A final constraint involves public perception and acceptance of hauling large quantities of contaminated sediments through congested urban areas to access the landfill.

The only significant opposition likely to be encountered in hauling the contaminated sediments to an approved disposal facility is the transportation itself. Transport by rail, which would eliminate the trucks traveling on public roadways, is anticipated to raise less concern, although a significant volume of contaminated sediments would still be transported through congested urban areas.

Legal constraints associated with ocean disposal can be expected to be enforced by state and federal agencies for depositing contaminated material into the oceans of the United States. A second hurdle that needs to be overcome is that the closest identified dump site - the West Island Spoil Area - is currently closed to further dumping.

Impacts on Historical and Cultural Resources

The City of New Bedford has a rich past that centered around the whaling and fishing industries. Many of the historical landmarks have been preserved and restored to original condition. The areas of historical significance are clustered together in one general area of New Bedford and would not be affected by clean-up activites in and around the harbor. No sites have been identified near the historical districts, with one exception. Palmer Island Light Station, located on Palmer Island, is listed in the State Register of Historic Places. Palmer Island is located near shoreline sites 10 and 10A, and has been suggested for island disposal. The Route 6 bridge spanning the harbor is also in the register, but should not be affected by cleanup activities.

8.4 COSTS

This section identifies the approximate costs associated with the different disposal scenarios discussed previously. These costs were developed based on numerous assumptions and are thus to be considered only preliminary.

The USACE developed cost estimates for ocean dumping at the West Island Spoil area. The following assumptions were made in preparing these costs:

- o The West Island Disposal Site is available for dumping of contaminated material, approximately 10 nautical miles from the rehandling area.
- o The material is dewatered adjacent to the Estuary below the I-195 bridge and is considered the rehandling area.
- o A clamshell dredge and 1,500 cy scows will be used for the rehandling operation. Two scenarios will be included; a 6 cy bucket and a 10 cy bucket.
- o Two scenarios are given for production rates: a 12-hour work day and a 24-hour around-the-clock work day for the rehandling operation.
- o The cost include mobilization and demobilization of plant labor, plant rental, contractor overhead and profit.

- o Average production rates for standard, mechanical dredge operations and for removing material from the rehandling facility into dump scows and towed to the West Island Site were used to produce the cost estimates.

- o The costs reflect October 1986 price levels.

Table 8-2 shows the approximate costs of the two scenarios given three different dredge quantities. Scenario No. 2, around-the-clock work days using the 10 cy clamshell bucket, clearly seems to be the more cost effective of the two alternatives.

Cost estimates for the CAD alternatives have not yet been developed due to the limited amount of information currently available. Numerous questions need to be answered prior to conceptual design of this alternative. The USACE is currently studying this alternative and will be developing as based upon their results.

The size of the individual CAD cells needs to be determined and is subject to volume changes between in-site, post dredging, and post diffusion building factors. The design of the cells has yet to be determined and will be influenced by factors as side slope stability, depth, and bearing strength problems during deposition

TABLE 8-2
NEW BEDFORD HARBOR
OCEAN DUMPING SCENARIO - COSTS
USACE COSTS

Scenario #1

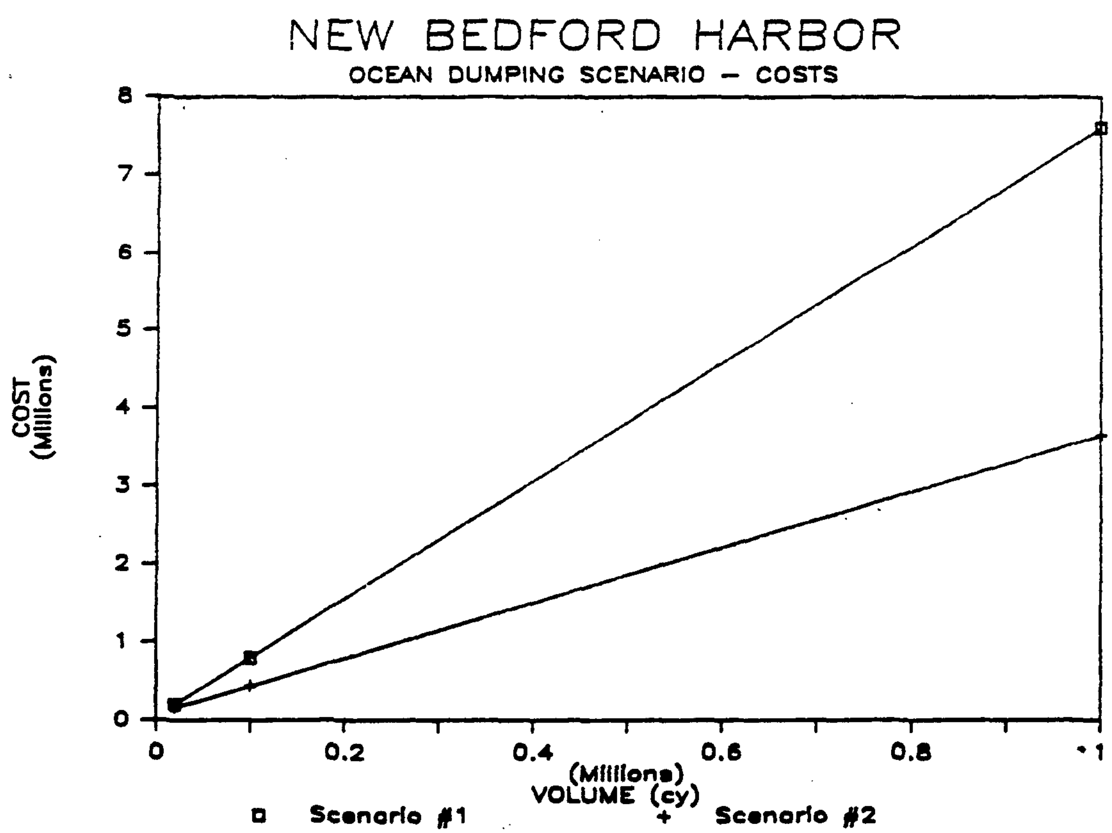
1 Shift, 12 hr/day, 6 days/week   6 cu yard (cy) clamshell bucket

DREDGE QUANTITY (cy)	ESTIMATED COST ($)
20,000	$200,000
100,000	$800,000
1,000,000	$7,600,000

Scenario #2

2-12 hr shifts/day, 7 days/week   10 cu yard clamshell bucket

DREDGE QUANTITY (cy)	ESTIMATED COST ($)
20,000	$160,000
100,000	$440,000
1,000,000	$3,650,000



of contaminated and clean material. These criteria will be dependent and may require further geotechnical exploration.

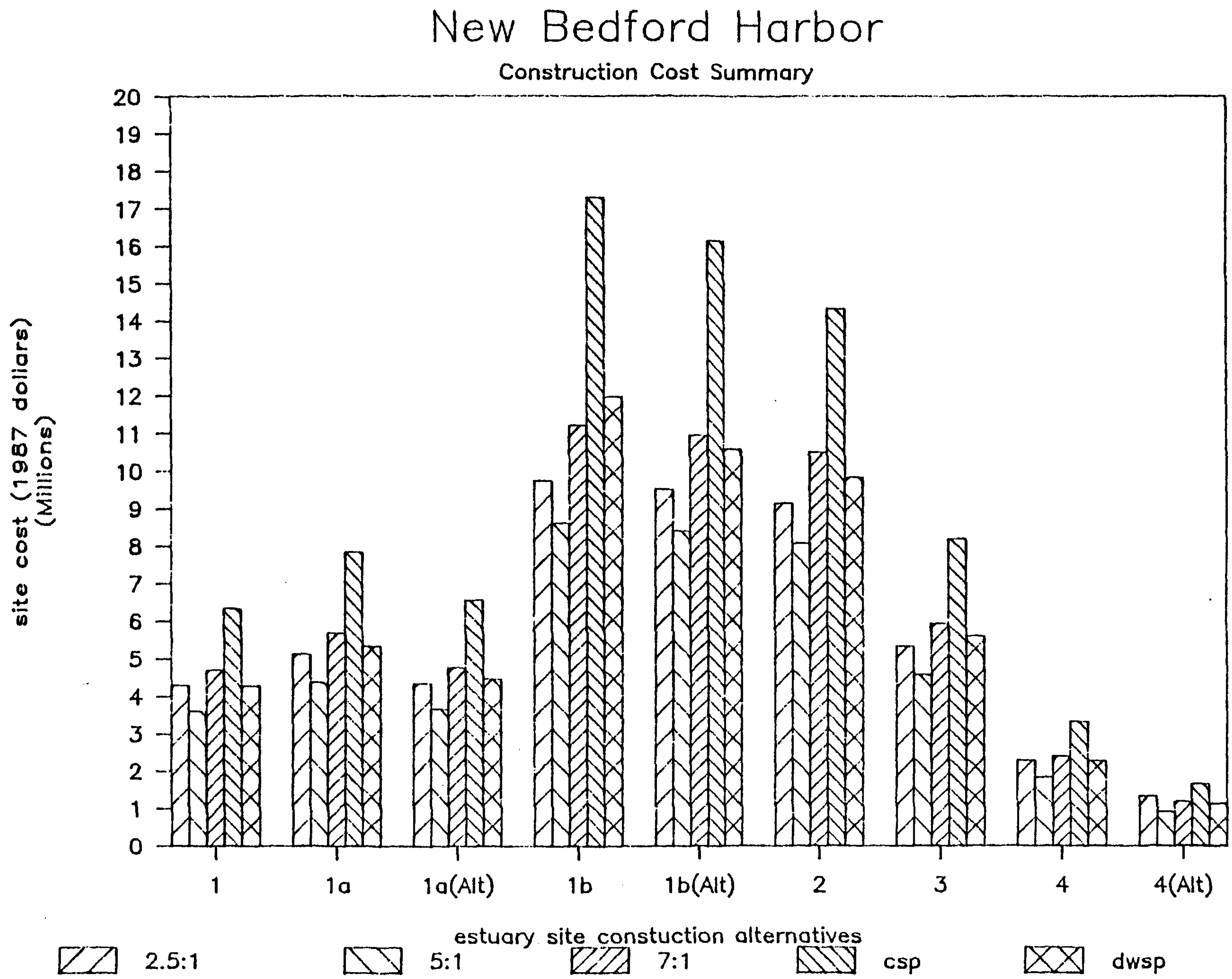
Costs have been developed for the fifteen different shoreline disposal sites identified by NUS Corporation and documented in the report "Investigation and Ranking of Potential In-Harbor Disposal Sites - New Bedford Site, Bristol County, Massachusetts," April 1986. Five different contaminant scenarios for each of these sites have been developed and are based on numerous assumptions. Thus, these costs are to be considered only preliminary. (Table 8-3, Figures 8-2 to 8-5). The areas identified for sediment disposal are based on maps from previously mentioned NUS report and not from actual surveyed locations (E.C. Jordan Co., October 1986). Each of these sites could be adjusted up or down in size to better suit the area topography and hydraulics. Second, very little geotechnical information is currently available for the majority of the sites in question, so wide-sweeping assumptions have been made based on the few borings present. This information could have significant cost implications since load-bearings capacities of the sediments will dictate the design criteria of the hydraulic controls. Among the assumptions used in determining costs are that 12 feet of soft sediment in the Estuary and 5 feet in the Lower Harbor/Bay would require removal to sustain an embankment slope of 2.5:1. Without sediment removal, the minimum slope required to sustain a stable embankment would most likely be 7:1 in the Estuary and either 7:1 or 5:1 in the Lower Harbor/Bay

TABLE 8-3

SHORELINE DISPOSAL SITES
SUMMARY OF TOTAL CONSTRUCTION COSTS

Site	Embankment Length (ft)	2.5/1 ($)	Embankment 5/1 ($)	Embankment 7/1 ($)	Steel Sheetpile Cellular ($)	Steel Sheetpile Double Wall ($)
1	3580	4,290,589	3,612,220	4,701,077	6,344,831	4,286,138
1A	4330	5,118,131	4,368,970	5,685,940	7,840,235	5,335,760
1a (Alt)	3620	4,334,906	3,652,580	4,753,603	6,556,310	4,461,015
1b	8550	9,750,791	8,626,950	11,227,433	17,304,296	11,973,513
1b(Alt)	8344	9,525,591	8,419,096	10,956,924	16,146,730	10,594,540
2	8006	9,154,706	9,078,054	10,513,079	14,342,125	9,854,152
3	4520	5,327,323	4,560,680	5,935,438	8,197,601	5,598,045
4	1820	2,276,585	1,836,380	2,389,933	3,330,500	2,274,365
4(Alt)	900	1,324,595	908,100	1,181,835	1,648,420	1,127,508
5	2420	2,034,945	2,972,728	3,900,072	5,292,495	3,543,885
6	2890	2,428,621	3,550,076	4,657,524	6,188,175	4,100,805
7	5230	4,358,573	6,424,532	8,428,668	11,584,213	7,791,373
8	2190	1,828,119	2,690,196	3,529,404	4,848,046	3,261,040
9	3040	2,545,576	3,734,336	4,899,264	6,545,705	4,346,735
10	4890	4,067,547	6,006,876	7,880,724	10,430,200	6,888,963
10a	1880	1,586,348	2,309,392	3,029,808	4,107,615	2,752,575
10a (Alt)	1312	1,348,049	1,611,661	2,114,419	2,869,032	1,917,864
11	3863	3,214,107	4,745,309	6,225,611	8,452,190	5,657,561
12	6510	NA	1,665,706	NA	13,882,413	9,170,700

Figure 8-2



New Bedford Harbor
Construction Cost Summary
site cost (1987 dollars)
(Millions)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
1a
1a(Alt)
1b
1b(Alt)
2
3
4
4(Alt)
estuary site constuction alternatives
2.5:1
5:1
7:1
csp
dwsp

Figure 8-3

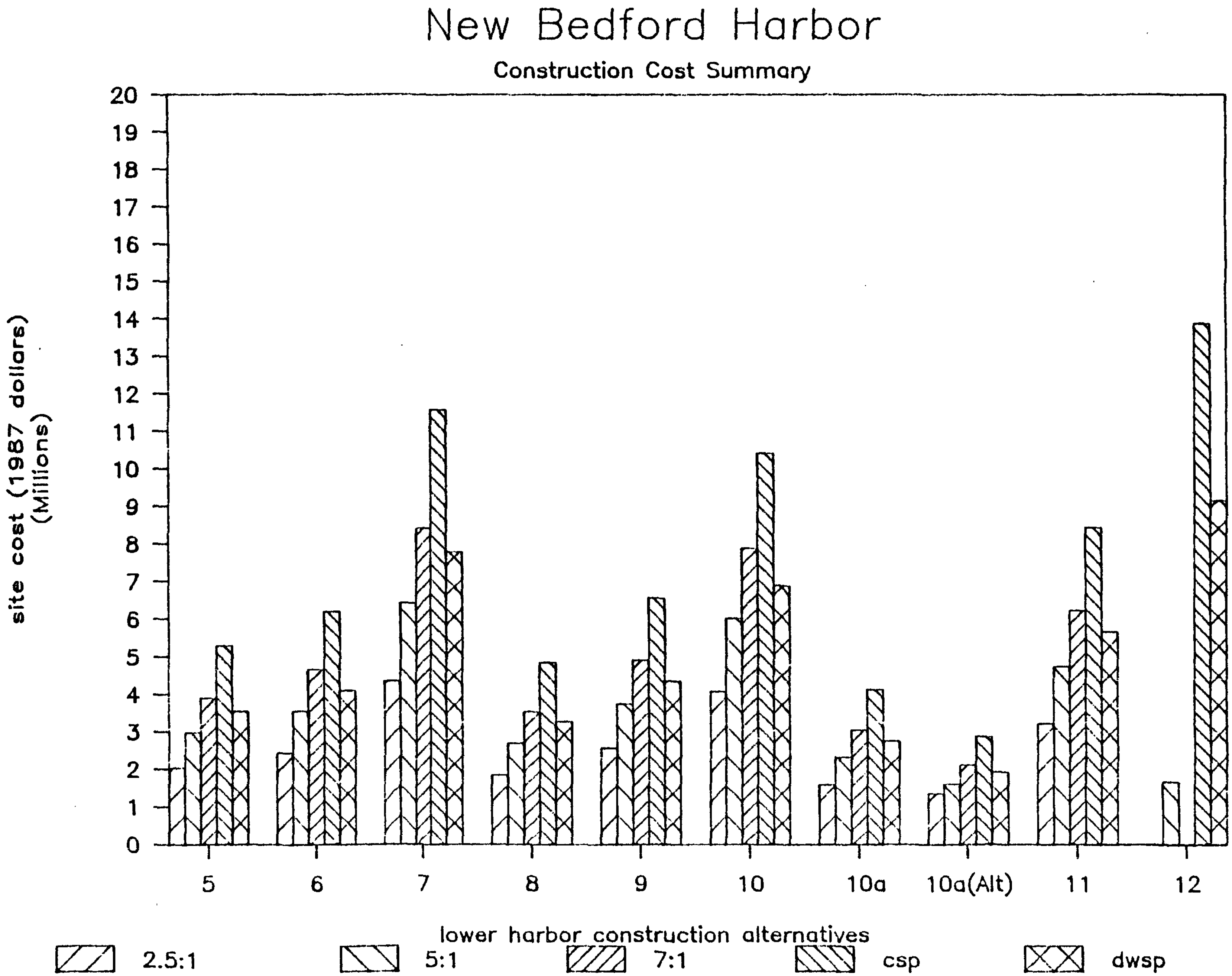

New Bedford Harbor
Construction Cost Summary
site cost (1987 dollars) (Millions)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
5
6
7
8
9
10
10a
10a(Alt)
11
12
lower harbor construction alternatives
2.5:1
5:1
7:1
csp
dwsp

Figure 8-4

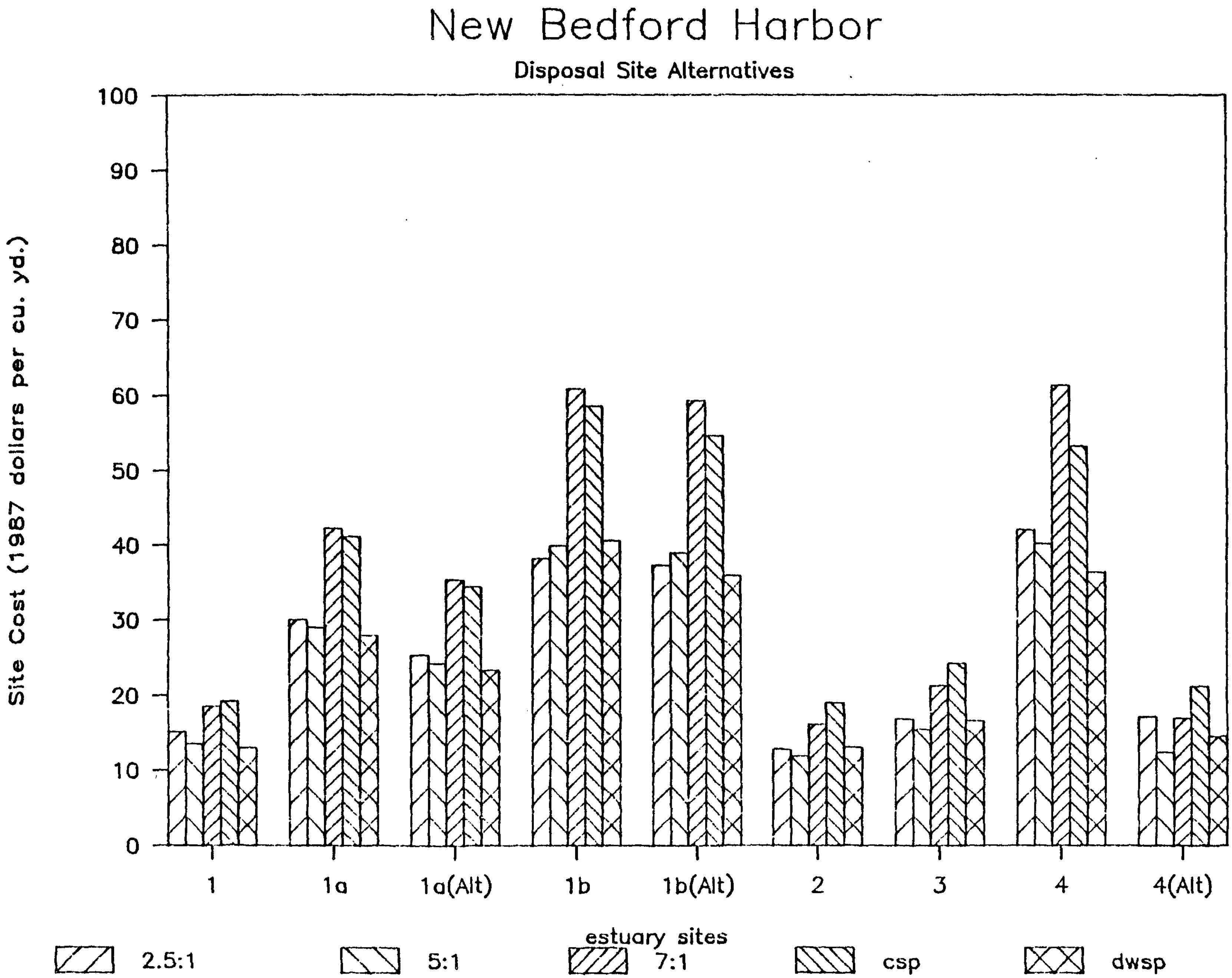
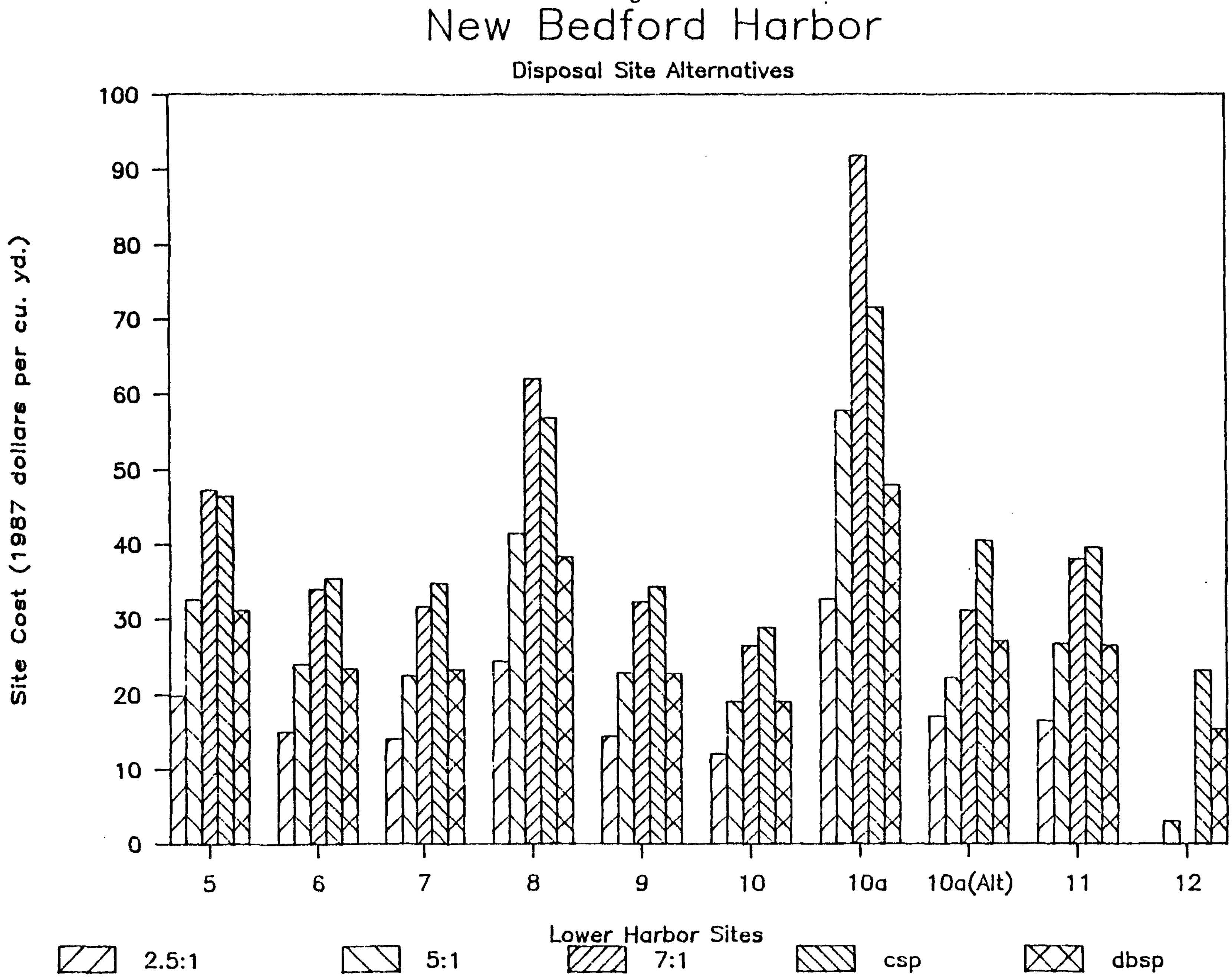

New Bedford Harbor
Disposal Site Alternatives
Site Cost (1987 dollars per cu. yd.)
100
90
80
70
60
50
40
30
20
10
0
1
1a
1a(Alt)
1b
1b(Alt)
2
3
4
4(Alt)
estuary sites
2.5:1
5:1
7:1
csp
dwsp

Figure 8-5


New Bedford Harbor
Disposal Site Alternatives
Site Cost (1987 dollars per cu. yd.)
100
90
80
70
60
50
40
30
20
10
0
5
6
7
8
9
10
10a
10a(Alt)
11
12
Lower Harbor Sites
2.5:1
5:1
7:1
csp
dbsp

when built utilizing geotextile membranes. In sheetpile cofferdam construction, the piles are assumed to be driven approximately 25 feet into the sediment.

Costs for material and labor were obtained from vendor quotes and cost estimating tables (Means Publishing Co., 1987). These costs, as discussed earlier, are preliminary in nature and should be used primarily for cost comparison between other sites and also other disposal alternatives. Actual costs could vary considerably after a detailed design has been accomplished both because of differing specifications and the potential for mixing different embankment designs due to variable surface conditions (as is being done for USACE Pilot Study CDF).

Estimated costs for conceptual island construction utilizing the design criteria and assumptions from the shoreline sites are provided in Table 8-4. Since both scenarios are located within the Lower Harbor, only those applicable designs were used.

As with the disposal alternatives in or along the waterfront, costs for upland disposal are also developed based on various assumptions. First our assumption is made that land is available for construction of this disposal site. The dikes are constructed using a 5:1 inside and 3:1 outside slope, and 10 foot height with a 20-foot wide crest. Costs include RCRA approved liner and leachate collection systems (Figure 8-1) with the lower liner

TABLE 8-4

NEW BEDFORD HARBOR
ESTIMATED COSTS FOR
CONCEPTUAL ISLAND CONSTRUCTION

ISLAND 1 (I1) located near Pope Island

1,600' x 800' 4,800-ft. linear embankment

@ 2.5:1 Slope Embankment

volume	403,000 cu yds	$7,000,000	$17.70/cu yd

@ 5:1 Slope Embankment

volume	372,000 cu yds	$8,300,000	$22.28/cu yd

ISLAND 2 (I2) located near Palmer Island

1,600' x 600' 4,400-ft linear embankment

@ 2.5:1 Slope Embankment

volume	290,000 cu yds	$6,400,000	$22.10/cu yd

@ 5:1 Slope Embankment

volume	262,000 cu yds	$7,600,000	$29.00/cu yd

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built up 5 feet above the surface.) The waste material is assumed to have a density of 1.25 tons/cy, 7:1 side slopes, water content of 50 percent and the ability of one press to dewater 66,700 c.y./year. Sand and clay would be hauled ten miles one-way. Waste hauling includes loading the 50 percent solids material with a loader at the harbor and hauling the material ten miles one-way in water-tight 20 cy containers. Leachate hauling costs include ten-mile one-way trips. Costs for leachate treatment are not included (see Table 8-5).

Preliminary costs have been developed for hauling the contaminated sediments to the nearest licensed hazardous waste disposed facility (Table 8-6). This facility, located in Model City, New York, has space available for up to 100,000 cy of material. A landfilling cost of $175/ton of material was gusted. Sediments removed from the harbor would require treatment and/or dewatering to meet the landfilling requirements, costs for which are not included in the estimates. (See section on treatment/dewatering). The most economical means of transport was determined to be by rail, so the waste staging area is assumed to be at the Conrail Railyard. Model City does not have direct rail access, so a transfer to trucks is required. A ten mile hauling distance is assumed for the final leg. Given this scenario, a cost of approximately, $27,000,000 would be incurred in hauling 100,000 cubic yards of material to Model City, New York.

TABLE 8-5

UPLAND DISPOSAL SITE

1987 COSTS

Landfill Volume (cy)	100,000	200,000	500,000	1,000,000	2,000,000
Land Aquisition/Preparation	$244,000	$259,000	$289,000	$338,000	$413,000
Landfill Construction	$1,271,000	$1,964,000	$3,590,000	$6,067,000	$9,269,000
Liner/Leachate Collection System	$1,416,000	$2,379,000	$3,863,000	$6,343,000	$10,010,000
Waste Handling	$1,045,000	$1,318,000	$2,100,000	$2,686,000	$3,142,000
Closure	$649,000	$785,000	$1,183,000	$1,312,000	$1,332,000
Monitoring/Maintenance	$138,000	$155,000	$213,000	$255,000	$288,000
Subtotal:	$4,763,000	$6,860,000	$11,238,000	$17,001,000	$24,454,000
Indirects:	$1,028,000	$1,614,000	$2,716,000	$4,472,000	$7,249,000
Contingency:	$1,632,000	$2,410,000	$3,974,000	$6,167,000	$9,432,000
TOTAL:	$7,423,000	$10,884,000	$17,928,000	$27,640,000	$41,135,000

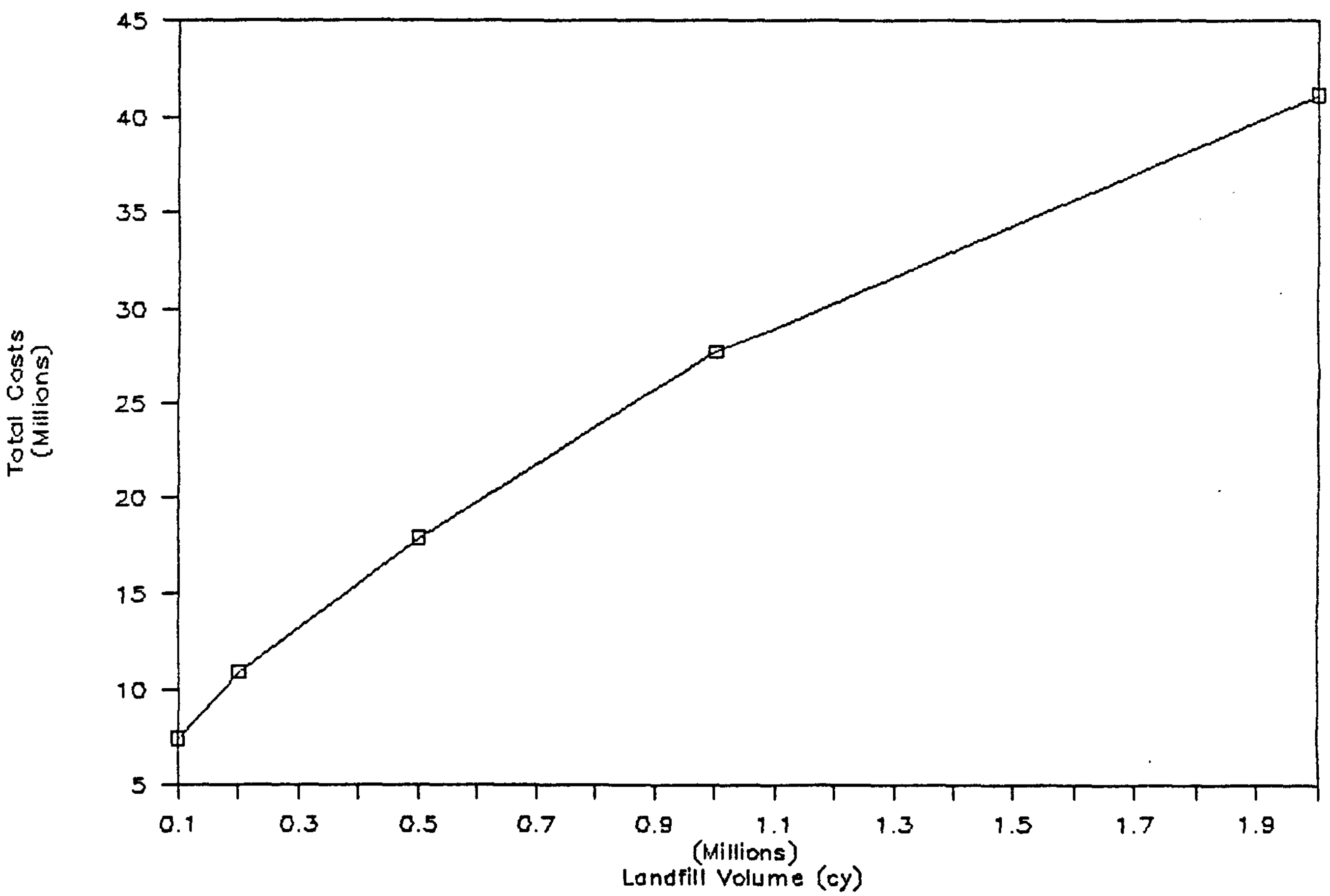

TABLE 8-6
NEW BEDFORD HARBOR
OFF-SITE APPROVED LANDFILL - COSTS

SCA - Model City Landfilling Costs Telecon: P. Cook SCA Chemical Services 10/01/86	$175.00/ton
Waste Leaching 80 cy/hr Level D Density: 1 cy = 1 ton $100.00/hr	$1.25/ton
Conrail Railroad Transport to Model City, NY Telecon: T. Cooke Conrail RR 10/24/86	$35.00/ton
Waste Transfer Telecon: T. Culter Clean Harbors Ind. 10/02/86	$5.00/ton
	$216.25/ton
Contingency (25%)	54.06
	$270.31/ton

Volume (cy)	Estimated Cost
10,000	$2,700,000
50,000	$13,500,000
100,000	$27,000,000

3Off-Sit - NB#11

8.5 SUMMARY

This section (Disposal Technologies) has identified five different types of disposal alternatives: (1) in-harbor sites; (2) shoreline sites; (3) upland sites; (4) off-site landfills; and (5) ocean sites. These alternatives have been analyzed for effectiveness, implementability, and cost individually and for comparison with each other.

With the exception of the CAD cell alternative each of the technologies has a past history to be technically feasible to construct and contain dredged sediments. CAD, shoreline, and island disposal alternatives have not been constructed thus far utilizing liners that would prevent contaminant migration. USACE is studying the potential and degree of migration from the different disposal alternatives as part of their Engineering Feasibility Study.

Costs for the different alternatives are both technology and size (volume) dependent and do not consider potential regulatory constraints. Given this, costs range from approximately $100,000 for 10,000 cubic yards of material dumped into the ocean to $270,000,000 for 1 million cubic yards shipped to an off-site licensed facility.

The effectiveness of the different technologies has been analysed for prevention of contaminated migration and protection of human health. The newly promulgated standards under SARA consider disposal of untreated sediments less desirable than treatment that permanently and significantly reduces the volume, toxicity or mobility of the contaminants: "The off site transport and disposal of hazardous substances or contaminated materials without such treatment should be the least favored alternative remedial action where such treatment technologies are available." All of the disposal scenarios are currently being retained since the extent of treatment available and feasible is still unknown. These scenarios range from open dumping with little regard for contamination to elaborate landfill designs incorporating a double liner/leachate collection system.

REFERENCES

American Marine and Machine Co., Inc., 201 Woodycrest Avenue, Nashville, Tennessee 37211. Don King

Austin, Douglas A. "The B.E.S.T. Process, Deoiling/Dewatering of Sludges and Soils"; Resources Conservation Co.; 1987.

Baker, J.E., Capel, P.D., and Eisenreich, S.J. "Influence of Colloids on Sediment - Water Partition Coefficients of Polychlorobiphenyl Congeners in Natural Waters"; Environmental Science and Technology; Vol. 20; No. 11; 1986

Battelle Pacific Northwest Laboratories, "In-Situ Vitrification of PCB Contaminated Soils," Electric Power Research Institute, Palo Alto, California, October 1986.

Battelle. Response to questionnaire to New Bedford Harbor, June 1987.

Battelle. "RI, FS Work Plan, Modelling of the Transport, Distribution and Fate of PCBs and Heavy Metals in the Acushnet River/NBH/Buzzards Bay System." May 1984.

Bedard, D.L., M.J. Brennan, and R. Unterman. "Bacterial Degradation of PCBs: Evidence of Distinct Pathways in Cornyebacterium sp. MB1 and Alcaligenes eutrophus H850." Proceedings 1983 PCB Seminar, Electrical Power Research Institute, Palo Alto, CA, pp. 4-101 to 4-117; 1984.

Bedard, D.L., M.L. Haberl, and S. Mendelson. "Biochemistry of PCB Degradation in Alcaligenes eutrophus H850: Congener Specificity and Production of Ring-Chlorinated Acetophenones." pp. 11-17 in Research and Development Program for the Destruction of PCBs, Fifth Progress Report; General Electric Company; June 1986a.

Bedard, D.L., R.L. Unterman, L.H. Bopp, M.J. Brennan, M.L. Haberl, and C. Johnson. "Rapid Assay for Screening and Characterizing Microorganisms for the Ability to Degrade Polychlorinated Biphenyls." Appl. Envir. Microbiol. 51: 761-768; 1986b.

Benson, R.E., H.W. Chandler, and K.A. Chacey. "Hazardous Waste Disposal as Concrete Admixture"; Journal of Environmental Engineering, ASCE, August 1985.

Bernard, William D. "Prediction and Control of Dredged Material Dispersion Around Dredging and Open-Water Pipeline Disposal Operation." U.S. Army Corps of Engineers; Vicksburg, Mississippi; 1978.

Bokuniewicz, H. "Burial of Dredged Sediment Beneath the Floor of New York Harbor." Marine Sciences Research Center, State University of New York, Stony Brook, New York 11794 - Reprinted from: OCEANS September 1982, 1982 IEEE.

Bopp, L.H. "Degradation of Highly Chlorinated PCBs by Pseudomonas Strain LB400." J. Industr. Microbiol., 1:23-29; 1986.

Bopp, L.H., R.J. May, S.B. Dorn, P.E. Donahue, and E.A. Williams. "Biochemistry of PCB Degradation in Pseudomonas putida LB400." pp. 19-23 in Research and Development Program for the Destruction of PCBs, Fifth Progress Report; General Electric Company; June 1986.

Brahme, Shashikant B. and John B. Herbich. "Hydraulic Model Studies for Suction Cutterheads." Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 112, No. 5; September 1986.

Brown, J.F., D.L. Bedard, L.H. Bopp, J.C. Carnahan, R.W. Lawton, R.D. Unterman, and R.E. Wagner. "Human and Environmental Biodegradation of PCBs." General Electric Research and Development Center, Schenectady, NY. pp. 10-7 to 10-10 in untitled report; 1986a.

Brown, J.F., D.L. Bedard, M.J. Brennan, J.C. Carnahan, H. Feng, and R.E. Wagner. "PCB Degradation in Aerobic and Anaerobic Environments." Submitted to Science, June 1986; 1986b.

Brown, J.F., D.L. Bedard, M.J. Brennan, J.C. Carnahan, H. Feng, and R.E. Wagner. "Polychlorinated Biphenyl Dechlorination in Aquatic Sediments." Science, 1987 (In Press).

Brown, J.F. "Environmental Dechlorination of PCBs." submitted to Environmental Toxicology and Chemistry, April 1986.

Brown J.F., R.E. Wagner, D.L. Bedard, M.J. Brennan, J.C. Carnahan, R.J. May, and T.J. Tofflemire. "PCB Transformations in the Upper Hudson Sediments." Northeast. Envir. Sci. 3:166-178; 1984.

Brown, M.P., and R.J. Sloan. "Hudson River PCB Contamination - A 1985 Perspective." Presented at the 58th Annual Meeting of the New York Water Pollution Control Association; January 14, 1986.

Buelt, James L., J.G. Carter, Description and Capabilities of the Large-Scale In-Situ Vitrification Process, Department of Energy, Pacific Northwest Laboratory, Richland, Washington, January, 1986.

Bumpus, J.A., M. Tien, D.S. Wright, S.D. Aust. "Biodegradation of Environmental Pollutants by White Rot Fungus Phanerochaete chrysosporium." Proc. 11th Ann. Res. Symp. 1985, USEPA, EPA 600/9-85/028, pp.120-126; 1985b.

Bumpus, J.A., M. Tien, D. Wright, and S.D. Aust. "Oxidation of Persistent Envirionmental Pollutants by a White Rot Fungus." Science 228:1434-1436; 1985a.

Bumpus, J.A. and S.D. Aust. "Biodegradation of Chlorinated Organic Compounds by Phanerocheate chrysosporium, a Wood-Rotting Fungus." BioEssays (In Press); 1986.

Bumpus, J.A. and S.D. Aust. "Mineralization of Recalcitrant Environmental Pollutants by a White Rot Fungus." Submitted to Hazardous Waste Symposium, March 1987, Washington, D.C.; 1987.

Bumpus, J.A., and S.D. Aust. "Studies on the Biodegradation of Organic Pollutants by a White Rot Fungus." International Conference on New Frontiers for Hazardous Waste Management: Proceedings, September 15-19, 1985 USEPA, EPA/600/9-85/025; 1985.

Bunce, N.J., Y. Kumar, and B.G. Brownlee. "An Assessment of the Impact of Solar Degradation of Polychlorinated Biphenyls in the Aquatic Environment." Chemosphere 7:155; 1978.

Calgon Carbon Corporation, P.O. Box 717, Pittsburg, Pennsylvania, 15230, Dave Jordan.

Carpenter, B.H. "Bio-Clean Process." pp. 52-65 in PCB Sediment Decontamination Processes -- Selection for Test and Evaluation; Research Triangle Institute, Research Triangle Park, NC; May 1987.

Carpenter, B. H. "PCB Sediment Decontamination, Technical/Economic Assessment of Selected Alternative Treatments"; Research Triangle Institute; April 1986.

Chantry, W.A., and W.C. Boyle, "Aerobic Biological Treatment of PCB Laden Sludge." pp. 507-535 in BIO EXPO '86 - American Commercial and Industrial Conference and Exposition in Biotechnology, May 1986, Butterworth Publishers, Stoneham, MA.

Charg, Daniel P., Nelson W. Sarbo, Gary S. Murchisan, Robert C. Adrian, and Dean C. Simeroth, "Evaluation of a Pilot-Scale Circulating Bid Combuster as a Potential Hazardous Waste Incinerator," Journal of the Air Pollution Control Association, Volume 37, No. 3, March 1987.

Church, H.K., Excavation Handbook; McGraw-Hill Book 6; New York, 1981.

Clark, R.R., E.S.K. Chian, and R.A. Griffin. "Degradation of Polychlorinated Biphenyls by Mixed Microbial Cultures." Appl. Envi. Microbiol. 37:680-685; 1979.

Clerici, John F. P.E., and J. Edmund Baker, P.E.: "Hydrogeologic Models for Siting of Waste Facilities," Advances in Irrigation and Drainage, John Borrelli, ed., 1983.

Cope, F., G. Karpinski, J. Pacey, and L. Steiner. "Use of Liners for Containment at Hazardous Waste Landfills"; Pollut. Engin. 16: 22-32; 1984.

Coron, Robert. Telephone conversation with E.C. Jordan staff, November 11, 1986.

Cortell, Jason M. and Associates, Inc.: "Draft Environmental Impact Report, Waterfront Park, New Bedford, MA," November 1982, Waltham, MA.

d'Angremond, Kees et. al. "Dredging of Polluted Sediment in the 1st Petroleum Harbor Rotterdam"; U.S. Army Corps of Engineers; Vicksburg, Mississippi.

Dataquest (Dun & Bradstreet Corp.) Rental Rate Bluebook for Construction Equipment San Jose, CA; June 1986.

des Rosiers, Paul E. "APEG Treatment of Dioxin-and Furan-Contaminated Oil at an Inactive Wood Treating Site in Butte, Montana"; October, 1986.

Dietz, Hans K.O., P.E., F.E.A.S.A. "Grouting Techniques Used in Deep South African Mines," Grouting in Geotechnical Engineering, 1982.

Dodge, R.H., C.E. Cerniglia, and D.T. Gibson. "Fungal Metabolism of Biphenyl." Biochem. J. 178:223; 1979.

E.C. Jordan Co. New Bedford Harbor Feasibility Study, Non-Removal and Removal Technologies Initial Screening Report, April, 1987.

E.C. Jordan Co. 1987a. Personal communication with Mr. Jeffrey Newton of International Waste Technologies; Wichita, Kansas.

E.C. Jordan Co. 1987b. Personal communication with VFL Technology Corp., Malvern, Pennsylvania.

E.C. Jordan Co. 1987c. Personal communication with Enreco, Inc., Amarillo, Texas.

E.C. Jordan Co. 1987d. Personal communication with Environmental Solutions, Inc., Baton Rouge, Louisiana.

E.C. Jordan Co./Ebasco Services Inc. "Draft Regulation Assessment for the New Bedford Harbor Site," September 1986, Portland, Maine.

E.C. Jordan Co./Ebasco Services Inc.: "New Bedford Harbor, Description of Alternative Disposal Sites Ranking and Selection for Evaluation in the Overall New Bedford Feasibility Study," October 1986, Portland, Maine.

E.C. Jordan Co. Telephone conversation with BioClean Inc., (612) 461-2093, 10/22/86; 1986b.

E.C. Jordan Co. Telephone conversation with Detox Industries, Inc., (713) 240-0892, 11/12/86; 1986a.

E.C. Jordan Co. Telephone conversation with Hazardous Organic Waste Destruction Inc., (301) 757-0100, 1/9/87; 1987a.

E.C. Jordan Co. Telephone conversation with Zymetech Ltd. (517) 374-6800, 1/8/87; 1987b.

Eckert, Charles A., Gregory W. Leman, Joan F. Brennecke, Steven R. Alferi: "Supercritical Solvent Extraction"; University of Illinois; May 1987

Eddy Pump Corporation, 3550 W. Pratt Avenue., Lincolnwood, Illinois, 60645 Harry Weinrib.

Elliot Machine Corporation, 1600 Bush Street, Baltimore, Maryland, 21230 Edward Bond.

Engineering News Record. "Building Costs Tracked in U.S."; McGraw-Hill, New York, New York; Vol. 218, No. 12, March 19, 1987.

ENSCO. Response to questionnaire for New Bedford Harbor, May 1987.

Environmental Information Ltd. "Individual and Hazardous Waste Management Firms 1986," Minneapolis, MN.

Environmental Pumping Services, Inc., 1816 Columbia Avenue, Steubenville, Ohio, 43952, Don Ogrizovich.

Environmental Solutions Inc. "Summary - Old Inger Superfund Site Pilot Studies." Unpublished report by Environmental Solutions, Inc., Baton Rouge, LA.

Erickson, P.R.; J. Hurst. "Mechanical Dewatering of Dredged Slurries"; U.S.-Japan Conference on Management of Bottom Sediments Containing Toxic Substances; State Department and Corps of Engineers; Jacksonville, Florida; October 1983.

Farmer, Eugene E. "An Annual Water Balance for a Surface Mining Overburden Waste Enbankment," Watershed Management in the Eighties, E. Bruce Jones, ed., 1985.

Francingues, Palermo, et. al. "Management Strategy for Disposal of Dredged Material: Contaminant Testing and Controls," August 1985.

Furukawa, K., F. Matsumura, and K. Tonomura. "Alcaligenes and Acinetobacter Strains Capable of Degrading Polychlorinated Biphenyls." Agric. Biol. Chem. 42:543-548; 1978.

Furukawa, K., and F. Matsumura. "Microbial Metabolism of Polychlorinated Biphenyls. Studies on the Relative Degradability of Polychlorinated Biphenyl Components by Alaligenes sp." J. Agric. Food Chem. 24: 251-256; 1976.

Furukawa, K., K. Tonomura, and A. Kamibayashi. "Effect of Chlorine Substitution on the Biodegradability of Polychlorinated Biphenyls." Appl. Envir. Microbiol. 35:223-227; 1978.

Furukawa, K., K. Tonomura, and A. Kamibayashi. "Metabolic Breakdown of Kaneclors (polychlorobiphenyls) and Their Products by Acinetobacter sp." Appl. Environ. Microbiol. 46:140-145; 1983.

Furukawa, K. "Microbial Degradation of Polychlorinated Biphenyls (PCBs)." pp. 35-57 in A.M. Chakrabarty (ed.). Biodegradation and Detoxification of Environmental Pollutants. CRC Press, Inc., Boca Raton, Florida; 1982.

Furukawa, K., K. Tonomura, and A. Kamibayashi. "Metabolism of 2,4,4'-trichlorobiphenyl by Acinetobacter sp. P6." Agric. Biol. Chem. 43:1577-1583; 1979.

GCA Corporation, GCA/Technology Division. New Bedford Environmental Investigation - Ambient Monitoring Program: Final Report. Prepared for the U.S. Environmental Protection Agency. Contract No. 68-02-3168. April 1984.

GCA Corporation. "New Bedford Environmental Investigation - Assessment of Groundwater Quality in the Vicinity of the Municipal Landfill and Sullivan's Ledge, New Bedford, MA," Technology Division, June 1983.

General Electric Co., 1987. Seminar on research conducted on PCB biodegradation; presented in Cambridge, Massachusetts on August 4, 1987.

GEOTECH, Response to questionnaire for New Bedford Harbor, May 1987.

Geotechnical Engineers, Inc. "Geological Reconnaissance - New Bedford Harbor and Acushnet River, New Bedford, MA," September 21, 1977, Winchester, MA.

Ghassemi, Masood, Michael Haro and Linda Fargo: "Assessment of Surface Impondment Technology," MEESA, Torrance, CA.

Gibson, D.T., L. Nadim, and F. Higson. "Biochemistry of PCB Metabolism in Alcaligenes eutrophus H850: Oxidation of Biphenyl and Biphenyl Derivatives." pp. 5-9 in Research and Development Program for the Destruction of PCBs, Fifth Progress Report; General Electric Company; June 1986.

Goodings, W.D., P.E. and D. Schram, M.C.I.P. "Quarries Can Make Viable Landfill Sites," August 1985, Waste Age.

Gundle Lining Systems. Product Literature; 1986.

Hancher, C.W.: "Removal of PCB from Soil Using Solvent Leaching," Martin Marietta Energy Systems, Inc.; April 1985.

Hand, T.D., et. al., 1978. "A Feasibility Study of Response Techniques for Discharges of Hazardous Chemicals That Sink." Report No. CG-D-45-78, U.S. Department of Transportation, U.S. Coast Guard, Office of Research and Development, Washington, D.C.

Harding, Lee: "Use of Fjords for Disposal of Mine Tailings," Coastal Zone 1983, Orville T. Magoon, et. al. eds., 1983.

Hauser, Robert, Jr., Warren N. Smith, and Paul J. Stoller. "Unique Landfill Built in a Mine Area," August 1986, Public Works.

Helfrich, Hans. "Geologic Site Evaluation - New Bedford," September 8, 1977, Skanska Sweden, Europe.

Hill, Mike and Frank Rutkey. "Development of an Industrial Waste Incinerator System: Pilot Testing through Full-Scale Operation," Proceedings of the 1984 National Waste Processing Conference, American Society of Mechanical Engineers, New York, New York, p. 471-477, 1987.

Iaconianni, Frank J. Project Summary: "Destruction of PCBs - Environmental Application of Alkali Metal Polythylene Glycolate Complexes"; USEPA; December 1985.

Iaconianni, Frank J. "Response to Questionnaire" New Bedford Harbor Feasibility Study, May 1987.

Inslaca, Sam. Telephone conservation with E.C. Jordan staff, November 19, 1986.

Insalaca, Sam. Telephone memorandum; New Bedford Harbor Feasibility Study; November 1986.

Jantzen Engineering Co. Inc., 6655 Amberton Drive, Baltimore, Maryland 21227. Robert Jantzen.

Kenner Marine and Machine, Inc., P.O. Box 1200, Laplace, Louisiana 70068. Thomas J. Wetta.

Killilea, William R., telephone conversation with E.C. Jordan staff, December 19, 1986.

Koerner R.M. Designing with Geosynthetics; Prentice Hall; 1986.

Lee, C.C., George L. Hoffman, and Donald A. Oberacker. "Hazardous/Toxic Waste Incineration," Journal of the Air Pollution Control Association, Volume 36, No. 8, p. 922-931, August 1986.

Louisiana Pump and Engineering Company, P.O. Box 716, Laplace, Louisiana 70069. Gerald Baker.

Malcolm Pirnie, Inc. Design Report: "PCB Hot Spot Dredging Program Containment Site"; White Plains, New York; September, 1980.

Malone, Philip G., James H. May, and Robert J. Larson: "Development of Methods for In-Situ Hazardous Waste Stabilization by Injection Grouting," USACE - Waterways Experiment Station, Vicksburg, Mississippi.

Massachusetts Department of Environmental Quality Engineering. Letter: Comments on two remedial alternatives; January 16, 1985, Boston, MA.

Matrecon, Inc., 1983. "Lining of Waste Impoundment and Disposal Facilities, SW-870"; Prepared for U.S. EPA, 1983.

McGovern, W. "Response to Questionnaire"; New Bedford Harbor Feasibility Study; May 1987.

Means, R.S. "Means Site Work Cost Data," 1987. 6th Edition. R.S. Means, Inc., Kingston, Massachusetts.

Mellini, Albert J., P.E., P.P. "Feasibility Assessment of Quarry Balefill," 6th Conference Municipal and Industrial Waste, September 14-15, 1983, University of Wisconsin, Madison.

Meyers, T.E.: "Innovative Solidification Techniques for Hazardous Wastes at Army Installations"; EL-85-7, Dept. of the Army, Waterways Experiment Station, Vicksburg, Mississippi, November 1985.

Miller, Jan A. "Confined Disposal Facilities on the Great Lakes," Chicago District.

MODAR, Response to questionnaire for New Bedford Harbor, May 1987.

Modell, Michael. "Supercritical Water Oxidation," (Chapters 8-11). Standard Handbook for Hazardous Waste Treatment and Disposal. McGraw Hill, New York, New York. To be Published Fall 1987.

Montgomery, Raymond L. and Jamie W. Leach, Editors. Dredging and Dredged Material Disposal. American Society of Civil Engineers; proceedings of a conference sponsored by the Waterway, Port, Coastal and Ocean Division; 1984.

Nemerow, N.L. Industrial Water Pollution Origins, Characteristics, and Treatment; Addison-Wesley Publishing Company, Inc.; Reading, Massachusetts; 1978.

NUS Corporation. "Addendum - Draft Feasibility Study of Remedial Action Alternatives, Acushnet River Estuary Above Coggeshall Street Bridge, New Bedford Site, Bristol County, MA," September 1984, Pittsburgh, PA.

NUS Corporation. Ambient Air Monitoring Program - Acushnet River Estuary, New Bedford, Massachusetts: Draft Report. 1986.

NUS Corporation. "Conceptual Development of an Onsite Sediment Disposal Facility," September 1986, Pittsburg, PA.

NUS Corporation. "Draft Feasibility Study of Remedial Action Alternatives, Acushnet River Estuary Above Coggeshall Street Bridge, New Bedford Site, Bristol County, MA," August 1984, Pittsburg, PA.

NUS Corporation. "Draft Feasibility Study of Remedial Alternatives - Acushnet River Estuary Above the Coggeshall Street Bridge - New Bedford Site, Bristol County Massachusetts," September 1984.

NUS Corporation. "Engineering of Feasibility Study Alternatives, Including Calculations," June - July 1984, Pittsburgh, PA.

NUS Corporation. "Groundwater Survey Information, New Bedford Harbor," 1984, Pittsburgh, PA.

NUS Corporation. "Initial Evaluation of Potential Disposal Sites for Contaminated Dredge Materials, New Bedford Site, Bristol County, MA," June 1984.

NUS Corporation. "Inventory of Groundwater Resources, New Bedford Study, Bristol County, MA," June 1986, Pittsburgh, PA.

NUS Corporation. "Investigation and Ranking of Potential In-Harbor Disposal Sites, New Bedford Site, Bristol County, MA," April 1986, Pittsburgh, PA.

NUS Corporation. "New Bedford Harbor Site Planning Dept. and SRPED Literature Search," November 7, 1983. NUS Memo, Pittsburgh, PA.

NUS Corporation. "Preliminary Site Inventory Forms - Initial Screening of Upland Sites, New Bedford Harbor," December 1983, Pittsburgh, PA.

NUS Corporation. "Subsurface Disposal Alternatives, Preliminary Design, New Bedford Harbor," August 1984, Pittsburgh, PA.

NUS Corporation. "Volume Calculations, Dredge/CAD, New Bedford Harbor," June - July 1984, Pittsburgh, PA.

OGDEN. Response to questionnaire for New Bedford Harbor, May 1987.

Olimpio and Delima. "Groundwater Resources of the Mattapoisett River Valley, Plymouth County, MA," 1984 USGS Water Resources Investigations Report 84-4043.

Otsuki, T., and M. Shima. "Soil Improvement by Deep Cement Continuous Mixing Method and its Effect on the Environment"; pp. 215-237 in Patin, T. (ed.), Management of Bottom Sediments Containing Toxic Substances, Proceedings of the 8th U.S. Japan Experts Meeting, Nov. 8-10, 1982, Tokyo, Japan, U.S. Army Corps of Engineers, Vicksburg, Mississippi.

Oxidyne, Response to Questionnaire for New Bedford Harbor, May 1987. Modell. Michael, Standard Handbook for Hazardous Waste Treatment and Disposal, Chapters 8-11 Supercritical Water Oxidation, McGraw-Hill, New York, New York, draft submitted October 15, 1986.

Penberthy, Larry. personal communication with E.C. Jordan staff, March 1987.

Penta-Ocean Construction Co., LTD., 2-8, Korakv 2-Chome, Bunkyo-ku, Tokyo, 112, Japan, Mitsuo Suehiro.

Peterson, Robert L. et. al. "Comparison of Laboratory and Field Test Data in the Chemical Decontamination of Dioxin Contaminated Soils. U.S. Environmental Protection Agency; April 1986.

Peterson, Robert L. "Response to Questionnaire" New Bedford Harbor Feasibility Study; May 1987.

Phillips, Keith and John Malek. "Dredging as a Remedial Method for a Superfund Site," Dredging and Dredged Material Disposal, Volume II, Proceedings of the Conference on Dredging, 1984, Published by the American Society of Civil Engineers, NY, NY.

Randhara, Ravi. Telephone conversation with E.C. Jordan staff, December 19, 1987.

Raymond, G. "Techniques to Reduce the Sediment Resuspension Caused by Dredging"; Proceedings of the 16th Annual Texas A & M Dredging Seminar, College Station, Texas, 1983.

Rexnord, Inc. "Ashtabula River Sediment Belt Filter Press Pilot Study"; Corporate Research and Innovation Group; Milwaukee, Wisconsin; January 30, 1986.

Rogers, Charles J., Donald L. Wilson, Alfred Kornel. "Preliminary Report on Treatment/Detoxification Alternatives for PCBs and Chlorinated Organics"; USEPA; 1987.

Rogers, Charles J. "Chemical Treatment of PCBs in the Environment"; USEPA; 1981.

Rogers, Charles J. et. al. Project Summary: "Interim Report on the Feasibility of Using UV Photolysis and APEG Reagent for Treatment of Dioxin Contaminated Soils"; USEPA; December 1985.

Rugg, Barry. "Response to Questionnaire" New Bedford Harbor Feasibility Study; June 1987.

Ruzo, L.O., M.J. Zabik, and R.D. Schuetz. "Photochemistry of Bioactive Compounds." J. Am. Chem. Soc. 96:3809; 1974.

Sato, Eisuke. "Dredging Techniques Applied To Environmental Problems"; WODCON Association; Irvine, California; World Dredging and Marine Construction pp. 32-38; November 1976.

Saunders, M.B. "Pilot Plant Studies for Solvent Extraction of Polychlorinated Biphenyl (PCB) from Soil"; Martin Marietta Energy Systems, Inc.; October 1985.

Science Applications International Corporation. "Capping Procedures as an Alternative Technique to Isolate Contaminated Dredge Material in the Marine Environment - Damos Contribution #11," May 21, 1980.

Science Applications International Corporation. "DAMOS, Disposal Area Monitoring System" Summary of Program Results 1981-1984; 1985.

Science Applications International Corporation. "DAMOS, Disposal Area Monitoring System; SAIC Report # SAIC-84/7521 and C46 Contribution #46; April 1985.

Semonian, R.C. "Studies on Capping of Contaminated Dredge Material in New England Division," May 1980, Unpublished Paper.

Shields, F. Douglas, and R.L. Montgomery. "Fundamentals of Capping Contaminated Dredged Materials," pp. 446-460 in Dredging and Dredged Material Disposal (Conference Proceedings); American Society of Civil Engineers; New York; 1984.

Shields, F. Douglas, and R.L. Montgomery. "Fundamentals of Capping Contaminated Dredge Material," 1984, Unpublished Paper.

Smith, R.V. and J.P. Rosazza. "Microbial Models of Mammalian Metabolism. Aromatic Hydroxylation." Arch. Biochem. Biophys. 161:551; 1974.

Smith, John M. Telephone conversation with E.C. Jordan staff, November 5, 1986.

Smith, John M. and Thomas J. Raptis. "Supercritical Deep Well Wet Oxidation of Liquid Organic Wastes," Proceedings of the International Symposium on Subsurface Injection of Liquid Wastes, National Water Well Association, Dublin, Ohio, pp. 715-739, 1986.

Spooner, P.A. "Stabilization/Solidification Alternatives for Remedial Action"; Proceedings of the Management of Uncontrolled Hazardous Waste Site Conference, 1985.

Staszak, Carl N., Kenneth C. Malinowski, and William R. Killilen. "The Pilot Scale Demonstration of the MODAR Oxidation Process for the Destruction of Hazardous Organic Waste Materials," Environmental Progress, Vol. 6, No. 1, pp. 39-43, February 1987.

Steiner W., B. Rugg, and W. Brenner. "Low Energy Process Technology for Extraction of PCB for Contaminated Sediment and Sludges"; New York University; June 1987.

Summerhayes, C.P. et. al. WHOI "Fine-Grained Sediment and Industrial Waste Distribution and Disposal in New Bedford Harbor and Western Buzzards Bay, Massachusetts." April 1977.

Suszkowski, D. J. "Studies on Capping of Contaminated Dredge Material by the New York District Corps of Engineers," 1982, U.S. Army Corps of Engineers, District New York Regulatory Branch.

Takenaka Komuten Co., Ltd. "Deep Chemical Mixing Method"; unpublished product literature; Tokyo, Japan.

Takenaka Komuten Co., Ltd. "Recent Developments in Dredged Material Stabilization and Deep Chemical Mixing in Japan"; unpublished report dated June 23, 1976; Takenaka Komuten Co., Ltd.; Tokyo, Japan.

Tibbetts Engineering Corp. "Melville - Frionor Basin Project - Special Soils Investigation," October 1979, New Bedford, MA 02746.

Tiedge, J.M., S.A. Boyd, and J.F. Quensen. "Reductive Dechlorination of PCBs in Anaerobic Microbial Communities." pp. 29-33 in Research and Development Program for the Destruction of PCBs, Fifth Progress Report; General Electric Company; June 1986.

TOA Harbor Works Co., LTD., 5, Yonban-Cho, Chiyodaku, Tokyo, 102, Japan, Junichi Hamasna.

Tomes, P.A. MIWM: "Quarries and Waste Disposal: Case Study of Practice," Quarry Management, Vol. 11 No. 3, March 1984.

Toyo Construction Co., LTD., 7-1, 3 Chome Kanda-Nishiki-cho, Chiyoda-ku, Tokyo, 101, Japan, M. Kurokawa.

Trenholm, Andrew, Paul Gorman, and Greg Jungclaus. Performance Evaluation of Full-Scale Hazardous Waste Incinerators, U.S. Environmental Protection Agency, Cincinnati, Ohio, May 1984.

Truitt, Clifford L. "The Duwamish Waterway Capping Demonstration Project: Engineering Analysis and Results of Physical Monitoring," USACE - Waterways Experiment Station, Vicksburg, Mississippi.

Tucker, E.S., V.W. Saeger, and O. Hicus. "Activated Sludge Primary Biodegradation of Polychlorinated Biphenyls." Bull. Envir. Contam. Toxicol. 14:705-713; 1975.

Unterman R., D.L. Bedard, L.H. Bopp, M.J. Brennan, C. Johnson, and M.L. Haberl. "Microbial Degradation of Polychlorinated Biphenyls." International Conference on New Frontiers for the Hazardous Waste Management. pp. 481-488; 1985.

U.S. Army Corps of Engineers. "Capping of Dredged Material Disposal, Management for New York Harbor," New York Regulatory Branch.

U.S. Army Corps of Engineers. "Commencement Bay Nearshore/Tide-flats Superfund Site, Evaluation of Alternative Dredging Methods and Equipment, Disposal Methods and Sites, and Site Control and Treatment Practices for Contaminated Sediments," June 1985.

U.S. Army Corps of Engineers. "Commencement Bay Nearshore/Tideflats Superfund Site, Tacoma, Washington, Remedial Investigations. Decision-making Framework for Management of Dredged Material Application to Commencement Bay, Washington," Waterways Experiment Station, Vicksburg, Mississippi, July 1985.

U.S. Army Corps of Engineers. "Dredging/Containment Area Technologies," copied from "Management of Bottom Sediment Containing Toxic Substances," Proceedings of the 5th-10th U.S./Japan Experts Meeting.

U.S. Army Corps of Engineers. "Dredge Material Monitoring/Disposal Criteria and Studies," copied from "Management of Bottom Sediments Containing Toxic Substances," Proceedings of the 5th-10th U.S./Japan Experts Meeting.

U.S. Army Corps of Engineers. "The Duwamish Waterway Capping Demonstration Project: Engineering Analysis and Results of Physical Monitoring"; Technical Report D-86-2; 1986.

U.S. Army Corps of Engineers. Duwamish Waterway - Environmental Effects of Dredging - Operational Aspects of Capping In-water Disposal of Contaminated Dredge Materials," October 1984, Seattle, Washington.

U.S. Army Corps of Engineers. "Effectiveness of Capping in Isolated Contaminated Dredged Material from Biota and the Overlying Water," November 1985, Final Report.

U.S. Army Corps of Engineers. "Engineering and Design, Confined Disposal of Dredged Material (Draft)," EM 1110-2-5027 Department of the Army, Office of the Chief of Engineers.

U.S. Army Corps of Engineers. "Engineering and Design, Dredging and Dredge Material Disposal," EM 1110-2-5025, March 25, 1983, Department of the Army, Office of the Chief of Engineers.

U.S. Army Corps of Engineers. "Engineering Feasibility Study of Dredging and Disposal of Highly Contaminated Sediment -- Acushnet River Estuary Above Coggeshall Street Bridge," September 1985, New England Division.

U.S. Army Corps of Engineers. "Environmental Effects of Dredging - All Dredged Up and No Place to Go," August 1984, Waterways Experimental Station, Vicksburg, Mississippi.

U.S. Army Corps of Engineers. "Environmental Effects of Dredging - Ocean Disposal of Dredged Material," May 1984, Waterways Experiment Station, Vicksburg, Mississippi.

U.S. Army Corps of Engineers. "Environmental Effects of Dredging - Technical Notes; Fate of Dredged Material During Open Water Disposal," September 1986, Waterways Experiment Station Report.

U.S. Army Corps of Engineers, "Management of Bottom Sediments Containing Toxic Substances"; Proceedings of the 5th-10th U.S./Japan Experts Meeting.

U.S. Army Corps of Engineers. "Evaluation of the 1980 Capping Operations with the Experimental Mud Dump Site, New York Bight Apex," October 1983, Final Report.

U.S. Army Corps of Engineers. Guidelines for Dewatering/Densifying Confined Dredged Material"; Vicksburg, Mississippi; September 1978; Technical Report DS-78-11.

U.S. Army Corps of Engineers. Thomas R. Patin, Editor. Management of Bottom Sediments Containing Toxic Substances, Proceedings of the 6th U.S./Japan Experts Meeting. Water Resources Support Center; Fort Belvoir, Virginia, March 1982.

U.S. Army Corps of Engineers. Thomas R. Patin, Editor. Management of Bottom Sediments Containing Toxic Substances, Proceedings of the 7th U.S./Japan Experts Meeting. Water Resources Support Center; Fort Belvoir, Virginia; October 1983.

U.S. Army Corps of Engineers. Thomas R. Patin, Editor. Management of Bottom Sediments Containing Toxic Substances, Proceedings of the 8th U.S./Japan Experts Meeting. Water Resources Support Center; Fort Belvoir, Virginia; July 1984.

U.S. Army Corps of Engineers. "Studies on Capping of Contaminated Dredged Material in New England Division."

U.S. Army Corps of Engineers. "Studies on Capping of Contaminated Dredge Material by the New York District, Corps of Engineers."

U.S. Army Corps of Engineers. "Upland Disposal - Management of Bottom Sediments Containing Toxic Substances," March 1985, Water Resources Support Center Proceedings from the 9th U.S./Japan Experts Meeting 17-19 October, 1983, Jacksonville, Florida.

U.S. Army Corps of Engineers - Waterways Experiment Station. Interim Draft Report. "Dredged Material Settling Tests for New Bedford Sediment"; Vicksburg, Mississippi. 1987.

U.S. Army Corps of Engineers, Waterways Experiment Station, P.O. Box 631, Vicksburg, Mississippi 39180. Daniel Averett.

U.S. Department of Agriculture. "Soils and Their Interpretations for Various Land Uses, City of New Bedford, MA," February 1977, Soil Conservation Service in Cooperation with Bristol Conservation District.

U.S. Environmental Protection Agency. Blazevich, J.N., et. al., Monitoring of Trace Constituents During PCB Recovery Dredging Operations: Duamish Waterway, U.S. EPA, Seattle, Washington. August 1977.

U.S. Environmental Protection Agency. "Draft Minimum Technology Guidance on Double Liner Systems for Landfills and Surface Impoundments -- Design, Construction, and Operation," Second Version, 530-SW-85-014, May 24, 1985. Washington, D.C.

U.S. Environmental Protection Agency. "Guide to the Disposal of Chemically Stabilized and Solidified Waste"; SW-872, September 1982.

U.S. Environmental Protection Agency. "Handbook of Remedial Action at Waste Disposal Sites" (revised); EPA/626/6-85/006; October 1985.

U.S. Environmental Protection Agency. "Handbook for Stabilization/Solidification of Hazardous Waste"; Waterways Experiment Station, Vicksburg, Mississippi. 1986.

U.S. Environmental Protection Agency. "Innovative and Alternative Technology Assessment Manual"; Office of Research and Development; Cincinnati, Ohio. February 1980; EPA 430/9-78-009.

U.S. Environmental Protection Agency. "Management of Hazardous Waste Leachate"; Office of Solid Waste and Emergency Response; Washington, D.C.; September 1982; EPA No. SW-871.

U.S. Environmental Protection Agency. "Microbial Decomposition of Chlorinated Aromatic Compounds." EPA/600/2-86/090; 1986.

U.S. Environmental Protection Agency. "Minimum Technology Guidance for Double Liner Systems for Landfills and Surface Impoundments - Design, Construction, and Operation"; 1985.

U.S. Environmental Protection Agency. "Mobile Treatment Technologies for Superfund Wastes"; Office of Solid Waste and Emergency Response; Washington, D.C.; September 1986a; EPA 540/2-86/003(f).

U.S. Environmental Protection Agency. "Process Design Manual for Carbon Adsorption"; Technology Transfer Office; Cincinnati, Ohio; October 1973. EPA 625/1-71-CERCLA.

U.S. Environmental Protection Agency. "Record of Decision Remedial Alternative Selection - Outboard Marine Corporation (OMC), Waukegan, Illinois," Lee Thomas, Assistant Administrator, Office of Solid Waste and Emergency Response, May 15, 1984.

U.S. Environmental Protection Agency. "Remedial Action at Waste Disposal Sites"; EPA/625/6-86/006, October 1985.

U.S. Environmental Protection Agency. "Treatment Technology Briefs, Alternatives to Hazardous Waste Landfill"; Hazardous Waste Engineering Research Laboratory; Cincinnati, Ohio, July 1986. EPA 600/8-86/017.

U.S. Geologic Survey. "Hydrologic Data of the Coastal Drainage Basins of Southeastern Massachusetts, Northwest Shore of Buzzards Bay," 1980, Massachusetts Hydrologic Data Report No. 20.

Volker, Stevin. Dredging and Public Works Department. "Dredging of Polluted Sediments in the 1st Petroleum Harbor, Rotterdam," Rotterdam, the Netherlands.

Wagner, P.J. "Conformational Changes Involved in the Singlet-Triplet Transitions of Biphenyl." J. Am. Chem. Soc. 89:2820; 1979.

Wallnofer, P.R., G. Engelhardt, S. Safe, and O. Hutzinger. "Microbial Hydroxylation of 4-Chlorobiphenyl and 4,4'-Dichlorobiphenyl." Chemosphere 2:69; 1973.

Water Pollution Control Federation. Wastewater Treatment Plant Design; Lancaster Press, Inc.; Washington, D.C. 1977.

Weber, W.J. Physiochemical Processes for Water Quality Control; John Wiley and Sons, Inc.; New York, New York. 1972.

Weitzman, Leo. "Solvent Cleaning of PCB Contaminated Soils"; Acurex Corp.; October 1985.

Westinghouse, vendor literature supplied to E.C. Jordan staff, June 1987.

WODCON Association, Twentieth Annual Directory of Worldwide Dredge Fleets; World Dredging and Marine Construction, Irvine, California, March 1986.

Woodward - Clyde Consultants. "Field Investigation and Analytical Testing, New Bedford Superfund Site, New Bedford, MA," January 6, 1987, Omaha, Nebraska.

Wooton, Frank T. "Dredging and Disposal of Toxic Material Using Japanese Technology Suggested for the United States"; WODCON Association; Irvine, California; World Dredging and Marine Construction, pp. 14-15; April 1980.

Yagi, O., and R. Sudo. "Degradation of Polychlorinated Biphenyls by Microorganisms." J. Water Poll. Contr. Fed. 52:1035-1042; 1980.