FOSTER WHEELER ENVIRONMENTAL CORPORATION

October 20,2000
2000-17-0291
No Response Required

New Bedford
6.4
217268

Mr. Robert Hunt
Project Manager
New England District
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

Subject: USACE CONTRACT NO. DACW-33-94-D-0002
TOTAL ENVIRONMENTAL RESTORATION CONTRACT (TERC)
TASK ORDER NO. 017 – NEW BEDFORD HARBOR SUPERFUND SITE OU-1
FINAL EVALUATION OF SIDEWALL LINER ALTERNATIVES FOR CDF C AND PCB LEAKAGE RATES MODELING

Dear Mr. Hunt:

Enclosed are responses to comments on the Draft Technical Memorandum evaluating: (1) sidewall liner alternatives for the sheet pile wall with half dike design, and (2) PCB leakage rates modeling. The Final Technical Memorandum, which incorporates the responses to comments, is also enclosed. Please note that the revised cost estimate of the double sheet pile wall with exterior dike and preferred liner system design, included in Section 8.0 of the document, are associated with only the offshore portion of CDF C.

If you have any questions or comments on the Final Technical Memorandum, please contact me at (617) 457-8234. Thank you.

Sincerely,

Allen J. Ikalainen

Allen J. Ikalainen, P.E.
Project Engineer

Enclosure: 2000-17-0290

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FOSTER WHEELER ENVIRONMENTAL CORPORATION
TOTAL ENVIRONMENTAL RESTORATION CONTRACT (TERC)
CONTRACT NO. DACW33-94-D-0002, TASK ORDER NO. 017
NEW BEDFORD HARBOR SUPERFUND SITE – NEW BEDFORD, MA

ANNOTATED RESPONSES TO REVIEW COMMENTS
ON THE EVALUATION OF SIDEWALL LINER ALTERNATIVES AND PCB LEAKAGE RATES
MODELING FOR CDF C

The following are responses to U.S. Army Corps of Engineers (USACE) review comments on the Draft Technical Memorandum: "Sheet Pile Wall with Half Dike Design, Evaluation of Sidewall Liner Alternatives and PCB Leakage Rates Modeling, Confined Disposal Facility (CDF) C", dated August 1, 2000. The USACE comments are provided in italic type followed by Foster Wheeler's responses in bold type.

Reviewer: Karen Schofield (USACE) Date: August 8, 2000

Comment 1: *Table 5-1, Soil-Based Slurry Wall – One disadvantage seems misplaced as stated. It says "Cement subject to corrosion in saltwater environment". This is the soil-based wall, doesn't this statement belong in the cement-based wall disadvantages instead?*

Response: **Yes, that statement was misplaced and has been moved to the disadvantages listed for a cement-based slurry wall.**

Comment 2: *Table 5-1 – In the discussions of the GSE GundWall, a depth limitation of 20 feet is mentioned. This depth should be specifically mentioned as a disadvantage in the table.*

Response: **The depth limitation of 20 feet has been added to the disadvantages listed for a GSE GundWall®.**

Comment 3: *Figure 7-1 – The slurry is only shown to the organic clay layer. Is this shown low enough?*

Response: **This figure presents a preliminary conceptual design where the slurry wall would fill the space between the two steel sheets, and the GundWall® would be inserted into the slurry wall and keyed five feet into the organic clay creating the most "impermeable" vertical barrier. In reality, there would likely be some mixing of the clay-bentonite slurry and the underlying organic clay. The degree of mixing is not known at this preliminary stage of the design.**

Comment 4: *Page 14 – In step 1 and step 5, please clarify that each row of sheet piling is 1360 linear feet long. It's hard to know for sure as written.*

Response: **Length of sheeting refers to the distance from the top of the sheet pile to the bottom of the sheet pile (i.e., the difference between the top elevation to the tip elevation). For clarification, it has been stated that the alignment of each row of steel sheet piling, as well as GundWall®, is 1,360 linear feet.**

Comment 5: *<u>Page 14</u> – In step 2, is 20 feet beyond toe, enough distance to help create contaminant free mud wave, it seems kind of short?*

Response: **For this conceptual design, 20 feet is just a preliminary estimate. This number will be refined as the design proceeds.**

Comment 6: *<u>Page 14</u> – In step 3, please state the type of clay making up the 20,200 CY. Is it inorganic or organic? Is there any sand mixed in? Also state how clean it is. As stated now, it's unclear. Shouldn't the clean be in quotes, "clean"? Also, if it is stated to need off-site disposal, state the type assumed, such as subtitle D, etc.*

Response: **The sediment to be excavated as part of CDF C construction consists of organic clay or organic silt containing varying amounts of fine to medium sand and shell fragments. This "clean" clay will have PCB concentrations less than the target cleanup level of 10 ppm. For estimating purposes, it is assumed that the excavated sediment will have a PCB concentration of at least 2 ppm, and will required out-of-state disposal at a Subtitle D landfill.**

Comment 7: *<u>Page 15</u> – In step 6, the first statement seems to say that the double sheet pile composite wall, is being built first in the water. Then the embankment is being placed. Do they need to be done simultaneously for stability of the wall and/or does wall have to go deeper? If so, please state in a little more detail.*

Response: **The embankment is being constructed to support the steel sheet pile walls once the CDF is filled and a temporary cap and surcharge have been applied. The embankment is not needed for the stability of the composite wall when the CDF is empty, and does not have to be constructed simultaneously with the composite wall.**

Comment 8: *<u>Page 15</u> – In step 7, it says "may". It would seem from discussions that desiccation is a big deal and something undesired, therefore, shouldn't it be "will" instead of "may". Therefore, it should be included in Figure 7-1 and in the cost estimate. At the very least, it should be stated on the cost estimate as a contingency in either a lump sum allowance, a unit cost (if known), or an appropriate percentage. Contingency is missing to begin with and should be added to the estimate.*

Response: **The material used to fill the space between the two sheet pile walls is still undetermined. It may be a clay-bentonite, cement-bentonite, or clay-cement-bentonite slurry. Because of the number of variables, it is not possible to say definitely if desiccation will or will not be an issue. Therefore, the best statement to make is that a cap "may" be installed over the clay-bentonite slurry wall to prevent possible desiccation. This cap has not been included as a contingency in the cost estimate since it is not known if it is needed.**

Foster Wheeler does not typically include a contingency with a cost estimate, and to be consistent with the cost estimate prepared for the alternatives evaluation it has not been added.

Comment 9: *Detail Sheets are missing in Cost Estimate for "Fill Between Sheets" and "Install GundWall", please add. Are they quotes or historical data? If so, add reference.*

Response: **A detail sheet has been added to the cost estimate for these two items (both items will be performed by the same subcontractor). They are quotes and are now noted as such.**

Comment 10: *Indirect Cost/Markups of only a little more than 33% (including fee) are shown in the cost estimate. This seems low; FWENC budgets carry 40%. Therefore, 40% should be carried here at this preliminary stage.*

Response: **To be consistent with the approach used in preparing the cost estimate for the alternatives evaluation, a fee of 33% is still carried. A Foster Wheeler estimator is currently trying to develop a better indirect cost/markup percentage (including fee) to use in construction cost estimates.**

Reviewer: Maurice Beaudoin (USACE) Date: August 18, 2000

Comment 1: *Paragraph 6.6 infers that there is a navigation channel north of the Coggeshall Street Bridge. There is no marked or regulated channel north of Coggeshall Street and should not be mentioned.*

Response: **Although the widening of the embankment would not encroach upon a marked or regulated channel, the mudline elevation drops is as low as -20 feet NGVD at the midpoint of this channel. This depth to mudline would make the construction of the embankment costly and difficult.**

Comment 2: *The proposed double sheet pile wall with a clay-bentonite slurry and "GundWall" seems to be overkill in my opinion. It would make economic sense to use a single wall with a clay-bentonite slurry wall within the embankment portion on the river side of the sheeting.*

Response: **As discussed in Section 6.6, there are several reasons that a clay-cement-bentonite slurry wall installed into the embankment would not serve as an effective liner system: (1) that the slurry wall would not be keyed into an aquitard (i.e., the organic clay) at any depth; (2) the embankment would have to be considerably wider; (3) it may be structurally infeasible; and (4) saltwater would have a negative impact on the bentonite in the wall.**

Additional changes that have been made based on internal comments are as follows:

Table 5-1:	Cement is subject to degradation rather than corrosion in a saltwater environment.
Table 5-1:	Desiccation and cracking lead to increased permeability of slurry walls rather than increased porosity.
Table 5-1:	Corrosion of the steel sheet pile wall leads to an increase in both horizontal and vertical migration of contaminants.
Section 5.2:	Sealants which are injected into the interlocking joints after the sheets are driven may ~~flow through~~ not fill joints which have become separated.
Section 5.4:	Vinyl sheet pile walls are constructed by driving prefabricated interlocking Z-shaped vertical sheets of rigid polymer into the soil....
Section 5.4:	Vinyl sheet pile walls are used as an alternative to steel sheet pile walls "where structural requirements are less".
Section 5.4:	A series of weep holes are usually installed to minimize, rather than accelerate the dispersion of, hydrostatic loads.
Section 5.4:	Sealants which are injected into the interlocking joints after the sheets are driven may ~~flow through~~ not fill joints which have become separated.
Section 5.5:	Once inserted into this layer, the ~~lateral~~ migration of fluids is theoretically blocked both laterally and vertically.
Section 6.0:	Introduction added to Section 6.0.
Section 6.3:	A third option would be to install a continuous vinyl sheet pile wall two to three feet in front of, and anchored to, the structural steel sheet piling.
Section 6.3:	Short-term permeability could theoretically be as ~~high~~ low as 10^{-7} cm/sec.
Section 6.4:	The slurry wall...would be subject to ~~corrosion~~ degradation in a relatively saltwater environment ~~because of~~, depending on the cement content.
Section 6.8:	Both the slurry wall and GundWall® would be keyed into the organic clay and would provide a system permeability ~~of up to~~ as low as 10^{-10} cm/sec.
Section 6.8:	Note, however, that the saltwater could ~~shrink~~ change the structure of the bentonite clay particles, slightly increasing the porosity of the barrier.
Section 6.8:	Because this option most closely meets the ~~composite~~ liner requirements specified in the ROD and the Massachusetts Solid Waste Management Regulations, it is recommended as the preferred liner system
Figure 7-1:	Riprap added on exposed face of embankment.
Section 7.0:	Step 6. An external embankment to support the sheet pile walls ~~once the CDF is filled and a temporary cap and surcharge have been applied~~ of the CDF will be built from a foundation elevation of approximately -14 NGVD to a crest elevation of 8 NGVD.
Section 8.0:	The cost estimate for the double sheet pile wall with exterior half dike....
Section 8.0:	Bullet 1. The disposal capacity of CDF C has been reduced to an estimate of 84,440 cubic yards based on the current configuration. The original disposal capacity was approximately 95,000 cubic yards. From that number, 8,900 cubic yards is used for the disposal of contaminated dredged sediment. Another 1,660 cubic yards is lost due to the second row of steel sheet piles being installed in front of the first row.
Appendix A:	Pages 1, 6, and 7. Marine fill has been changed to fill below water, and land fill has been changed to fill above water.
Appendix A:	Page 4: Title has been changed to Pre-dredge Contaminated Sediment.
Appendix A:	Page 5: Title has been changed to Excavate Organic Clay.

6.4

Total Environmental Restoration Contract

New England Division

USACE Contract No. DACW33-94-D-0002

FOSTER WHEELER ENVIRONMENTAL CORPORATION

USACE CONTRACT NO. DACW33-94-D-0002
TASK ORDER NO. 017
TOTAL ENVIRONMENTAL RESTORATION CONTRACT

FINAL
TECHNICAL MEMORANDUM
SHEET PILE WALL WITH HALF DIKE DESIGN
EVALUATION OF SIDEWALL LINER ALTERNATIVES
AND
PCB LEAKAGE RATES MODELING
CONFINED DISPOSAL FACILITY (CDF) C
NEW BEDFORD HARBOR SUPERFUND SITE

New Bedford, Massachusetts
October 2000

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

2000-17-0290
10/23/00

USACE CONTRACT NO. DACW33-94-D-0002
TASK ORDER NO. 017
TOTAL ENVIRONMENTAL RESTORATION CONTRACT

FINAL TECHNICAL MEMORANDUM

SHEET PILE WALL WITH HALF DIKE DESIGN EVALUATION OF SIDEWALL LINER ALTERNATIVES AND PCB LEAKAGE RATES MODELING CONFINED DISPOSAL FACILITY (CDF) C NEW BEDFORD HARBOR SUPERFUND SITE

New Bedford, Massachusetts

October 2000

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

Prepared by
Foster Wheeler Environmental Corporation
133 Federal Street
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Revision	Date	Prepared by	Approved by	Paged Affected
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2000-17-0290
10/17/00

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1.0 INTRODUCTION

The information contained in this Technical Memorandum provides an evaluation of: (1) the vertical liner requirements of the sheet pile wall with an exterior "half dike" design for CDF C; and (2) the computer modeling performed by the U.S. Army Corps of Engineers Waterways Experiment Station (WES) to estimate contaminant transport, or PCB leakage rates, through all four CDFs. Vertical barrier systems, and applications of these systems to the current design of CDF C, are discussed in detail. A summary of both the initial modeling assumptions used by WES, and how those relate to the current CDF design, are provided. Also included is a discussion of modeling assumptions which have changed significantly, and which may require further evaluation to more accurately determine PCB leakage rates.

2.0 LINER REQUIREMENTS SPECIFIED IN THE RECORD OF DECISION

TSCA chemical waste landfill liner requirements, which were determined to be inappropriate for shoreline CDFs, were waived under TSCA. Specifically, requirements regarding soil, synthetic bottom liner, hydrogeologic conditions, and leachate collection were waived. The sediment underlying the CDFs, however, was considered to be sufficiently protective with a permeability standard equal to or less than 10^{-7} cm/sec in accordance with the Record of Decision (ROD). The ROD also states that the sidewalls of these CDFs shall be lined with a synthetic impermeable material. The combination of the underlying sediment and impermeable sidewall liner and cap were determined to provide sufficient impermeability so that the long-term combined PCB leakage rate from all four CDFs is limited to an estimated 37 kg over thirty years. The substantive requirements of the Massachusetts Solid Waste Management Regulations that are more stringent than TSCA regulations for liners, and that are relevant and appropriate, shall also be met.

The Massachusetts Solid Waste Management Regulations require that a landfill liner shall, at a minimum, be comprised of a composite liner consisting of a low permeability compacted soil layer or admixture overlain by a flexible membrane liner (FML). The compacted low permeability soil or admixture layer shall have a minimum thickness of two feet, a maximum in-place saturated hydraulic conductivity of 10^{-7} cm/sec throughout the entire thickness of the layer, and a minimum slope of two percent. The FML layer shall be of sufficient thickness as determined by the Department and constructed so that the FML material is in direct contact with the low permeability soil layer. Based on discussions with the Massachusetts Department of Environmental Protection (MADEP), these requirements should be considered in the design if they can be practically applied. The most important consideration, however, should be the PCB leakage rates.

3.0 LINER SYSTEMS CONVENTIONALLY EMPLOYED IN LANDFILLS

3.1 General Requirements

In general, landfills must be underlain by one or more liners and have a leachate collection and removal system above and between such liners. The liners must be designed, constructed, and installed to minimize the migration of wastes out of the landfill to the adjacent subsurface soil or groundwater or surface water at anytime during the active life and post-closure care period of the landfill. Liners may range from very thick natural clay deposits to double composite liner systems installed on the base of the landfill and composite liners installed on the sloping sidewalls. Composite liner systems generally consist of a two- to three-foot layer of compacted low permeability soil, such as clay, overlain by welded high density polyethylene (HDPE) geomembrane.

The following requirements should be considered when assessing the performance of a composite liner system used for waste containment over the intended design life of the barrier:

1. Hydrogeologic conditions in which the barrier is to function;
2. Permeability, or hydraulic conductivity, of the system;
3. Geochemical properties of the contaminants;
4. Compatibility of materials used with the waste; and
5. Construction quality control at the time of installation.

The hydrogeologic conditions acting on the liner system form the basis from which the contaminants are transported across the barrier. The geochemical properties of the waste contribute to the aqueous concentration of the contaminants, and, coupled with the hydrogeologic conditions, influence the rate of transport across the liner system. The hydraulic conductivity and compatibility of the liner system are largely dependent on the barrier materials selected and the method of installation. The first four requirements are generally considered during the design and approval processes.

Provided that a proper design has been approved, construction quality control is perhaps the most crucial requirement for the successful performance of soil and geosynthetic barriers. The installed permeability of a geomembrane liner largely depends on the level of quality control carried out during its installation. Construction issues, such as wrinkles, poor seaming, and holes, all contribute to the increased permeability, or higher leakage rate, of the liner system.

3.2 Evaluation of Liner Systems

In the United States, landfill liner systems have traditionally been evaluated using prescriptive based standards to limit contaminant release, including liner permeability standards, composite liner materials, and minimum slope for liner placement. Performance based design standards, such as leakage rates, however, are more frequently being used to evaluate alternative liner systems by demonstrating that the liner sufficiently limits contaminant release to a specified level. These performance-based standards are necessary where site conditions limit the application of prescriptive based standards. Note that the majority of the requirements specified in the ROD imply that prescriptive standards would apply to the CDF sidewall liner design. The ROD, however, also specifies a leakage rate, which would imply that performance based standards apply.

4.0 OVERVIEW OF VERTICAL BARRIERS

Vertical barriers, usually slurry walls, are often installed at solid waste and hazardous waste landfills and other waste disposal sites to limit the off-site migration, or horizontal flow, of contamination. They are almost always used in conjunction with a remedial action such as dewatering and excavation of contaminated soil, groundwater extraction and treatment, leachate collection, bioremediation, and/or soil vapor extraction. A vertical barrier, however, is most often used as a flow control device to enhance the efficiency of a groundwater extraction system by restricting inward lateral flow of water from surrounding areas, and intercepting lateral, off-site migration of contaminated groundwater. They are also used to isolate areas of highest contamination during remedial activities and minimize off-site migration of hazardous substances. When used in conjunction with a remedial action and a capping system tied directly into the barrier wall, vertical barriers can be effective, although a general lack of monitoring, especially long-term monitoring, makes containment system effectiveness difficult to determine. For long-term applications, usually considered to be in excess of 30 years, both the hydraulic transport of contaminants and the diffusion of contaminants through vertical barriers should be considered. Diffusion is an important component in estimating the integrity of vertical barriers when used to contain hazardous substances for extended periods of time.

5.0 EXAMPLES OF VERTICAL BARRIER SYSTEMS

5.1 Slurry Wall

Slurry walls have been used for pollution control since 1970 to isolate hazardous waste and minimize the migration of contaminants. Barriers installed with a slurry trenching technology consist of a vertical trench excavated two to five feet into an aquitard along the perimeter of the site, filled with bentonite slurry to support the trench, and subsequently backfilled with a mixture of low-permeability material which forms the hydraulic barrier. Varying the composition of the backfill can alter the properties of the barrier to obtain the desired strength and permeability. Backfill can be soil-based, cement-based, or a combination of soil and cement. Note that the addition of cement increases the strength of the barrier while increasing the permeability of the backfill and, subsequently, the porosity of the wall.

The advantages and disadvantages of the two major types of slurry cutoff walls, soil-based and cement-based, have been summarized in Table 5-1. The estimated system permeabilities and design lives of these slurry walls are provided in Table 5-2. In general, soil-based slurry walls have a lower strength and a lower permeability, while cement-based slurry walls have a higher strength and a higher permeability. Soil-cement-based slurry walls, which have not been included in Tables 5-1 and 5-2, have the strength of a cement-based slurry wall and the permeability of a soil-based slurry wall. Cement-based slurry walls, although strong, do not offer the high strength of steel sheet pile walls and are prone to cracking due to shrinkage, thermal stress, and wet/dry cycling. Another disadvantage of slurry walls is that organic and inorganic contaminants in the soil and groundwater (such as strong organic and inorganic acids and bases, inorganic salts, and some neutral polar and nonpolar organic compounds) can have a negative impact on bentonite in the wall and/or in the backfill which will lead to the increased porosity of the wall over time.

5.2 Steel Sheet Pile Wall

Cantilever sheet pile walls are constructed by driving prefabricated interlocking vertical sheets of steel into the soil, a few feet at a time, to the desired depth. Where hard or rocky soil is encountered, their depth of penetration is limited. The most common use of a sheet pile wall is to retain temporary excavations of moderate depth, but they can also be used as vertical barriers. Since the interlocking joints between the sheet piles are vulnerable to leakage, improved interlock designs to accommodate sealing of joints have been developed. In addition to different types of interlocking joints, a variety of sealants including grout, fly ash, and cement have been used to seal the joints. Patented innovative techniques, such as the Waterloo Barrier® (refer to Section 5.3), have also been developed to seal and test the joints between the sheet piles.

The advantages and disadvantages of a conventional sheet pile vertical barrier have been summarized in Table 5-1. One major disadvantage is that the steel piling corrodes, which limits its effectiveness for long-term containment, and may actually provide a preferred pathway for the vertical migration of contaminants into the interbedded sands as it corrodes. Another major disadvantage is that it is sometimes difficult to keep the sheets in perfect vertical alignment while driving, and, as a result, the interlock configuration may be compromised. Sealants, therefore, which are applied before the sheets are driven are subject to being stripped off or damaged, and sealants which are injected into the interlocking joints after the sheets are driven may not fill joints which have become separated. Additional interlock

Table 5-1
Advantages and Disadvantages of Vertical Barrier Systems

Vertical Barrier	Advantages	Disadvantages
Soil-based Slurry Wall	• Construction techniques well understood, practiced, and accepted • Installed to depths of up to 200 feet • Can be installed quickly on land	• Installation requires excavation and a mixing area • Substantial quantities of spoils must be disposed of • Very low strength, cannot accommodate structural loading • Porosity may increase over time due to contaminants in soil and groundwater • Wet/dry and freeze/thaw cycles can cause desiccation which could lead to increased permeability of wall
Cement-based Slurry Wall	• Construction techniques well understood, practiced, and accepted • Can be installed quickly on land • Much stronger than soil-based slurry walls • Self-hardening slurries do not require backfill, so walls can be constructed in limited access areas and at a lower cost • Little to no slurry displaced	• Only moderately strong, cannot accommodate large structural loading as steel sheet piling • Difficult to ensure panel continuity • Higher permeability than soil-based slurry walls • Porosity may increase over time due to contaminants in soil and groundwater • Cement subject to degradation in saltwater environment • Cracking due to shrinkage, thermal stress, and wet/dry cycling could lead to increased permeability of wall
Steel Sheet Pile Wall	• Installation procedures are well established • Excavation is not required • High strength • Chemically resistant • Able to construct irregularly shaped barriers in confined area	• More expensive than slurry walls • Limited depth of penetration • Steel corrodes which would create preferred pathway for the horizontal, and possibly vertical, migration of contaminants • Interlocking joints leak • Interlocking joints may separate during installation • Interlocking joints may separate due to structural loads on the wall which create significant bending moments • Integrity of sealant cannot be confirmed once driven

Table 5-1 (cont'd)

Vertical Barrier	Advantages	Disadvantages
Waterloo Barrier®	• Excavation is not required • Able to construct irregularly shaped barriers in confined area • Installation uses same equipment as conventional sheet piling • Chemically resistant • Sealable interlocking joints which provide an effective barrier • Video inspection of joints ensures quality of seal • Joint separation or blockage can be repaired • Cost compares well with conventional sheet pile wall	• Limited strength compared to conventional sheet piling • Limited depth of penetration • Steel corrodes which would create preferred pathway for the horizontal, and possibly vertical, migration of contaminants • Interlocking joints may separate due to structural loads on the wall which create significant bending moments
Vinyl Sheet Pile Wall	• Does not corrode • Chemically resistant • Vinyl has a long design life and low permeability • Excavation is not required	• Very low strength • Difficult to install in dense soils • Interlocking joints leak • Interlocking joints may separate during installation • Integrity of sealant cannot be confirmed once driven • Hydrophilic, urethane-based sealant has limited resistance to chlorinated hydrocarbons, which includes PCBs, and will not swell to seal joints if above water table
GSE GundWall®	• Does not corrode • Durable and chemically resistant • HDPE has a long design life and low permeability • Easy to install • Excavation is not required • Sealable interlocking joints • Integrity of the sealed interlocks can potentially be verified after installation	• Depth limitation of 20 feet with vibratory installation • Can be inserted into a slurry wall or vibrated into loose to medium dense, non-cohesive soils only • Chloroprene-based sealant has poor resistance to chlorinated hydrocarbons, which includes PCBs

Table 5-2
Vertical Barrier Short-term System Permeability and Design Life

Vertical Barrier	Short-term System Permeability	Estimated Design Life
Soil-based Slurry Wall	10^{-7} to 10^{-9} cm/sec(1)	up to 30 yrs
Cement-based Slurry Wall	10^{-5} to 10^{-6} cm/sec(1)	up to 30 yrs
Steel Sheet Pile Wall	10^{-4} to 10^{-5} cm/sec(2)	up to 30 yrs
Waterloo Barrier®	10^{-8} to 10^{-10} cm/sec(3)	up to 30 yrs
Vinyl Sheet Pile Wall	10^{-5} to 10^{-6} cm/sec(4)	vinyl sheet pile wall: up to 100 yrs(4) wales and tie-backs: limited urethane sealant: unknown
GSE GundWall®	10^{-9} to 10^{-10} cm/sec(5)	HDPE geomembrane: 100 to 200 yrs HyperTite™ sealant: unknown

Notes:
1. Pearlman, Leslie (1999)
2. standard for unsealed steel sheet piling
3. Smyth, David et al (1997)
4. based on manufacturer's data
5. based on permeability of welded HDPE with limited quality control

separation, which could occur if the wall is subjected to structural loading or is being used to act as a structural support of adjacent soils, would compromise the integrity of the seal.

The estimated design life as well as the short-term permeability of the sheet pile wall system, which is governed by rate of flow through the interlocking joints, are provided in Table 5-2. The short-term system permeability takes into account the problems associated with sealing the interlocking joints. Long-term permeability is not easily quantified since the system will no longer serve as a barrier once the steel has corroded.

5.3 Waterloo Barrier®

Private companies such as Waterloo Barrier, Inc. have successfully adapted the general sealable sheet pile wall for containment uses. With the Waterloo Barrier®, Waterloo Barrier, Inc. has developed a unique method of sealing and testing the joints between the sheet piles to reduce the overall system permeability, which has been a problem in the past. Installation involves driving sheet piles into the ground, flushing the interlocking joint cavity to remove soil and debris, and injecting sealant into the joints. Depending on site conditions, the cavity may be sealed with a variety of materials including clay-based, cementitious, polymer, or mechanical sealants Video inspection of the joint cavity prior to sealing ensures that the joint can be sealed.

The advantages and disadvantages of a Waterloo Barrier® have been summarized in Table 5-1. As with the conventional steel sheet pile wall, the major disadvantage is that the steel piling corrodes, which limits its effectiveness for long-term containment, and may actually provide a preferred pathway for the vertical migration of contaminants into the interbedded sands as it corrodes. Another disadvantage is that the section modulus of the heaviest Waterloo Barrier® sheeting is lower than that of conventional steel sheeting. The major advantage of the Waterloo Barrier® is the ability to seal the joints. Video inspection of each joint cavity prior to sealing provides a level of construction quality control and ensures that the joint can be sealed. If the joint cannot be sealed, repair procedures, which may include pulling sheets, will be required. Interlock separation, which could occur if the wall is subjected to structural loading or is being used to act as a structural support of adjacent soils, would compromise the integrity of the seal.

The estimated design life as well as the short-term permeability of the Waterloo Barrier® system, which is governed by rate of flow through the interlock sealant, are provided in Table 5-2. As with conventional sheeting, long-term permeability is not easily quantified since the system will no longer serve as a barrier once the steel has corroded.

5.4 Vinyl Sheet Pile Wall

Vinyl sheet pile walls are constructed by driving prefabricated interlocking Z-shaped vertical sheets of rigid polymer into the soil, using conventional vibratory equipment, to the desired depth. They are used as an alternative to steel sheet pile walls for a variety of waterfront projects, such as seawalls and bulkheads, where corrosion is an issue and where structural requirements are less. A vinyl sheet pile wall generally consists of vinyl sheet piles driven into loose or medium dense granular soil, bolted to front and back bracing wales, tied back to anchors, backfilled, and capped with wood or concrete. The long-term allowable moment reported by the manufacturer must be used when determining the strength capabilities of vinyl sheet piling as the material tends to creep over time. Vinyl sheet pile walls can accommodate only short-term increases in hydrostatic loads due to rainfall or tidal changes, and a drainage system, such as a series of weep holes, is usually installed to minimize hydrostatic loads. As with steel sheet pile walls, the interlocking joints are vulnerable to leakage and hydrophilic sealants made from polymeric rubber, such as urethane, can be applied to seal the joints.

The advantages and disadvantages of a vinyl sheet pile vertical barrier have been summarized in Table 5-1. One major disadvantage is that the vinyl has a very low strength and cannot be used in a structural application where the wall may be subjected to moderate static or hydrostatic loads. If subjected to such loading, the wall may fail and/or the interlocking joints may become separated. Another major disadvantage is that it is sometimes difficult to keep the sheets in perfect vertical alignment while driving, and, as a result, the interlock configuration may be compromised (i.e., the interlocking joints may become separated). Therefore, sealants which are applied before the sheets are driven are subject to being stripped off or damaged, and sealants which are injected into the interlocking joints after the sheets are driven may not fill joints which have become separated.

The estimated design life as well as the short-term permeability of the system, which is governed by rate of flow through the interlocking joints, are provided in Table 5-2. The short-term system permeability takes into account the problems associated with sealing the interlocking joints. This permeability will increase if the wall is subjected to structural loading and the interlocking joints become separated. The long-term permeability of the system, which is governed by rate of flow through the interlocking joints as the vinyl material creeps or flows due to constant loading over time, may be one to two orders of magnitude higher than the short-term permeability.

5.5 GSE GundWall®

The GSE GundWall® is a geomembrane vertical barrier constructed of interlocking HDPE panels. It is designed to prevent or deflect the flow of underground containment plumes, subsurface water flow, and other subsurface liquid transport. The HDPE geomembrane used for the vertical panels is available in thicknesses ranging from 80 to 120 mil (2.0 to 3.0 mm) and includes mechanical interlocks permanently attached to the vertical edges of the geomembrane panel. The GSE GundWall® interlock configuration (refer to Figure 5-1) allows for panels to be inserted into a slurry wall or vibrated into place using an insertion plate in loose to medium dense, non-cohesive soils without prior excavation. Panels are installed to the depth of an aquitard, or naturally impermeable, cohesive soil layer. Once inserted into this layer, the migration of fluids is theoretically blocked both laterally and vertically.

The GSE GundWall® interlock consists of male and female HDPE profiles which are fusion welded to the HDPE panel at the factory. The interlock is tight and creates a mechanical seal by compressing an 8-mm extruded, hydrophilic gasket into a 6-mm key cavity at the time of installation. The chloroprene-based hydrophilic rubber gasket, called HyperTite™, swells up to five times its dry volume when exposed to water. Because the HyperTite™ gasket is installed in one continuous section as the interlocks are joined, the seal can be monitored for continuity as it is vibrated into the ground. In addition, GSE offers an optional procedure for electrical confirmation, assuring full-length makeup of the joint once installed.

The advantages and disadvantages of the GSE GundWall® have been summarized in Table 5-1. The major advantages are as follows: (1) HDPE will not corrode and is extremely resistant to chemical attack, which theoretically provides the GundWall® with a long service life; (2) HDPE provides the GundWall® with a low permeability; and (3) the integrity of the sealed interlocks can potentially be verified after installation. One major disadvantage is that the chloroprene-based rubber HyperTite™ gasket has poor resistance to chlorinated hydrocarbons, which includes PCBs. Another potential disadvantage is that the GundWall® can be installed to a depth no greater than 20 feet, which may not allow for sufficient keying into an aquitard at certain sites.

The estimated design life as well as the short-term permeability of the system, which is governed by rate of flow through the geomembrane and interlock sealant, are provided in Table 5-2. The long-term permeability of the system, which is governed by rate of flow through the interlocking joints after the sealant has deteriorated, may be two orders of magnitude higher than the short-term permeability.

6.0 APPLICATIONS OF VERTICAL LINERS FOR CDF C

The following subsections discuss applications of vertical barrier systems, and combinations of vertical barrier systems, to provide a synthetic impermeable liner for CDF C.

6.1 Steel Sheet Pile Wall with Welded I Sections and Geomembrane Liner

One option is to weld steel I sections onto every other sheet at the top and at the mean high water level, insert steel or plywood sheets to create a continuous and generally flat surface, and then fill the channels formed by pairs of sheets with a clay-cement-bentonite slurry. A geomembrane would then be used to line the steel or plywood sheets by laying HDPE panels against the flat sheets, weighting them so that they would key into the organic clay, and attaching them at the top of the steel sheet piles. Installation of the flat steel or plywood sheeting through the fabricated I sections could prove difficult if the sheet piles are out of alignment. Another disadvantage of this option is that the HDPE panels would have to be welded together after being installed, which would likely be difficult since portions of the HDPE would be underwater. In addition, there is no way to ensure that the weighted HDPE panels would drop vertically and lay flat against the steel or plywood sheets and be keyed into the organic clay. If the HDPE panels do not lay flat, the stresses on the geomembrane at the interface of the dredged sediment and the HDPE panels once the CDF has been filled may result in failure of the liner.

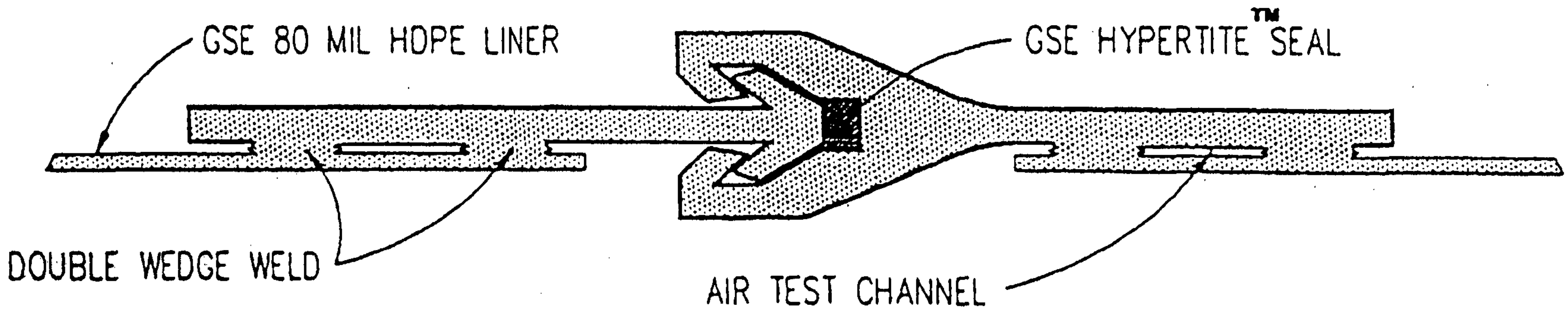


FIGURE 5-1

NEW BEDFORD, MASSACHUSETTS
CONFINED DISPOSAL FACILITY C

GSE GUNDWALL®
INTERLOCK

NOT TO SCALE

Lining flat sheets of steel or plywood also presents problems. The disadvantage of lining flat steel sheets is that the geomembrane would be in direct contact with the sharp edges of the corroding steel which would lead to tears and holes in the liner, compromising its integrity. The disadvantages of lining flat plywood sheets is that: (1) the plywood would tend to float and would have to somehow be weighted; and (2) the wood would decompose over time and the geomembrane would be left to stand vertically unsupported which is not possible (i.e., it would slump and wrinkle). In addition, placing the geomembrane across the I sections could puncture the liner as it is being, or once it has been, installed. Because of these disadvantages, the system would not serve as an effective liner.

6.2 Steel Sheet Pile Wall with Plywood Templates and Geomembrane Liner

A second option would be to construct plywood templates to fit in the channels formed by pairs of steel sheet piles so that a continuous flat surface is created, place weighted panels of HDPE geomembrane across the steel sheet piles and plywood templates, and fix the top of the geomembrane to the tops of the steel sheet piles. A major disadvantage of this option is that these HDPE panels would have to be welded together after being installed, which would likely be difficult since portions of the HDPE would be underwater. In addition, there is no way to ensure that the weighted HDPE panels would drop vertically and lay flat against the plywood templates and steel sheet piles. If the HDPE panels do not lay flat, the stresses on the geomembrane at the interface of the dredged sediment and the HDPE panels once the CDF has been filled may result in failure of the liner. Another disadvantage is that the geomembrane would be in direct contact with the sharp edges of the corroding steel which would lead to tears and holes in the liner, compromising its integrity. In addition, the plywood would decompose over time and, in combination with the corroding steel, the geomembrane would be left to stand vertically unsupported which is not possible (i.e., it would slump and wrinkle). Because of these disadvantages, the system would not serve as an effective liner. The constructablity issues associated with this option, including forming the plywood templates, weighting the HDPE geomembrane, and attaching the HDPE to the tops of the steel sheets, also serve to make this option both difficult and costly.

6.3 Vinyl Sheet Pile Wall

A third option would be to install a continuous vinyl sheet pile wall two to three feet in front of, and anchored to, the structural steel sheet piling. If the interlocking joints could be successfully sealed, then the short-term permeability could theoretically be as low as 10^{-7} cm/sec. One major disadvantage of this option is that there would be no way to ensure the integrity of the seals and, as such, the system permeability would likely be well above 10^{-7} cm/sec. In addition, the hydrophilic urethane-based sealant would not effectively swell in those portions of the interlocking joints above the mean high tide. The interlocks would, therefore, not be sealed and the system permeability would again be well above 10^{-7} cm/sec. The disadvantage that makes this option completely infeasible is the low strength of the vinyl material. The static and hydrostatic forces exerted upon the vinyl sheet pile wall once the CDF is filled, and a temporary cap and surcharge have been applied, would be so great that the vinyl would fail and the wall would no longer serve as an effective liner.

In an attempt to mitigate this failure, the two- to three-foot space between the vinyl and steel sheet pile walls could be filled with a clay-cement-bentonite slurry. An added benefit of this slurry wall would be its low permeability, which would be on the order of 10^{-7} to 10^{-9} cm/sec, depending on the clay content and cement mix used. Since the wall could not withstand the loading applied by this slurry, the filling would have to be done in stages, each time allowing the cement to cure. The cold joints resulting from this staged filling, however, would contribute to the increased permeability of the slurry wall. In addition, the bending moment exerted on the vinyl sheet pile wall once the CDF is filled, and a temporary cap and surcharge have been applied, would be so great that the vinyl sheet pile wall would either fail or deflect so much that the clay-cement-bentonite slurry wall would crack. As the cracks propagated towards the steel sheet pile wall, the system would no longer serve as an effective liner.

6.4 Two Steel Sheet Pile Walls with Clay-Cement-Bentonite Slurry Backfill

A fourth option would be to install two rows of steel sheet piling spaced roughly three feet apart, and fill the space between the two rows with a clay-cement-bentonite slurry. The slurry wall would be keyed into the organic clay and would have a permeability of 10^{-7} to 10^{-9} cm/sec, depending on the clay content and the cement mix used. As an advantage, the slurry wall would be strong and could potentially have a long design life. It, however, would be subject to degradation in a relatively saltwater environment, depending on the cement content. The saltwater could also have a negative impact on the bentonite in the wall which would lead to its increased porosity over time. The structural loading of the steel sheet piling and the resultant deflections of the walls could also be a possible disadvantage. The bending moment exerted on the exterior sheet pile wall by the embankment would cause it to deflect inward; and the bending moment exerted on the interior wall once the CDF is filled, and a temporary cap and surcharge have been applied, would cause the wall to deflect outward. These deflections could lead to the cracking of the clay-cement-bentonite slurry wall. Shrinkage, thermal stress, and wet/dry cycling could also lead to cracking. As the cracks became continuous between the two steel sheet pile walls, the system would no longer serve as an effective liner.

6.5 Two Steel Sheet Pile Walls with Clay-Bentonite Slurry Backfill

A fifth option would be to install two rows of steel sheet piling spaced roughly three feet apart, and fill the space between the two rows with a clay-bentonite slurry. The slurry wall would be keyed into the organic clay and would have a permeability of 10^{-7} to 10^{-9} cm/sec, depending on the clay content. Although a clay-bentonite slurry wall would be less likely to crack as a result of the structural loading of the steel sheet piling and the resultant deflections of the walls, it would not be as strong as a clay-cement-bentonite slurry wall. Desiccation above the water table could lead to cracking, and as the cracks became continuous between the two steel sheet pile walls, the system would no longer serve as an effective liner. As with the clay-cement-bentonite slurry wall, the saltwater could also have a negative impact on bentonite in the wall which would lead to its increased porosity over time.

6.6 Clay-Cement-Bentonite Slurry Wall in Embankment

A sixth option would be to install a clay-cement-bentonite slurry wall into the embankment, adjacent to the steel sheet pile wall. This would theoretically provide an effective low permeability vertical barrier if it could be keyed into an aquitard (i.e., the organic clay). Since the organic clay was removed to provide a firm foundation for the embankment, this keying of the slurry wall into an aquitard is not possible. A second disadvantage of this option is that the crest of the embankment would have to be wide enough to accommodate slurry trenching equipment, which would make the construction of the embankment costly and difficult as the mudline drops to an elevation of -20 feet NGVD at the midpoint of the channel. A third possible disadvantage is that the deflection of the steel sheet pile wall, which would occur once the CDF is filled, and a temporary cap and surcharge have been applied, may present structural difficulties when considering the lower strength of the slurry wall. The strength and section modulus of the steel sheeting may have to be increased to maintain the structural integrity of the system. This increase in the structural requirements of the steel may result in a cost prohibitive and/or possibly structurally unachievable liner system. In addition, as mentioned previously, saltwater could also have a negative impact on bentonite in the wall which would lead to its increased porosity over time. Because of these disadvantages, the system would not serve as an effective liner.

6.7 GundWall® in Embankment

A seventh option would be to install a GundWall® 20 feet into the embankment, parallel to, and outside of, the steel sheet pile wall. This would theoretically provide an effective low permeability vertical barrier if it could be keyed into an aquitard (i.e., the organic clay). Since the organic clay was removed to provide a firm foundation for the embankment, this keying of the GundWall® into an aquitard is not possible. The preferred pathway for the migration of contamination would be through the interlocking joints of the steel sheet pile wall, into the embankment fill, beneath the GundWall®, and out into the harbor. This option would, therefore, not serve as an effective liner.

6.8 GundWall® in Slurry Backfill between Two Steel Sheet Pile Walls

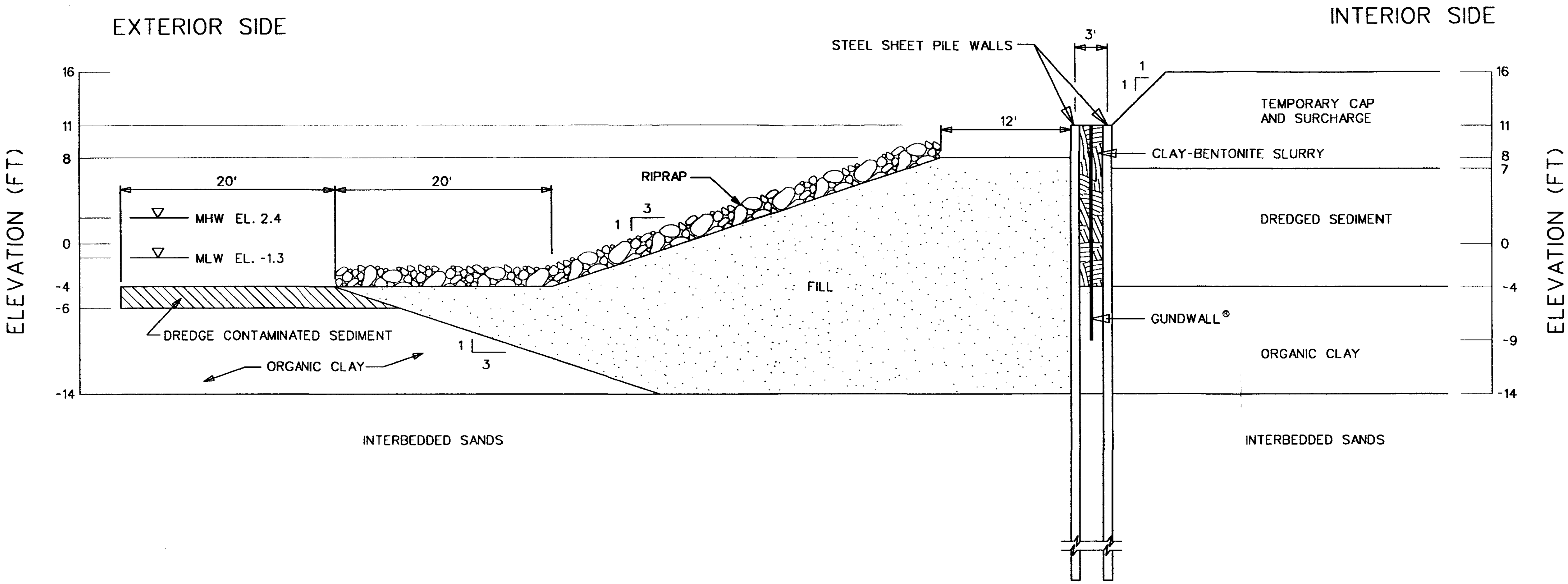
An eighth option would be to install two rows of steel sheet piling spaced roughly three feet apart, pump a slurry backfill into the space between the two rows, and install a GundWall® into the slurry wall to form a composite wall and provide an added level of protection. Both the slurry wall and GundWall® would be keyed into the organic clay and would provide a system permeability as low as 10^{-10} cm/sec. Since cement in the slurry wall could prohibit the installation of the GundWall®, a clay-bentonite mixture would be used. A high clay content in the mixture would cause the slurry wall to act as a barrier in itself, and would potentially limit the amount of PCBs migrating to the GundWall® and degrading the interlock sealant. Note, however, that the saltwater could change the structure of the bentonite clay particles, slightly increasing the porosity of the barrier. Because of the absence of cement, cracking of the slurry wall due to the structural loading of the steel sheet piling and the resultant deflections of the walls is less likely. Any cracks that formed as a result of desiccation, however, would provide a preferred pathway for the migration of contaminants from the interior steel sheet pile wall to the GundWall®. Another possible disadvantage may result from the corrosion of the steel sheet pile wall installed next to the contaminated dredged sediment. Since structural requirements dictate that the steel sheeting be driven through the organic clay into the underlying interbedded sands, corrosion of the steel could perhaps provide a preferred pathway for the vertical migration of contaminants into this sand layer. And although PCB-contaminated leachate reaching the GundWall® could, over time, degrade the chloroprene-based rubber HyperTite™ gasket, flow through the interlocking joints, and eventually out into the harbor, this option appears to provide the vertical barrier with the lowest system permeability and longest design life. Because this option most closely meets the liner requirements specified in the ROD and the Massachusetts Solid Waste Management Regulations, it is recommended as the preferred liner system.

7.0 CDF C CONSTRUCTION AND INSTALLATION OF PREFERRED LINER SYSTEM

The construction of CDF C and the installation of the preferred liner system, presented as the eighth option, are described below. In addition, a schematic diagram has been included as Figure 7-1.

Step 1: Two rows of cantilever steel sheet piles, spaced three feet apart, will be driven from barges offshore using falsework templates to keep the sheets aligned and vertical. The steel sheets will be 45-feet-long PZ35 sections, installed to a bottom elevation of -34 NGVD. The top of the sheets will be at elevation 11 NGVD. The alignment of these two rows of offshore sheet piling will be approximately 1,360 linear feet.

Step 2: An area of approximately 2.7 acres of contaminated sediment from the outboard side of the steel sheets will be hydraulically dredged to a depth of two feet. This will result in 8,900 cubic yards of dredged sediment being pumped to the hot spot cell for temporary storage. The majority of



NOTE:
ELEVATIONS ARE IN FEET
AND REFER TO NATIONAL
GEODETIC VERTICAL DATUM (NGVD)

FIGURE 7-1

NEW BEDFORD, MASSACHUSETTS
CONFINED DISPOSAL FACILITY C

CDF C WITH PREFERRED
LINER SYSTEM

NOT TO SCALE | 17FC101F.DGN

this sediment will be dredged from the footprint of the earthen embankment constructed to support the steel sheeting. Just over 20% of the 8,900 cubic yards of sediment will be dredged 20 feet beyond the toe of the embankment in the event a mudwave were to occur during the construction of that portion of the embankment overlying soft soil. If this additional dredging were not performed, and a mudwave were to occur, it would result in the mixing of contaminated sediment with clean sediment, which could result in the need for dredging to depths greater than two feet below the mudline to assure that all of the contaminated sediment is removed.

Step 3: An additional 20,200 cubic yards of "clean" organic clay, containing varying amounts of fine to medium sand and shell fragments, will be excavated from the footprint of the embankment to provide a generally firm foundation on which to construct. This "clean" organic clay will have PCB concentrations less than the target cleanup level of 10 ppm, and will be mechanically dewatered. For estimating purposes, it is assumed that the excavated organic clay will have a PCB concentration of at least 2 ppm, and will require out-of-state disposal at a Subtitle D facility.

Step 4: Approximately 2,300 cubic yards of clay-bentonite slurry will be mixed onshore and pumped into the slot formed by the two rows of steel sheeting. It is possible that the clay from the dewatered dredged sediment could be reused in the slurry mixture.

Note: A loose, clean sand would not be placed into this slot, as it is possible that the sand could densify when the GundWall® is vibrated in. This may mean that the GundWall® would not fully penetrate and, as such, could not be keyed into the organic clay layer. Densification of the sand fill may also cause the steel sheeting to come out of alignment.

Note: Excavated sediment could not be directly placed into this slot, since the material would need to be raked and screened, the sand would need to be separated out, and the water content may need to be reduced. Also, the addition of bentonite to the clay is beneficial because it swells and lowers the overall permeability of the mixture.

Step 5: A GundWall® will be vibrated into the clay-bentonite slurry using an insertion plate from a barge offshore. The GundWall® will be 20-feet-long and keyed into the organic clay approximately 5 feet, or to bottom elevation of -9 NGVD. The alignment of this geomembrane will extend over the full length of the offshore sheet piling, approximately 1,360 linear feet.

Step 6: An embankment to support the sheet pile walls of the CDF will be built from a foundation elevation of approximately -14 NGVD to a crest elevation of 8 NGVD. The crest will have a width of 12 feet to accommodate earthmoving equipment. The design of the embankment is such that it will support the CDF in the long-term condition, after the steel sheet pile walls have corroded.

Step 7: A cap may be installed over the clay-bentonite slurry wall to prevent desiccation. This detail is not included in Figure 7-1 or in the revised cost estimate summarized in Section 8.0.

8.0 REVISED COST

The cost estimate for the double sheet pile wall with exterior half dike, selected as a result of the alternatives and value engineering evaluations, has been revised and updated to include the preferred liner system.

- The disposal capacity of CDF C is has been reduced to an estimate of 84,440 cubic yards based on the current configuration. The original disposal capacity was approximately 95,000 cubic yards. From that number, 8,900 cubic yards is used for the disposal of contaminated dredged sediment. Another 1,660 cubic yards is lost due to the second row of steel sheet piles being installed in front of the first row.

- Construction cost has been increased from $11,339,000 to $13,044,000. Refer to Appendix A for a complete breakdown of this revised cost estimate.

- The cost per cubic yard of disposal volume has increased from approximately $113 to just over $154.

9.0 LEAKAGE RATES MODELING

9.1 Previous Evaluation of Leakage Rates

In preparation of this evaluation, Foster Wheeler reviewed historical documentation of leaching analyses from 1989 to 1997. The initial leakage investigation and analysis was conducted by the U.S. Army Corps of Engineers Waterways Experiment Station (WES). Figure 9-1(a) and 9-1(b) present the vertical and horizontal pathways considered for the release of contaminants from the CDFs. The pathway considered was essentially a vertical flow-through system, where contaminants are transferred from dredged sediment to the groundwater flowing through the soil.

The contaminant concentration contained in the sediment (C_o – initial concentration in the soil), and the rate at which it would "leach" from the soil to the water flowing through (K_d – soil/water partitioning coefficient) were estimated from batch and column leaching tests conducted as part of Feasibility Study Report #5 on composite samples of the upper estuary sediment.

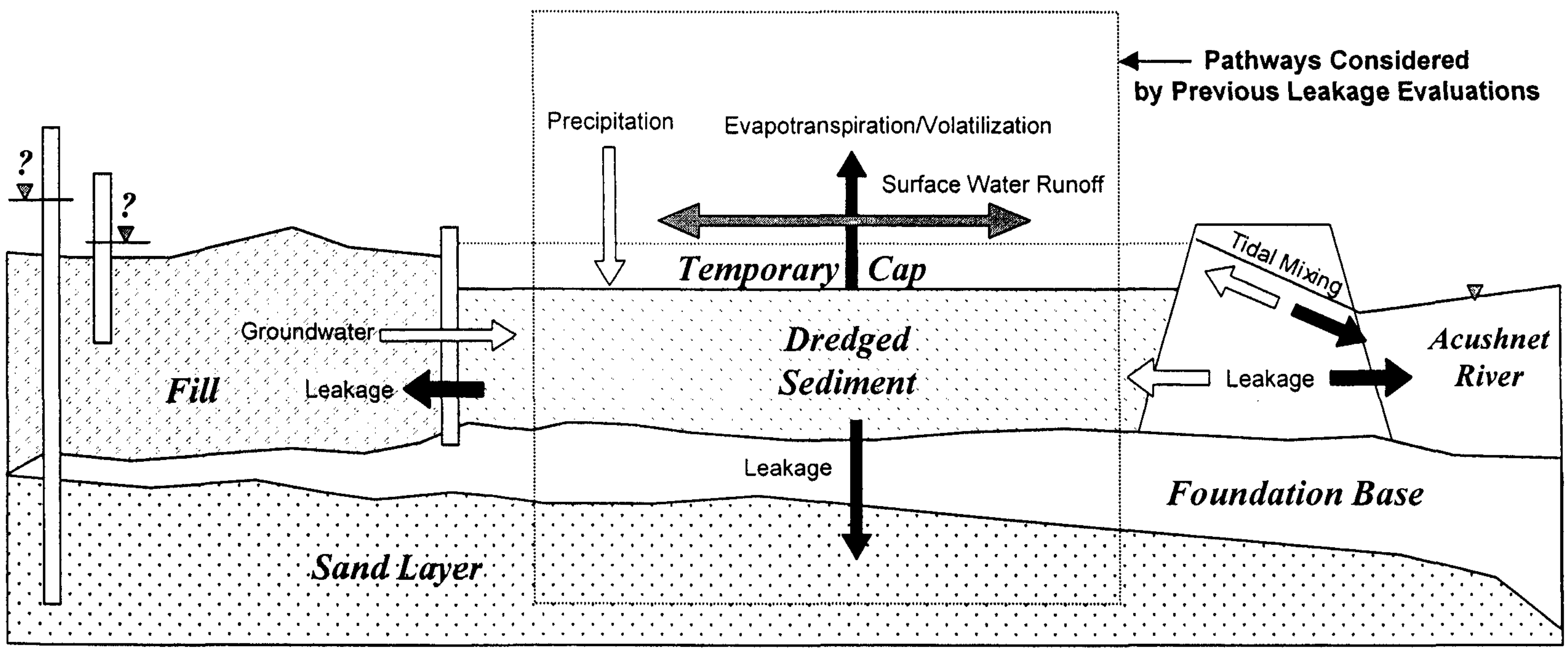
The critical pathway of release was qualitatively assumed as the loss of leachate from the contaminated sediment through the bottom of the facility. The liners at the sides of the CDF were considered to be "impermeable". Assuming an "impermeable" horizontal liner would imply that the leakage at the horizontal boundaries is negligible in comparison with that of the vertical boundary. Similarly, an "impermeable" horizontal boundary would imply that there is no additional water flow/infiltration from either the landside groundwater gradient and/or the shoreline tidal influences.

Since the first leakage rate evaluation in 1989, many of the original assumptions pertaining to the design and construction of the CDFs have changed. Accordingly, the assumptions were revisited over time as additional design information was developed, and the leakage rates were updated to reflect the new information. In general, two stages were typically considered for the adopted vertical flow-through system. The stages were based on short-term and long-term construction and operation scenarios for the CDFs.

1. Short-Term Filling & Consolidation Stage:

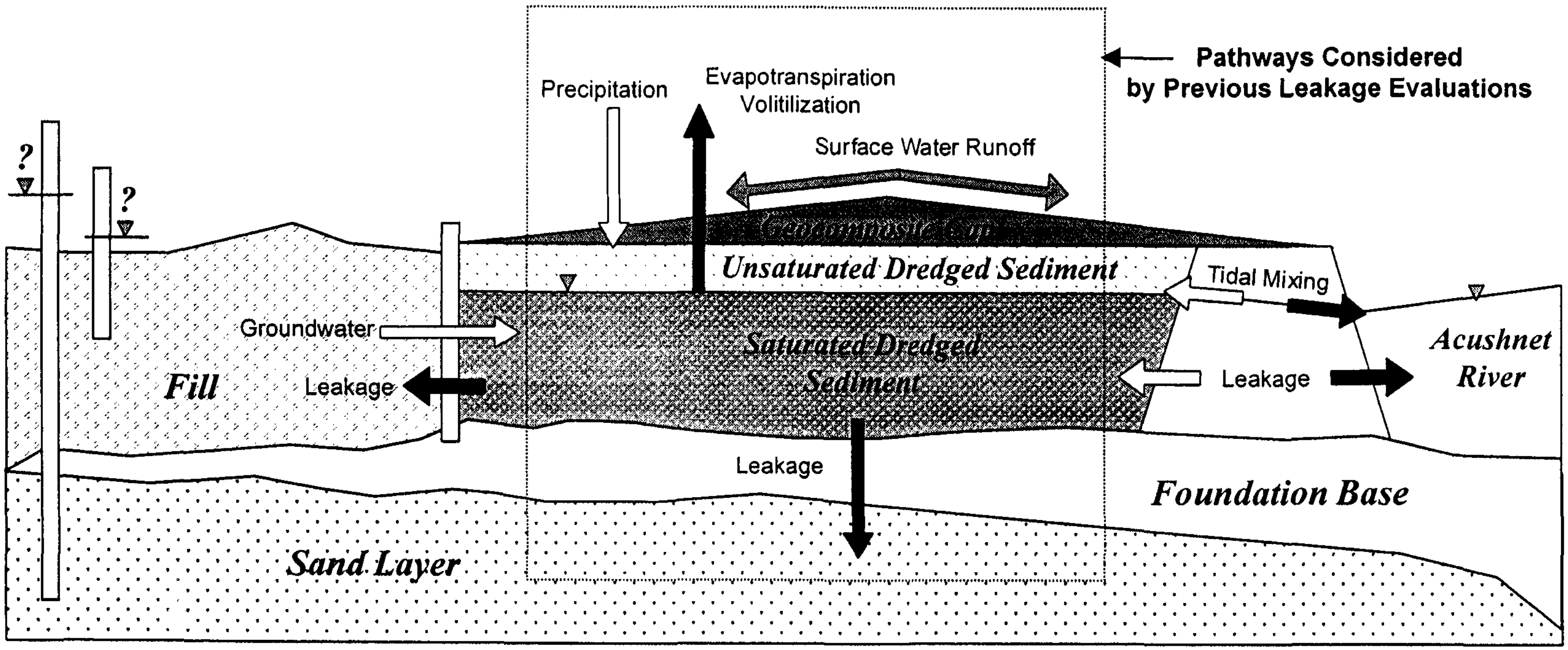
Dredged sediments were to be hydraulically pumped into the CDF and the solids in the dredged material would separate out from liquid by gravity. After filling the CDF, a temporary cap would be constructed and the sediments allowed to consolidate (i.e. the pore water would be "squeezed" out under the pressure of overlying material).

Figure 9-1 (a)



Pathways Considered for the CDF Filling & Consolidation Stage

Figure 9-1 (b)



Pathways Considered for the CDF Final Capped Stage

During this stage, vertical flow of contaminants was generated by two water sources:

- All pore water released from the dredged sediment during the consolidation process
- Precipitation and surface water entering the temporary cap

2. Long-Term Final Capped Stage

After the consolidation stage, the temporary cap would be removed and a geocomposite cap would be constructed to minimize infiltration of precipitation and surface water. The dredged material was assigned a reduced permeability that resulted from three years of consolidation. Long-term leakage rates were generally evaluated after 30 years from initial dredged sediments placement (some calculated up to 100 years)

9.2 Summary of HELPQ Leakage Rates

The most recent WES leakage rate investigation for CDF C was conducted in 1997. Permeability and settlement data was estimated using PSDDF - Primary Consolidation and Secondary Compression and Desiccation of Dredged Fill (Stark 1996). HELP - Hydrogeologic Evaluation of Leachate Production and HELPQ - Hydrogeologic Evaluation of Leachate Production and Quality (Schroeder and Aziz 1996) were used to estimate groundwater flow and corresponding mass transfer of contaminants. Limitations of the HELPQ analysis are discussed in Section 9.4. The following section reports the findings of previous investigations. Table 9-1 presents a general summary of the leakage rates, along with some pertinent changes in assumptions over time.

The following documents the latest evaluation of leakage rates (1997), using HELPQ and PSDDF, for CDF C. The CDF modeling assumed:

- Surface area covered by the CDF was 8.3 acres (361,050 ft^2 or 1340 feet by 270 feet)

- Placed 10 feet of dredged sediment over an existing 5-foot-thick foundation, allowing for consolidation in both the dredged sediment and foundation layer

- Soil properties of dredged sediment were identical to the foundation material

- Underlying the foundation layer was an incompressible sandy layer (thickness unspecified)

- Mean water table was assumed to be 3 feet above the foundation

- Two feet of clean dredged material was to be used as a temporary cap, augmenting the consolidation of the underlying dredged sediment and foundation

- The permeability of the dredged material and base of the CDF was estimated to change from 1.9×10^{-7} to 1.4×10^{-7} cm/sec after capping
- Dredged material was assumed to desiccate 90 days after the end of disposal operations (time of disposal operation was not specified)

- Three years after disposal, the CDF was capped with 2 feet of vegetated soil and a geosynthetic liner.

Table 9-1
General Summary of the Leakage Rate Evaluations

Parameter	Units	CDFs 1, 1B, 3, 12 1989	CDFs 1, 1B, and 12 1993	CDFs A,B,C,D 1997
Total CDF Surface Area	ft^2	2,400,000	1,500,000	1,800,000
Insitu Estuary Sediment Volume	yd^3	484,000	N/A	450,000
Total Percolation Through Bottom of CDFs 1-30 Years	in	23	N/A	37
PCB Leakage Rate at Year 1	kg	150 (years 1-10)	23	5.0
PCB Leakage Rate at Year 3	kg	N/A	4.3	5.1
PCB Leakage Rate at Year 5	kg	N/A	0.0018	2.6
PCB Leakage Rate at Year 20	kg	40 (years 10-30)	0.0108	0.1665
Total PCB Released Over 30 Years	kg	190	40	37
Total Copper Released Over 30 Years	kg	6	N/A	2.4
Leachate Concentration		Maximum Batch Leaching Concentrations	Maximum Batch Leaching Concentrations	Reduced Leachate Concentrations w/time
Hydraulic Conductivity Of Dredge Sediment	cm/s	$1.0x10^{-6}$ to $1.0x10^{-7}$	$6.5x10^{-7}$ to $1.0x10^{-7}$	$1.9x10^{-7}$ to $1.4 x10^{-7}$
Capping Times		Final Cap immediately after draining ponded water, 6 months after of disposal	Capped 2-3 years after filled with dredged material	3 years of temporary cap, 27 years of final cap
Base Boundary Condition		Free draining No resistance to flow	Free draining No resistance to flow	Underlain by sandy material, more permeable than sediment

9.2.1 Modeling Assumptions

Review of the WES modeling indicates that the following assumptions were made:

- Consolidation data used in PSDDF were obtained from the programs default database of soils, and correlated with leachate permeameter tests reported in Feasibility Study Report #5.

- Conservative parameters (not specified) were reportedly selected for drainage and evaporation processes in HELPQ model.

- Soil moisture retention used in HELPQ was selected to yield the same drainage of initial moisture content as the predicted settlement from PSDDF.

  "...settlement and porosity were set to initial conditions, and the field capacity was adjusted to yield the drainage from consolidation. The wilting point was then adjusted to yield appropriate unsaturated drainage properties."

  (Note: the difference between the soil field capacity and the wilting point give the water holding capacity that is available to plants. The field capacity can be thought of as a full soil moisture reservoir, while the wilting point can be thought of as an empty one.

- 10 feet of dredged sediment was divided into three layers

    1) Top 10 inches used to incorporate runoff, evapotranspiration, and infiltration
    2) Below 10 inches and above mean low water (MLW)
    3) Below MLW (3 feet)

9.2.2 Properties of Contaminants and Sediments

Physical and geochemical properties of contaminants and sediments used in the modeling were:

- Geoenvironmental properties of the critical contaminants were taken from Report #5 of the Feasibility Study based on batch and column leaching tests conducted on composite upper estuary samples

- Sediment contaminant concentrations (1500 mg/kg PCBs, 1730 mg/kg Cu, and 2013 mg/kg Pb) were based on the composite upper estuary sediment sample

- Leachate concentration (C_o) was (0.266 mg/l PCBs)

- Soil-water partitioning coefficient (K_d) was (4863 l/kg PCBs)

- All geotechnical properties of contaminated sediments placed in the CDF were assumed and quantitatively verified based on the column leaching tests conducted in Report #5 of the Feasibility Study (i.e., water content, void ratio, porosity, density, plasticity, permeability, consolidation properties)

- Select geotechnical properties of contaminated sediments placed in the CDF included the following:

    1) Liquid limit (LL) 94%, plasticity index (PI) 62%
    2) 23% sand, 77% fines
    3) Specific gravity was 2.4
    4) Void ratio was 3.4

9.3 Release of Contaminants From Solid Phase of Sediments

The release of contaminants from the solid phase of the soil sediment to the water flowing through is dependant on the estimated leaching concentration ($C_o \sim 0.266$ mg/l) defined by the soil/water partitioning coefficient ($K_d \sim 4863$ l/kg). It is important to note some of the findings presented in Report #5 of the Feasibility Study, especially when considering the salinity of the water coming in contact with the contaminated sediments and exposure to air.

- Additional findings of the report indicate that freshwater passed through the sediments resulted in a higher leachate concentration ($C_o \sim 0.327$ mg/l) and a lower partitioning coefficient (K_d was N/A) than saline water.

- It appears that the leachate concentration of 0.266 mg/l was selected from the aerobic batch leaching tests. Comparison of sediment concentrations (mg/kg) determined from aerobic tests exhibited lower PCB concentrations (mg/kg) than similar anaerobic tests. This was attributed to volatilization, which allowed the release of PCB during the aerobic tests.

Table 9-2 reports the results of the leakage rates for PCB from CDF C determined in 1997.

The results illustrate how the partitioning coefficient has been employed to linearly correspond with the rate of water percolation (how contaminants in the solid phase of sediment are transferred to the liquid phase). With this in mind, the flow of water exiting the base of the CDF is largely dependent on: (1) the pressure head of water acting on the base of the CDF (assumed to be 3 feet); (2) the infiltration of precipitation and (3) the surface water into the CDF passing through the cap; and the water content of the dredged sediment.

Water content will largely depend on the method of dredging and/or whether dewatering of the sediment is conducted before placement. Infiltration will have the greatest impact during the filling of the CDF and subsequent surcharge/temporary capping stages. Long-term infiltration should be reasonably reduced by a geocomposite capping system installed with adequate quality control. The pressure head acting on the base of the CDF is perhaps the greatest influence on the flow of water. Inherent in the assumption of a 3 feet head acting at the CDF base is a knowledge of the groundwater conditions in the sandy layer below the 5 feet foundation material. In the initial leakage evaluation in 1989, it is clear this was not known and, at that time, it was suggested that additional hydrogeological data and modeling would be required to confirm site-specific flow patterns and rates for the CDF sites. From the documentation reviewed to date, it is not clear whether the groundwater levels and hydrogeologic data used in the leakage evaluation accurately reflect the site-specific conditions at each CDF.

9.4 Limitations of HELPQ Leakage Rate Modeling

The software model HELP was initially developed for evaluating percolation of water through semi-permeable landfill caps. The HELP model is known as a water balance method which computes water movement across, into, through, and out of landfills using climatological, soil, and CDF/landfill design data. It evaluates runoff, drainage, and leachate generation by taking into account water entering and exiting the CDF/landfill (i.e. surface storage, runoff, infiltration, percolation, and evapotranspiration). The HELPQ model is similar to the HELP model, but incorporates contaminant characteristics to estimate leachate generation from waste.

To determine leaching rates from the CDF, HELPQ uses the contaminant concentrations and partitioning coefficients determined from batch and column leaching tests, and evaluates the leakage based on a mass balance. The mass of contaminants contained in the sediment is transported by the flow of water entering the CDF through the processes of infiltration, percolation, and evapotranspiration. Hence, when HELPQ balances water flow and equates a corresponding mass of contaminants with the flowrate, it is modeling advective transport.

Typically, contaminant transport through a saturated layer consists of two mechanisms: an advective (groundwater flow) component and a diffusive component (concentration flux of contaminants from high concentration to low concentration). In an advective/diffusive system it is commonly known that when advection is minimized, through a low permeable material, and/or negligible/opposing groundwater velocities, diffusion becomes the primary mechanism and can dominate the contaminant transport.

Considering the permeability of the dredged material, diffusion could play a role in the transport of contaminants from the CDF. The relative magnitude of diffusion to advection through the base of the CDF can be evaluated by the Peclet number:

$$P_e = k \cdot \frac{\partial h}{\partial z} \cdot \frac{t_i}{D_e}$$

Table 9-2
Leakage Rate of PCB from CDF C 1997 HELPQ Analysis

Calculated PCB Release (WES 1997)			Back Calculated Leachate Concentration (FWENC 2000)	
Time	Water Exiting CDF Base Calculated	PCB Mass	PCB	PCB
years	ft^3/yr	g/yr	ft^3/g	mg/l
1	168,600	1,090	154.7	0.228
2	168,800	1,091	154.7	0.228
3	173,600	1,123	154.6	0.228
4	106,000	685	154.7	0.228
5	85,200	551	154.6	0.228
6	72,000	465	154.8	0.228
7	68,700	444	154.7	0.228
8	64,700	419	154.4	0.229
9	61,000	395	154.4	0.229
10	57,400	371	154.7	0.228
11	44,500	288	154.5	0.229
12	6,600	42.9	153.8	0.230
13	5,800	37.4	155.1	0.228
14	5,000	32.3	154.8	0.228
16	4,100	26.7	153.6	0.230
18	3,700	24.1	153.5	0.230
20	3,400	21.9	155.3	0.227
25	2,800	18.1	154.7	0.228
30	2,200	14	157.1	0.225
35	2,200	14.1	156.0	0.226
40	2,300	14.9	154.4	0.229
50	2,200	14.1	156.0	0.226
60	2,200	14.1	156.0	0.226
80	2,200	14.1	156.0	0.226
100	2,100	13.5	155.6	0.227

P_e	Peclet Number
k	Hydraulic Conductivity (cm/sec)
t_i	Effective Thickness of Barrier Layer (cm)
D_e	Diffusion/Dispersion Coefficient (cm^2/sec)
$\partial h/\partial z$	Groundwater Gradient Across Barrier Layer (dimensionless)

If the magnitude of the Peclet Number is much greater than one ($P_e>>1$), then advective transport dominates over diffusion. Conversely, if the value is much less than one ($P_e<<1$) then diffusive transport dominates over advective. Peclet Numbers near unity (one) suggests a dual advective/diffusive system. Aqueous phase effective diffusion coefficients typically range from ~1 x 10^{-6} cm^2/s to ~1 x 10^{-5} cm^2/s for saturated soils. This range of D_e values is sufficiently narrow for many applications such that measurement of solute specific D_e values with specific soils may not be required to provide reasonable accuracy. For cases where there is a need for greater accuracy, several procedures are available for measuring D_e.

For a 3 feet groundwater head, acting on a 5 feet CDF foundation base, the Peclet Numbers estimated range from approximately 9.4 to 0.94, for a typical range of effective diffusion coefficients and a dredged sediment hydraulic conductivity of 1.4 x 10^{-7} cm/s. This implies there is potential, if the effective diffusion coefficient is at the upper range of typical values, that diffusion could result in additional flux of contaminants from the base of the CDF. This will largely depend on the assumptions of groundwater head elevation. For example, increasing the head of water acting on the base would suggest additional transport through advection.

9.5 Discussion of Previous Leakage Rate Investigations

The overall review of previous leakage rate investigations conveys a consistent reduction in the level of conservatism inherent in latter investigations. Closer examination of Table 9-1 reveals four significant changes in the assumptions used to evaluate the leakage rates.

1) Decrease in Hydraulic Conductivity

   The initial hydraulic conductivity of the placed dredged sediment was incrementally reduced in each subsequent leakage rate investigation. This is significant since the highest rates of contaminant loss occur during the first three years when both precipitation and surface water are allowed to infiltrate the CDF. Final permeability of the foundation layer was decreased slightly from the 1993 to 1997 leakage evaluations. Typically, the hydraulic conductivity of insitu soils can vary an order of magnitude and generally its sensitivity should be incorporated into the evaluation of clay barrier layers. Table 9-3 gives some recent evaluation of the permeability of dredged sediments and the corresponding effective stress.

   The results of the column consolidation tests suggest lower conductivity values would be expected for placement of a slurry-like dredged sediment. Dewatering of the dredged sediment, currently being evaluated, will alter the hydraulic conductivity properties of the dredged material to be placed in the CDF. The relative change will depend on the dewatering process itself.

2) Change from Constant Concentration to Finite Mass

   The 1997 modeling report (Otis M.J 1997) states that the concentration of contaminants in the dredged sediment was reduced over time (although when examining Table 9-2 it would seem that the concentration remains constant and the water flow reduced). Nevertheless, in contaminant transport terminology, this represents a finite mass of contaminants. Previous leakage investigations assumed a constant concentration of contaminants over time. The evaluation of contaminant transport using a constant concentration over time is typically viewed as a conservative assumption when representing the contaminant source. The choice of appropriate boundary conditions often represents a major source of uncertainty in practical applications involving contaminant transport modeling. In cases where the appropriate boundary condition is either unknown or is uncertain, prudence dictates the use of a conservative boundary condition. Therefore, it is recommended that a constant source be initially evaluated and, if necessary, a finite mass evaluation may be performed based on the change of contaminant concentration over time.

3) Change in Surface Area and Volume

   The change in surface area and volume has been incorporated incrementally with each HELPQ modeling as the CDF sizes were changed. In the latest leakage evaluation, it was reported that "despite greater water flow through the base of the CDFs from the 1997 evaluation, the 1989 fluxes were greater by 5.2 for PCBs and 2.5 for Copper". A third of the "greater" was attributed to the differences in surface area and volume from 1997 and 1989. The rest was attributed to the change in source sediment concentrations from a constant source to a finite mass, as outlined above.

Table 9-3
Various Permeability Testing on Dredged Organic Sediment

Tests	Effective Stress (psf)	Hydraulic Conductivity (cm/s)
Average of Column Consolidation	20.6	6.10×10^{-4}
(Soil Technologies)	49.5	5.63×10^{-5}
- Soil tested contained no particles greater than the	101.15	2.07×10^{-6}
#200 sieve (i.e. no sand)	209.9	1.71×10^{-6}
	419	6.34×10^{-7}
Average Of Oedometer Tests Conducted	120	6.24×10^{-7}
On Samples from Column Consolidation	260	2.67×10^{-7}
(Soil Technologies)	500	3.07×10^{-7}
- Soil tested contained no particles greater than the	1000	6.64×10^{-8}
#200 sieve (i.e. no sand)	2000	5.62×10^{-8}
	4000	2.72×10^{-8}
	8000	2.31×10^{-8}
	16000	6.78×10^{-9}
Insitu Borehole Permeability Testing (Foster Wheeler 2000)	~ 87	1.05×10^{-3} to 1.46×10^{-6}
Laboratory Flexible Wall Permeability Testing (Foster Wheeler 2000)	720	3.3×10^{-7}

4) Change in Bottom Boundary Conditions

Another potentially significant assumption which changed from 1989 to 1997 (Otis M.J 1997), was the properties of the material underlying the 5 feet base foundation layer. Initially it was assumed to be free draining and infinitely permeable. This condition was later changed to reflect a more site specific sandy layer with a higher permeability than the foundation layer (layer thickness and exact conductivity not reported). While this suggests a more representative layering system, the influence of the sand layer is largely dependent on the local groundwater gradients.

9.6 Future Considerations

The following considerations should be addressed in any future CDF leakage rates modeling:

- The review of the leakage evaluation suggests that the allowable leakage rates from the horizontal boundaries (slurry wall, vinyl sheeting, etc.) be negligible with respect to the vertical boundary (clay foundation base). Vertical barriers should be modeled if it is desired to confirm this quantitatively.

- Vertical and horizontal groundwater gradients, along with respective hydraulic conductivities, should be verified from current documentation to verify the assumed hydrogeologic conditions at each CDF.

- The use of the HELPQ model assumes that the contaminants are transported by advection, in the absence of diffusion. This assumption is largely dependent on the assumed soil permeabilities and groundwater gradients and should be quantified and documented.

- Changes in source contamination (i.e., dredged sediment water content, density, void ratio) can significantly impact the leakage rates and their impact on contaminant transport should be evaluated.

10.0 CONCLUSIONS

The current design configuration of CDF C, a sheet pile wall supported by an earthen embankment, results in the necessity to implement a vertical liner system, not typically employed for permanent, or even long-term, containment. Based on preliminary design calculations and analyses as summarized in this Memorandum, the liner system will consist of two rows of steel sheet piling filled with a clay-bentonite slurry into which interlocking HDPE geomembrane panels will be inserted. This composite liner system most closely meets the intent of the ROD, which specifies the use of a "synthetic impermeable material" to line the sidewalls of the CDF, and the substantive requirements of the Massachusetts Solid Waste Management Regulations. Although PCB-contaminated leachate reaching the HDPE geomembrane vertical liner could slowly degrade the chloroprene-based gaskets used to seal the interlocking joints, and the flow through the joints would increase over time, this option appears to provide the vertical barrier with the lowest system permeability and longest design life. These assumptions, however, cannot be verified with actual data, as none appears to exist.

The leakage rate evaluations conducted by WES address only the vertical flow through the CDF. Horizontal flow into and out of the CDF was not accounted for in the model. In addition, the HELPQ model assumes that the contaminants are transported by advection only. The transport of contaminants by diffusion, which is an important component in estimating contaminant transport for long-term applications (in excess of 30 years), was not considered. Other modeling assumptions which have significantly changed based on current information require further evaluation. Changes in the properties of the dredged sediment due to mechanical dewatering, in particular, should be evaluated to determine their impact on contaminant transport, or leakage rates.

11.0 REFERENCES

11.1 Vertical Barriers

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11.2 PCB Leakage Rates Modeling

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Appendix A

Revised Cost Estimate

FOSTER WHEELER ENVIRONMENTAL

New Bedford Harbor - CDF C

Revised by Erin Griffin 7/25/00

Sheet sheets with half dike option						
	Quantity		Unit Rate	Total	Duration	SUBTOTALS
Mobilization				$169,000		
Drive Sheets	122,400	sf	$27.00	$3,304,800	5	
Pre-Dredge Contaminated	8,900	cy	$111.03	$988,156	1	
Excavate Organic Clay	20,200	cy	$150.77	$3,045,654	1.25	
Fill Below Water	33,300	cy	$37.80	$1,258,881	2.25	
Fill Above Water	11,600	cy	$20.68	$239,869	0.75	
Fill Between Sheets	20,400	sf	$5.00	$102,000	0.25	
Install GundWall	27,200	sf	$25.00	$680,000	1	$9,788,360
Supervision & Management	11.5	mo	$15,000.00	$172,500		
Administration	11.5	mo	$20,000.00	$230,000		
Procurement	11.5	mo	$20,000.00	$230,000		
Engineering & QC	11.5	mo	$50,000.00	$575,000		
Health & Safety	11.5	mo	$35,000.00	$402,500		
Temporary Facilities	11.5	mo	$20,000.00	$230,000		
Project Utilities	11.5	mo	$10,000.00	$115,000		
Misc. Expenses	11.5	mo	$10,000.00	$115,000		$2,070,000
TOTAL COST				$11,858,360		
22.12 Fee 10%				$1,185,836		
TOTAL				$13,044,000		

FOSTER WHEELER ENVIRONMENTAL

New Bedford Harbor - CDF C

Mobilization

Craft Labor	Units		Unit Rate	Total Cost	Comments
Operator		hrs	43.15	0	
Operator OT		hrs	57.54	0	
Laborer		hrs	32.62	0	
Laborer OT		hrs	46.73	0	
Subtotal Cost	0			0	

Equipment	Units	Unit Rate	Total Cost	Comments
			0	
			0	
			0	
Subtotal Cost			0	

Materials	Units	Unit Rate	Total Cost	Comments
			0	
			0	
			0	
Subtotal Cost			0	

Subcontract	Units	Unit Rate	Total Cost	Comments
Mobilize Equipment	16 ea	500	8,000	
Mobilize Crane	2 ea	40,000	80,000	
Mobilize Barges	4 ea	20,000	80,000	
Mobilize Boats	2 ea	500	1,000	
			0	
			0	
			0	
Subtotal Cost			169,000	

TOTAL COST		**169,000**

FOSTER WHEELER ENVIRONMENTAL

New Bedford Harbor - CDF C

Drive Sheets

Craft Labor	Units		Unit Rate	Total Cost	Comments
Operator		hrs	43.15	0	
Operator OT		hrs	57.54	0	
Laborer		hrs	32.62	0	
Laborer OT		hrs	46.73	0	
Subtotal Cost	0			0	

Equipment	Units	Unit Rate	Total Cost	Comments
			0	
			0	
			0	
			0	
Subtotal Cost			0	

Materials	Units	Unit Rate	Total Cost	Comments
			0	
			0	
			0	
Subtotal Cost			0	

Subcontract	Units	Unit Rate	Total Cost	Comments
Permanent Sheets	122,400 sf	27.00	3,304,800	2 rows at 61,200 sf each (quote)
Subtotal Cost			3,304,800	

TOTAL COST	**3,304,800**

FOSTER WHEELER ENVIRONMENTAL

New Bedford Harbor - CDF C

Pre-Dredge Contaminated Sediment 8,900 cy

Craft Labor	**Units**	**Unit Rate**	**Total Cost**	**Comments**
Operator	1,116 hrs	43.15	48,156	1.5 Operators 24/7 Water Treatment
Operator OT	hrs	57.54	0	
Laborer	hrs	32.62	0	
Laborer OT	hrs	46.73	0	
Subtotal Cost	1,116		48,156	

Equipment	**Units**	**Unit Rate**	**Total Cost**	**Comments**
			0	
			0	
			0	
			0	
Subtotal Cost			0	

Materials	**Units**	**Unit Rate**	**Total Cost**	**Comments**
			0	
Subtotal Cost			0	

Subcontract	**Units**	**Unit Rate**	**Total Cost**	**Comments**
Water Treatment	1 mnth	50,000	50,000	Power,Sampling, Supplies
Dredging	8,900 cy	100	890,000	
Subtotal Cost			940,000	

TOTAL COST			**988,156**	

FOSTER WHEELER ENVIRONMENTAL

New Bedford Harbor - CDF C

Excavate Organic Clay	20,200 cy	750 cy/day	27 days

Craft Labor	Units	Unit Rate	Total Cost	Comments
Operator	600 hrs	43.15	25,890.25	3 ea. @40 hrs/wk x 5 weeks
Operator OT	150 hrs	57.54	8,630.83	3 ea. @10 hrs/wk x 5 weeks
Laborer	1,200 hrs	32.62	39,138.17	6 ea. @40 hrs/wk x 5 weeks
Laborer OT	300 hrs	46.73	14,020.16	6 ea. @10 hrs/wk x 5 weeks
Subtotal Cost	2,250		87,679.41	

Equipment	Units	Unit Rate	Total Cost	Comments
Clamshell & Barge	1 mo	15,000.00	15,000.00	1 ea
Spoils Barge	1 mo	8,500.00	8,500.00	1 ea
Pushboats	2 mo	6,000.00	12,000.00	2 ea
Bottom Dump Barge	1 mo	12,000.00	12,000.00	1 ea
Pump & Pipeline	1 mo	20,000.00	20,000.00	
			0.00	
Subtotal Cost			67,500.00	

Materials	Units	Unit Rate	Total Cost	Comments
Fuel & Maint.	25%	67,500.00	16,875.00	
Small Tools	0 mo	2,500.00	0.00	
Subtotal Cost			16,875.00	

Subcontract	Units	Unit Rate	Total Cost	Comments
Disposal Facility Research & Approval - Regulatory Compl.	1 ls	20,000.00	20,000.00	
Clay Disposal Fees	27,270 ton	80.00	2,181,600.00	20,200 cy @ 1.35 tons/cy
Analytical Testing	55 ea	1,200.00	66,000.00	1 sample/500 tons
Dewatering	20,200 cy	30.00	606,000.00	
Subtotal Cost			2,873,600.00	

TOTAL COST **3,045,654.41**

FOSTER WHEELER ENVIRONMENTAL

New Bedford Harbor - CDF C

Fill Below Water	33,300 cy	750 cy/day	44.4 days

Craft Labor	**Units**	**Unit Rate**	**Total Cost**	**Comments**
Operator	1,800 hrs	43.15	77,670.75	5 ea. @40 hrs/wk x 9 weeks
Operator OT	450 hrs	57.54	25,892.49	5 ea. @10 hrs/wk x 9 weeks
Teamsters	360 hrs	43.15	15,534.00	1 ea. @40 hrs/wk x 9 weeks
Teamster OT	90 hrs	57.54	5,178.60	1 ea. @10 hrs/wk x 9 weeks
Laborer	2,160 hrs	32.62	70,448.70	6 ea. @40 hrs/wk x 9 weeks
Laborer OT	540 hrs	46.73	25,236.29	6 ea. @10 hrs/wk x 9 weeks
Subtotal Cost	5,400		219,960.84	

Equipment	**Units**	**Unit Rate**	**Total Cost**	**Comments**
140' Material Barges	4 mo	8,500.00	34,000.00	2 ea
Cranel W/ Barge	2 mo	18,800.00	37,600.00	1 ea
90' Deck Barges	4 mo	3,800.00	15,200.00	2 ea
Pushboats	4 mo	6,000.00	24,000.00	2 ea
Loaders	2 mo	10,000.00	20,000.00	1 ea
100' Conveyor's	4 mo	8,000.00	32,000.00	2 ea
Feed Conveyor	2 mo	6,000.00	12,000.00	1 ea
Subtotal Cost			174,800.00	

Materials	**Units**	**Unit Rate**	**Total Cost**	**Comments**
Fuel & Maint.	25%	174,800.00	43,700.00	
Small Tools	2 mo	2,500.00	5,000.00	
Fill Material	53,280 ton	14.00	745,920.00	33,300 cy @ 1.6 ton/cy
Armor Stone	3,000 cy	22.00	66,000.00	
Subtotal Cost			860,620.00	

Subcontract	**Units**	**Unit Rate**	**Total Cost**	**Comments**
Sieve & Proctor	20 ea	175.00	3,500.00	
In-Place Density Test	0 hr	75.00	0.00	
Subtotal Cost			3,500.00	

TOTAL COST			**1,258,880.84**	

FOSTER WHEELER ENVIRONMENTAL

New Bedford Harbor - CDF C

Fill Above Water	11,600 cy	750 cy/day	15.5 days

Craft Labor	**Units**	**Unit Rate**	**Total Cost**	**Comments**
Operator	720 hrs	43.15	31,068.30	6 ea. @40 hrs/wk x 3 weeks
Operator OT	180 hrs	57.54	10,357.00	6 ea. @10 hrs/wk x 3 weeks
Laborer	480 hrs	32.62	15,655.27	4 ea. @40 hrs/wk x 3 weeks
Laborer OT	120 hrs	46.73	5,608.06	4 ea. @10 hrs/wk x 3 weeks
Subtotal Cost	1,500		62,689	

Equipment	**Units**	**Unit Rate**	**Total Cost**	**Comments**
D5 Dozer	1 mo	5,500	5,500	1 - D5
Excavator	1 mo	10,000	10,000	1 ea
Loaders	1 mo	10,000.00	10,000	1 ea
90' Deck Barges	0 mo	3,800.00	0.00	
100' Conveyor's	0 mo	8,000.00	0	
Feed Conveyor	0 mo	6,000.00	0	
			0	
Subtotal Cost			25,500	

Materials	**Units**	**Unit Rate**	**Total Cost**	**Comments**
Fuel & Maint.	25%	25,500	6,375	
Small Tools	1.00 mo	2,500	2,500	
Misc. Supplies	1 ls	1,000	1,000	
Fill Material	18,560 ton	6.75	125,280.00	12,000 cy @ 1.6 tn/cy
Subtotal Cost			135,155	

Subcontract	**Units**	**Unit Rate**	**Total Cost**	**Comments**
Sieve & Proctor	3 ea	175.00	525	
In-Place Density Test	80 hr	75.00	6,000	
Surveys	1 ls	10,000.00	10,000	
Subtotal Cost			16,525	

TOTAL COST	**239,869**

FOSTER WHEELER ENVIRONMENTAL

New Bedford Harbor - CDF C

Fill Between Sheets and Install GundWall

Craft Labor	Units		Unit Rate	Total Cost	Comments
Operator		hrs	43.15	0	
Operator OT		hrs	57.54	0	
Laborer		hrs	32.62	0	
Laborer OT		hrs	46.73	0	
Subtotal Cost	0			0	

Equipment	Units	Unit Rate	Total Cost	Comments
			0	
			0	
			0	
			0	
Subtotal Cost			0	

Materials	Units	Unit Rate	Total Cost	Comments
			0	
			0	
			0	
Subtotal Cost			0	

Subcontract	Units		Unit Rate	Total Cost	Comments
Fill Between Sheets (Slurry Wall)	20,400	sf	5.00	102,000	quote
Install GundWall	27,200	sf	25.00	680,000	quote
Subtotal Cost				782,000	

TOTAL COST	**782,000**

Labor Rates

Decision No:

Equip Oper Engi0004I Group 1

Rate	26.04	Base	
Fringe	10.62	Hlth & Wlfre,etc	
Fringe a	0.00	Haz Premium	
Fringe b	1.04	Holiday	10 Days
FICA	2.07	7.65%	
FUTA	0.22	0.80%	
SUTA	1.38	5.10%	
Work Comp	1.78	6.57%	
	43.15		

Equip Oper OT Engi0004I Group 1

Rate	39.06	Base	
Fringe	10.62	Hlth & Wlfre,etc	
Fringe a	0.00	Haz Premium	
Fringe b	0.00	Holiday	10 Days
FICA	2.99	7.65%	
FUTA	0.31	0.80%	
SUTA	1.99	5.10%	
Work Comp	2.57	6.57%	
	57.54		

Laborer - Haz Labo0022L Group 6

Rate	20.95	Base	
Fringe	7.45	Hlth & Wlfre,etc	
Fringe a	0.00	Haz Premium	
Fringe b	0.00	Holiday	0 Days
FICA	1.60	7.65%	
FUTA	0.17	0.80%	
SUTA	1.07	5.10%	
Work Comp	1.38	6.57%	
	32.62		

Laborer - HazOT Labo0022L Group 6

Rate	31.43	Base	
Fringe	7.45	Hlth & Wlfre,etc	
Fringe a	0.00	Haz Premium	
Fringe b	0.00	Holiday	10 Days
FICA	2.99	7.65%	
FUTA	0.31	0.80%	
SUTA	1.99	5.10%	
Work Comp	2.57	6.57%	
	46.73		