Appendix B

Technology Screening

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Appendix B – Technology Screening

The Terminal 4 engineering evaluation/cost analysis (EE/CA) work plan (BBL, 2004a) identified general technologies that would be considered for inclusion in the development of Removal Action alternatives. Section 101(23) of CERCLA defines "remove" or "removal" as follows:

> …cleanup or removal of released hazardous substances from the environment; such actions as may be necessary taken in the event of the threat of release of hazardous substances into the environment; such actions as may be necessary to monitor, assess, and evaluate the release or threat of release of hazardous substances; the disposal of removed material; or taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare of the United States or to the environment, which may otherwise result from a release or threat of release.

In accordance with U.S. Environmental Protection Agency (USEPA) guidance (USEPA, 1993) for Non-Time-Critical Removal Actions (NTCRAs), "only the most qualified technologies that apply to the media or source of contamination" should be considered for the development of Removal Action alternatives. Based on the definition of removal action under CERCLA, USEPA NTCRA guidance, and prior experience with a number of contaminated sediment projects in the Pacific Northwest, the technologies identified in the approved EE/CA work plan for consideration in development of the alternatives were:

- monitored natural recovery (MNR), which may be applicable to portions of the Removal Action Area with low contaminant concentrations;
- in-situ capping of contaminated sediment; and
- sediment dredging (both mechanical and hydraulic) followed by auxiliary technologies such as transport, treatment, and/or onsite disposal of dredged sediments in a confined disposal facility (CDF) or offsite disposal at an appropriately permitted facility.

The Port of Portland (Port) screened these potentially applicable technologies to identify the technologies that are feasible and implementable and then assembled the alternatives to include the screened technologies as components. As discussed in more detail in Section 7 of the EE/CA report, other factors were considered in the development of the alternatives, including the physical, chemical, and operational characteristics of the Removal Action Area and community feedback. The Administrative Order on Consent for Removal Action (the AOC) executed by the Port and USEPA in October 2003 required the Port, as part of the Terminal 4 EE/CA process, to prepare a technical briefing for USEPA, the Oregon Department of Environmental Quality (DEQ), the Tribes, and the Trustees on the proposed Removal Action alternatives that would be presented in the EE/CA. The Port presented this technical briefing to USEPA, DEQ, the Tribes, and the Trustees on October 29, 2004. The technical briefing included the results of the technology screening process. At that time, the Port and USEPA reached general agreement on the Removal Action alternatives that would be evaluated in the EE/CA.

Appendix B summarizes the screening of the above-identified technologies for their effectiveness and implementability at Terminal 4. Where a technology can be implemented in multiple ways, the key differences between technology types are summarized. This appendix concludes with a summary of the technologies that were retained for development of Removal Action alternatives and the rationales for those selections.

B.1 Monitored Natural Recovery

MNR is defined by USEPA as a "…sediment cleanup method that uses ongoing, naturally occurring processes to contain, destroy, or otherwise reduce the bioavailability or toxicity of contaminants in sediment" (USEPA, 2002). MNR can be implemented as a stand-alone technology or in conjunction with other active measures, such as source control or source removal. MNR is a fundamental component of the USEPA's Contaminated Sediment Management Strategy (USEPA, 1998) and is a USEPA-accepted technology that has been selected as a primary cleanup method for contaminated sediments at many Superfund sites (USEPA, 2002). MNR has also been applied successfully as a key component at many sediment remediation projects in the Pacific Northwest, including the Whatcom Waterway site, the Manchester Annex site (Thornburg and Garbaciak, 1997), the Sitcum Waterway site (Hart Crowser, 2004), the Thea Foss Waterway site (Hart Crowser, 2003), the Eagle Harbor site, the Ketchikan Pulp Company site, the Puget Sound Naval Shipyard site, and the Middle Waterway site (Keeley, 2004).

MNR relies on natural recovery processes to achieve site-specific remediation objectives within a time frame that may be longer than other active methods but is still reasonable in comparison. Natural recovery processes for contaminated sediment are well documented. The USEPA defines natural processes as the following physical, biological, or chemical mechanisms that reduce risks associated with chemicals of potential concern (COPCs) in sediment (USEPA, 2002):

- physical processes: sedimentation, advection, diffusion, dilution, bioturbation, and volatilization;
- biological processes: biodegradation, biotransformation, phytoremediation, and biological stabilization; and
- chemical processes: oxidation/reduction, stabilization, and sorption.

The physical, biological, and chemical processes that may contribute to the natural recovery of Removal Action Area sediment are shown graphically on Figure B-1. Risks associated with COPCs in sediment may be reduced through MNR in one or more of the following ways (USEPA, 2002):

- the mixing in of cleaner sediments or covering of the surface by cleaner sediments, resulting in a reduction of the concentrations of COPCs in surface sediment;
- biodegradation or chemical transformation, resulting in the conversion of a COPC to a less toxic form; and
- sorption to sediment, resulting in reduced COPC mobility and bioavailability.

MNR is a technology based on understanding and quantitatively documenting the natural processes. Rather than implementing engineered technologies, MNR involves evaluating natural processes that reduce risk to acceptable levels (USEPA, 2001). The benefits of MNR (USEPA, 1999) are that:

- As an in-situ process, MNR generates less volume of remediation wastes, reduces potential for cross-media transfer of contaminants, reduces risk of human exposure to contaminants and contaminated media, and reduces risks to ecological receptors due to exposure to contaminants and contaminated media.

- MNR can result in in-situ destruction of contaminants.

- MNR results in less intrusion, including less disruption of sediment ecosystems, because few surface disturbances are required.

- MNR is flexible and is potentially applicable to all or part of a site, depending on site conditions and remedial action objectives.

- MNR can be used in conjunction with other, more active technologies.

- MNR results in remediation costs that may be lower overall than the cost of more active remediation.

B.1.1 MNR Evaluation Process

Based on USEPA guidance (USEPA, 2002), the feasibility of MNR for contaminated sediment is evaluated on the basis of five components:

- COPC fate and transport;
- changes in COPC concentrations with time;
- source control;
- limited COPC exposure during recovery, to the extent possible; and
- ability to monitor sediment recovery.

Section B.1.3 applies this evaluation process to the screening of MNR for potential inclusion in the development of Removal Action alternatives.

B.1.2 Technology Type

MNR is considered a single technology type that includes physical, biological, and/or chemical mechanisms that reduce risks associated with COPCs in sediment. A thin cap is sometimes referred to as enhanced MNR. For the purposes of the Terminal 4 EE/CA, MNR does not include sediment capping. Capping technologies are discussed in Section B.2.

B.1.3 MNR Screening Analysis

This section evaluates the sediment conditions within the Removal Action Area against the five components USEPA recommends assessing to determine the applicability of MNR for contaminated sediments, as stated in Section B.1.1. The purpose of this screening was to determine whether all or portions of the Removal Action Area could be amenable to MNR (i.e., whether MNR "screens in" as a possible Removal Action technology). To achieve this goal, the screening assesses the five components of MNR in a conceptual manner. The results of the screening (as described in Section B.1.4) support that certain areas of the Removal Action Area may be appropriate for MNR; these results are supported by Appendix H, which provides a detailed analysis (including fate and transport modeling) of MNR in the subareas identified herein.

B.1.3.1 COPC Fate and Transport

The fate and transport of COPCs within the Removal Action Area were conceptually evaluated for the following elements during this screening:

- surface sediment concentration of COPCs;
- COPC concentration profiles with depth;
- sedimentation rates;
- resuspension and advection;
- diffusion, including bioturbation;
- degradation of organic compounds; and
- sediment/water partitioning.

As detailed in the site characterization report (BBL, 2004b), surface sediment COPC concentrations and potential risk posed by COPCs are low in several areas of the Removal Action Area. These areas are (see Figure 7-1):

- a portion of Berth 401;
- a portion of Slip 1;
- a portion of Wheeler Bay; and
- the North of Berth 414 subarea.

COPC concentration profiles in these areas generally decrease with depth or COPC concentrations have a subsurface maximum, supporting that MNR is feasible (BBL, 2004b). Sedimentation rates indicate that these areas are either in dynamic equilibrium or depositional (Striplin, 2003). Finally, literature data support that bioturbation and degradation of organic compounds will occur in the Removal Action Area (see Appendix H for the reference list of documents on bioturbation and degradation). Other areas within the Removal Action Area may not be as conducive to MNR, because COPC concentrations in the surface sediments and resuspension rates are higher (e.g., within Slips 1 and 3).

B.1.3.2 Assessment of COPC Concentrations with Time

Areas with low COPC concentrations, decreasing COPC concentrations with depth, low resuspension rates, and stable or depositional sedimentation environments would also be expected to have decreasing COPC concentrations with time. Based on this conceptual assessment, areas with anticipated decreasing COPC concentrations with time are:

- a portion of Berth 401;
- a portion of Slip 1;
- a portion of Wheeler Bay; and
- the North of Berth 414 subarea.

Other areas of the Removal Action Area may also experience decreasing concentrations with time; however, the initial COPC concentrations were higher and decreases may not be seen in a "reasonable" time frame, based on comparison to other Removal Action alternatives, due to resuspension from vessel traffic.

B.1.3.3 Source Control

Potential ongoing sources of contamination will be effectively controlled following implementation of the Removal Action. Potential ongoing sources are summarized in Section 3.4.1 of the EE/CA report and discussed in detail in Appendix A. The characterization and control of potential upland sources at Terminal 4 is currently being implemented under Voluntary Cleanup Program Agreements between the Port and the DEQ.

B.1.3.4 Limited COPC Exposure During Recovery

Because access to Terminal 4 is restricted, the Removal Action Area sediments have limited human exposure (see discussion of risk in Section 3 of the EE/CA report). Several areas within the Removal Action Area have low surface sediment COPC concentrations and are in depositionally stable or increasing environments. The low COPC concentrations in these areas currently present low risks to ecological receptors (BBL, 2004c), and the COPC concentrations would continue to decrease during the recovery period due to the depositional environment. The areas fitting these criteria are:

- a portion of Berth 401;
- a portion of Slip 1;
- a portion of Wheeler Bay; and
- the North of Berth 414 subarea.

B.1.3.5 Ability to Monitor Recovery of Sediment

MNR includes monitoring of the sediment to evaluate recovery. Monitoring requirements could include:

- periodic bathymetric surveys to evaluate whether the areas are depositional or erosional; and
- periodic collection of surface sediment samples to evaluate COPC concentrations.

The Removal Action Area is accessible to either of these continued monitoring techniques.

B.1.4 MNR Screening Outcome

The MNR screening analysis presented in Section B.1.3 shows that MNR is a feasible technology for the following subareas:

- a portion of Berth 401;
- a portion of Slip 1;
- a portion of Wheeler Bay; and
- the North of Berth 414 subarea.

A detailed analysis of MNR in these subareas is provided in Appendix H in support of the Removal Action alternatives analysis.

B.2 Capping

Capping is a generic term for the in-situ containment of contaminated sediment. Contaminated sediments are covered (capped) by an appropriate material that isolates the contaminants from the water body and from ecological and human receptors.

Capping involves the placement of a natural material such as sand or gravel or a synthetic material on top of the contaminated sediment, thereby isolating chemicals from the overlying water. A cap will therefore prevent receptors from having direct contact with chemicals in the sediment, as well as prevent or substantially decrease the rate of flux of chemicals from the underlying sediments. In addition, a cap will prevent resuspension and downstream migration of chemicals adsorbed onto suspended sediment. The thickness of a cap is determined using the following criteria (USEPA, 1998):

- limitation of chemical flux, sediment resuspension, and downstream migration of sediment;

- effective isolation of chemicals from burrowing benthic organisms; and

- long-term serviceability of the cap, i.e., its ability to resist gravity and seismic loads; erosion caused by floods, waves, tides, currents, and incidental vessel-induced turbulence ("propeller wash"); and other adverse events such as vessel grounding or ice damage.

Sediment caps normally require a long-term maintenance and monitoring program, partly to verify that the cap has reduced the mobility of the chemicals and partly to ensure that the cap material is not eroding. Regular bathymetric surveys or diver inspections are normally conducted to verify that the thickness of the cap remains unchanged. Monitoring normally consists of periodic sampling of the cap sediment, as well as biota in the vicinity of the cap, to ensure that chemicals under the cap remain contained.

B.2.1 Capping Evaluation Process

The evaluation of capping technologies consisted of three steps:

- Identify the main types of capping technologies based on a review of existing sediment capping projects.
- Screen the capping technologies for their effectiveness and implementability with respect to Terminal 4 conditions.
- Evaluate whether any of the capping technologies are suitable for inclusion in the development of Removal Action alternatives.

Sections B.2.2 and B.2.3 apply this evaluation process to the screening of capping for potential inclusion in the development of Removal Action alternatives.

B.2.2 Capping Technology Types

Sediment capping is considered a well-developed and mature technology. Numerous design issues and challenges are associated with caps, but ample examples and engineering guidance are available to address these design issues. Capping has been successfully used at numerous contaminated sediment sites. A recent survey conducted by Louisiana State University includes more than 100 contaminated sediment sites that were remediated using capping (http://www.hsrc.org/capping/). In USEPA Region 10, a number of contaminated sediment sites have included the use of capping; for example, Eagle Harbor (Bainbridge Island, Washington), Pacific Sound Resources (Elliott Bay, Washington), the Thea Foss and Wheeler Osgood Waterways (Tacoma, Washington), McCormick and Baxter (Willamette River, Oregon), the Union Pacific Railroad site (The Dalles, Oregon), and the Oregon Museum of Science and Industry site (Portland, Oregon).

Further information and design guidance for sediment caps can be found in USEPA, 1998. In addition, a description of capping and examples of its implementation can be accessed at http://www.epa.gov/grtlakes/sediment/iscmain/one.html - Capping.

Capping contaminated sediments at Terminal 4 would require selecting an appropriate capping material, conducting site-specific slope stability analyses, and developing appropriate design and construction procedures. Special consideration needs to be given to the protection of the toe of the cap, where the forces associated with the river currents or propeller scour are the most potentially damaging to the integrity of the cap. Toe protection often involves the construction of rock berms, cofferdams, or bulkheads. These structures are designed to resist erosion and wave forces and to provide lateral confinement of contaminated sediment under the cap. As an example, the toe protection could consist of a grouted sheet pile supplemented by rock berms that could serve both as protection for the edges of the cap and as fish habitat.

With these factors in mind, two general types of sediment caps were screened:

- sand or gravel caps; and
- caps made of synthetic materials.

Section B.2.2.1 describes each of these types of sediment caps; Section B.2.3 screens these technologies for potential further analysis in the development of Removal Action alternatives.

B.2.2.1 Description of Sand or Gravel Caps

Caps are most easily constructed using only one type of material, such as sand or gravel. The particle size is selected to maximize limitation to chemical flux from the sediment and resistance to burrowing animals, as well as to provide maximum serviceability. The cap material can be placed in one of several ways, including:

Clamshell Placement Releasing Material in Proximity of the River Bottom. The material is placed with a relatively high level of accuracy (both vertically and horizontally) and with relatively little impact to water quality in terms of resuspension of sediment or release of the cap material. This method has a relatively low production rate.

Clamshell Placement Releasing Material Below the Water Surface. The material is placed at a higher production rate than is the case with placement near the river bottom; however, the accuracy of the placement is not as great. The potential impact to water quality is greater than with placement near the river bottom.

Barge Dumping Placement. Relatively large amounts of cap material can be placed with bottom-dump barges, which may open across the hull or have hatches that open to release the cap material. Either method allows a high production rate. Relatively accurate placement of the material can be achieved by sequencing the opening of the barge hatches. Water quality impacts are similar to those associated with clamshell placement of cap material.

Tremie Piping/Pumping Placement. The cap material is typically piped in a slurry form directly onto the river bottom. This placement technique provides good accuracy and relatively low impact to water quality. This method is best for the placement of fine-grained cap material.

Sand Wash Technology. The cap material is placed on the deck of a barge over the intended area of placement and washed overboard. This method is suitable for very soft or unstable river bottoms where clamshell placement may cause resuspension or release of contamination. The water quality impact is greater with this technique, because the cap material travels across the entire water column to reach its target area.

Conveyor Placement. Articulated conveyors can be used to place capping material. Intermediate accuracy can be achieved with this method, but results are generally dependent on operator skill. The impact on water quality may be relatively high because the material is dumped above the water. This method may be suitable for placement of capping material under pier structures.

B.2.2.2 Description of Synthetic Caps

Synthetic caps may be constructed of synthetic liners, self-hardening aggregate, concrete-filled fabric mattresses, and absorbent layers, as discussed below.

Synthetic Liners. Synthetic liners have been used extensively in environmental restoration projects, but their inclusion in Superfund sediment caps has been relatively limited.

Self-Hardening Aggregate. Self-hardening aggregate capping material uses a proprietary blend of clay minerals, polymers, and other additives around an aggregate core. After installation, the mixture hydrates and forms a continuous low-permeability barrier that also resists erosion. AquaBlok™, one type of self-hardening aggregate, has been used for this application in a demonstration project on the Ottowa River near Toledo, Ohio. According to the manufacturer, results of that capping project were favorable in that the AquaBlok™ remained in place, did not erode, and little mixing occurred at the sediment-AquaBlok™ interface. However, the project does not yet provide information on the performance of AquaBlok™ over the long term.

Concrete-Filled Fabric Mattresses. Concrete mattresses, such as FabriForm™ (http://www.fabriform1.com/), typically consist of two layers of non-woven geotextile stitched together and filled with a cement-based grout. The thickness of the barrier is 4 to 8 inches. The installation involves floating the geotextile mattress in place, sinking it to the bottom, and then filling the mattress with a cement-based grout. A layer of habitat substrate (a manufactured gravel/sand mix that provides suitable habitat for the recolonization of benthic communities) may be placed on the mattress to expedite reestablishment of a benthic community.

Absorbent Caps. Absorbent caps typically consist of two layers of non-woven geotextile stitched together and filled with organoclay. Organoclay materials are usually a proprietary blend of montmorillonite or hectorite clay and various polymer additives. These clay minerals exhibit high capacity for absorbing liquid-phase contamination. Absorbent layers in caps are normally used to capture chemicals that might be driven through the cap by an upward groundwater gradient and especially to capture nonaqueous-phase liquid (NAPL) seeps, which are not anticipated to be a concern at Terminal 4.

B.2.3 Capping Screening Analysis

B.2.3.1 Sand or Gravel Caps

As mentioned in Section B.2.2, capping has been used successfully on a relatively large number of projects. The majority of the projects used sand or sand and gravel caps (i.e., for the latter, a cap composed of a gradation of both sand and gravel). There are several design aspects that need to be addressed. The most important is the ability of a sand and gravel cap to effectively isolate chemicals of potential concern (COPCs) from the benthic environment and reduce flux of COPCs (further discussed in Appendix I). Other design aspects that need to be addressed include geotechnical aspects such as slope stability, bearing capacity, and settlement, and the ability of the cap material to resist erosional forces. Based on the subsurface conditions, physical characteristics at the site, and experience on similar projects in the Pacific Northwest (e.g., Commencement Bay Superfund site, Tacoma, Washington), sand and gravel caps should generally be feasible. A few steep slope areas within the Terminal 4 Removal Action Area may require the use of additional reinforcement of the cap (e.g., geoweb confinement system) or the use of concrete-filled fabric mattresses. However, the majority of the areas including the slopes should be suitable for placement of regular sand and gravel caps. The expectation is that deformations within the cap due to strong seismic shaking may occur and the cap would therefore have to be inspected and possibly repaired following such events. Erosion protection measures (e.g., riprap armoring) may have to be employed in areas subject to high-velocity currents, tidal changes, or high vessel traffic. Cap placement in under-pier areas may have to be performed using articulated conveyors.

B.2.3.2 Synthetic Caps

Synthetic liners have been used relatively rarely for sediment capping, both because there can be some difficulties associated with their underwater placement, especially at greater depths, and because they are generally used to overcome unusual or challenging circumstances. In addition, the use of impermeable liners is limited because of concerns regarding gas generation in the underlying sediments. In 2004, a high-density polyethylene liner was incorporated into a cap structure at the head of the Thea Foss Waterway (Tacoma, Washington) to control potential NAPL seeps, but performance data are not yet available on that installation. The Terminal 4 Removal Action Area contains no NAPL seeps. For these reasons, this technology was not retained for inclusion in the development of Removal Action alternatives.

Projects involving the installation of AquaBlok™, a self-hardening aggregate cap material, are few and provide no experience with how this technology performs over the long term. Although the initial demonstration work appears favorable, the lack of long-term performance data means that this technology is not considered desirable at Terminal 4, and this technology was not retained for inclusion in the development of Removal Action alternatives.

A concrete mattress resists erosion, provides relatively low permeability, and has a high degree of long-term serviceability. Concrete mattresses can be installed in areas where access is difficult, under piers, on steep slopes, and around obstructions. However, the surface of a concrete mattress is not conducive to the reestablishment of habitat. Further, concrete mattresses are less conforming to settlement of underlying sediments than are granular caps. Despite those limitations, this technology was retained for inclusion in the development of Removal Action alternatives because it can be implemented where access is difficult and slopes are relatively steep. It is expected that the use of concrete mattresses would be limited to marginal slopes where slope stability is a particular concern and slopes are considered too steep for sand and gravel caps. In addition, a number of project examples are available in which concrete mattresses have been successfully used for Superfund projects in the Pacific Northwest, including portions of the Thea Foss Waterway in Tacoma, Washington. Based on experience on these projects, concrete mattresses are considered generally feasible.

Absorbent caps have been used on several Superfund projects, including McCormick and Baxter in Oregon and the Anacostia River in Alabama. A potential concern with absorbent caps is their finite ability to absorb contaminants, i.e., the absorbent cap may become “filled” and thus replacement or an additional overlay may be required. Careful groundwater movement and fate and transport modeling should be performed to aid in selecting the type of absorbent and its thickness. Because these caps have not been in service for long, there are no data to verify the long-term serviceability of such structures.

B.2.4 Capping Screening Outcome

Based on the screening analysis, sand and gravel caps and concrete mattresses were retained for further consideration during the design phase. Sand or gravel caps are considered suitable for the majority, if not all, of the capping areas. Concrete mattresses were retained for further consideration in the event there are marginal slope areas within the Removal Action Area that are not suitable for sand and gravel caps because of slope stability concerns. Synthetic liners, absorbent caps, and AquaBlok™ (a self-hardening aggregate) were not retained because of a lack of performance data and/or because they were not deemed suitable for the conditions at Terminal 4.

B.2.5 Institutional Controls

To increase the long-term effectiveness of sediment caps, certain institutional controls may be implemented. These include:

- Instituting commercial vessel anchoring restrictions. These restrictions would require US Coast Guard coordination and permanent inclusion on U.S. Coast Guard navigational maps.

- Updating Port engineering maps/plans to include the capped areas and formalizing notification to tenants to ensure that the integrity of the caps are not disturbed or compromised during future construction or marine maintenance projects.

B.3 Dredging, Transport, Treatment, and Disposal

This section summarizes the evaluation of dredging technologies and technologies that would be used subsequent to and in conjunction with dredging, which include transport, treatment, and disposal technologies.

B.3.1 Dredging

Dredging technologies can generally be placed in one of four broad categories:

- mechanical;
- hydraulic;
- pneumatic; and
- specialized.

B.3.1.1 Dredging Evaluation Process

Dredging technologies were evaluated with regard to the following factors:

Sediment Resuspension. The effectiveness of each technology is evaluated in terms of sediment resuspension. The resuspension characteristics of a dredging technology determine how well the contractor can meet the requirements of water quality standards. If water quality standards cannot be met during construction, the contractor may have to change procedures or switch to a different technology, which could result in delays and additional costs. Poor sediment resuspension characteristics could also result in reduced production rates, slowed construction, and the spread of contaminants.

Availability. Availability of a technology can determine its feasibility. Even when technologies are generally available, mobilization may be costly because the equipment is distant from the site. However, other characteristics may make a technology with limited availability desirable and cost-effective for specific conditions.

Site Compatibility/Technical Feasibility. To be technically feasible, a technology needs to be compatible with the characteristics of the site, including sediment volumes to be dredged, water depths, channel widths, and the presence of structures, obstructions, and debris. The compatibility of a dredging technology with subsequent technologies is a separate question.

Solids Content. The solids content of the dredged material affects subsequent technologies, including transport, treatment, and disposal. If large amounts of water are added to the sediments during dredging, the solids content decreases. For offsite disposal options that include transport by truck, rail, and barge, as well as for treatment, it is generally beneficial if the sediments can be dredged near the in-situ solids content (i.e., without additional water). However, if, for example, the dredged material is to be disposed of in an onsite CDF and the material is to be transported there by pipeline, it may not be an issue to pump the material as a slurry at a relatively low solids content. Therefore, while a high solids content is often an advantage, in some circumstances it may not be critical and should be evaluated in conjunction with the subsequent technologies being considered.

Production Rate. The dredging production rate affects the construction schedule and costs. Production rates often vary widely among dredging technologies and depend heavily on site conditions such as the presence of debris, obstructions, and structures, as well as water depths. Frequently, manufacturers' stated production rates are based on experience with dredging that is not performed for environmental purposes. However, dredging may have to be performed at slower rates when contaminated sediments are being dredged to accomplish specific environmental objectives, such as minimizing the amount of sediment resuspension; the extent to which resuspension is reduced by slower production rates depends on the dredging technology, as well as on the transportation and disposal technologies selected.

Past Performance. The performance of a technology on other, similar dredging projects can be used as an indicator of how the technology would perform at Terminal 4.

Section B.3.1.3 applies this evaluation process to the screening of dredging technologies for potential inclusion in the development of Removal Action alternatives.

B.3.1.2 Dredging Technology Types

Dredging is conducted for many purposes, including navigational, environmental, and harbor maintenance. The type of dredging technology selected is often based on the purpose of the dredging. Because there are many dredging technologies available, a prescreening of the technologies was conducted to evaluate which technologies could be suitable for the Removal Action. Section B.3.1.2.1 describes the prescreening and results; Section B.3.1.2.2 provides a more detailed description of the dredging technologies retained from the prescreening.

B.3.1.2.1 Prescreening of Technology Types

The dredging technologies typically mentioned in the literature were prescreened. The prescreening compared the available dredging technology attributes of the Removal Action or conditions at Terminal 4, including volume of sediment to be removed, physical characteristics (water depth, waterway widths, steepness of slopes), and in-water and upland operations. Table B-1 tabulates the results of the prescreening. Technologies primarily used for navigational dredging (i.e., hydraulic types such as hopper and dustpan dredges, and mechanical types such as bucket-ladder and drag-line dredges) were eliminated, because limitations on the size of equipment used at Terminal 4, the lack of vertical and horizontal accuracy required for environmental dredging applications, the lack of effective resuspension control, and physical characteristics such as existing structures and relatively steep slopes make them unsuitable. Dry excavation was also eliminated from consideration because it would result in unacceptable disruption of Port operations and because water depths make the installation of sheet pile cofferdams or similar wall structures impractical.

The dredging technologies retained from the prescreening are listed below. These technologies are generally considered suitable for environmental dredging projects (Palermo et al., in press; Herbich, 2000):

1. Mechanical
    a. Open clamshell bucket
    b. Enclosed clamshell bucket
    c. Barge-mounted excavator with conventional bucket
    d. Barge-mounted excavator with bucket-closing mechanism

2. Hydraulic
    a. Plain suction
    b. Cutterhead dredge
    c. Horizontal auger

3. Pneumatic
    a. Oozer pump
    b. Pneuma pump

4. Specialized
    a. Toyo pump
    b. Eddy pump

B.3.1.2.2 Description of Prescreened Dredging Technologies

This section provides descriptions of the dredging technologies that were retained for further screening. The advantages and disadvantages of each of these technologies relative to conditions at Terminal 4 is provided in Table B-2.

Mechanical Dredges

Open Clamshell Bucket. The open clamshell bucket is typically operated via the wires of a conventional cable arm crane. The crane can operate from land or it can be barge-mounted. The clamshell bucket is lowered to the mudline and penetrates the sediment in the open position by gravity impact. Sediment is trapped in the clamshell bucket by closing the bucket using the crane's wires. The sediment can then be lifted to the surface and out of the water, where it is typically placed on a barge for transport to shore. Different bucket types and sizes are available. Buckets of up to about 60 cubic yards (cy) are available regionally, but sizing of 5 to 20 cy would be more applicable to environmental dredging. Particularly on slopes, a smaller bucket should be used to avoid excessive overdredging and sediment instability. Some buckets make circular-shaped cuts; newer buckets are capable of making level cuts, leaving a relatively flat surface. Level-cut buckets should be used when possible to increase dredge accuracy, avoid large amounts of overdredging, and reduce sediment resuspension. In addition, sediment resuspension is further reduced by using level-cut buckets to dredge unconsolidated soft sediments. However, lightweight level-cut buckets are unsuitable for digging in harder consolidated sediments.

Enclosed Clamshell Bucket. This technology uses a modification of the conventional clamshell bucket described above. While the bucket is also operated by a cable arm crane, the clamshell is modified such that the bucket is nearly watertight or sealed in the closed position. This reduces sediment resuspension, particularly in the upper water column. Recent designs also incorporate the capability of making level cuts as opposed to the circular-shaped cuts made by conventional buckets. As with the open clamshell bucket technology, level-cut buckets should be used when possible to increase accuracy, minimize the need for overdredging, and further reduce sediment resuspension.

Barge-Mounted Excavator with Conventional Bucket. Excavators with conventional digging buckets can be mounted on a barge for dredging operations. Instrumented buckets have been used for greater dredging accuracy (e.g., the Bonacavor by Bean Stuyvesant, LLC). However, the availability of instrumented excavators is likely very limited; such equipment might have to be mobilized from as far away as Louisiana. Less highly specialized excavators with conventional buckets are available and have been used for projects in the Pacific Northwest. The maximum dredge depth is about 25 feet unless a specialty long-reach backhoe is used. Land-based excavators could be used for slope cuts, if required, although this would typically require an even larger excavator arm due to dock or bank height.

Barge-Mounted Excavator with Bucket-Closing Mechanism. The setup for this equipment is generally the same as for the conventional barge-mounted excavator, with the exception that the bucket attached to the excavator is modified to include a closing mechanism that reduces the amount of sediment washed out of the bucket.

Hydraulic Dredges

Hydraulic Cutterhead Dredges. A number of dredges use a combination of mechanical cutting action and hydraulic suction created by pumps to excavate sediments. Hydraulic cutterhead dredges are typically available as barge-mounted units, although dredging depth is typically limited to 40 feet or less because these units are smaller than other types of dredges. The main components of these dredges are a dredge head, which cuts the material to be dredged, and a submersible centrifugal pump, which creates suction to pick up the material. The dredge head is typically mounted on a moving support system (referred to as a ladder) that also supports a suction line. The suction line transports the material to the main pump and on to the discharge pipe. Dredges with different dredge heads are available. The most commonly available type on the West Coast is the cutterhead dredge, which uses a rotating cutting device to dislodge sediments. Another hydraulic cutterhead dredge type available on the West Coast is the horizontal auger dredge, commonly referred to as the Mud Cat™ (Baltimore Dredges LLC). Other dredges with specialty dredge heads include the Boskalis Environmental Disc Cutter, the Slope Cleaner, Clean Sweep, Water Refresher, Clean Up, and Swan 21 systems (Palermo et al., in press). These dredges are not as widely available as the cutterhead and horizontal auger dredges and were not evaluated further in this technology screening. Specialty dredge heads are available equipped with design features such as mud shields to reduce sediment resuspension.

Plain Suction Hydraulic Dredges. Dredges that use only hydraulic action and no cutting action to excavate sediments are commonly referred to as plain suction dredges. Several designs with different dredge heads are available, including cutterhead dredge with no cutter basket mounted, Matchbox dredge head, articulated Slope Cleaner, Scoop-Dredge BRABO, and others (Palermo et al., in press). Many of these designs incorporate dredge heads with special design features such as flexible enclosures or special suction heads to reduce sediment resuspension. Smaller-size dredge heads can be used for diver-assisted dredging.

Pneumatic Dredges

Several types of pneumatic dredges have been used in the cleanup of contaminated sediments. The more common pneumatic dredge types are described below.

Oozer Pump. The Oozer pump is an air-operated submersible pump that is typically mounted at the end of a ladder. Suction is created by use of hydrostatic pressure and additional creation of a vacuum to pick up the sediment and fill two cylinders. The pump is typically equipped with special high-frequency acoustic sensors that measure the sediment thickness being dredged, the bottom elevation after dredging, and the amount of resuspension. Additionally, cameras can provide the operator with visual information.

Pneuma Pump. The Pneuma pump creates pneumatic force to suck sediments into three cylinders. Compressed air is then used to force the sediment out of the cylinders and into the discharge pipeline. The pump can be suspended from a barge-mounted crane or mounted at the end of a ladder similar to a cutterhead dredge. Dredging results are typically better when the pump is mounted to a ladder.

Specialized Dredge Technologies

Toyo Submersible Agitator Pump. The Toyo system typically consists of a submersible agitator pump that is attached to a flexible pipe and suspended from a barge-mounted (typically 30- to 50-ton) crane. Mobilization of the pump itself is relatively easy and can be accomplished by truck. The built-in agitator consists of rotating cutter blades and is located at the intake end of the pump. The system can be equipped with a global positioning system mounted on the crane and depth sensors to provide information on the location of the pump during dredging. A magnetic flow meter/density meter can provide solids content and production measurement. The manufacturer claims that the pump is capable of moving material at up to 70% solids by weight and of picking up rock of 5-inch size or less. Production rates range from about 30 to 60 cy/hour for the DP-30 model to about 150 to more than 300 cy/hr for the DP-150-B model. Production rates would likely be lower if debris larger than 5 inches is present.

Eddy Pump. The Eddy pump is a submersible pump that creates a dynamic fluid eddy effect within the pump housing and inlet to pick up sediments. The manufacturer compares this mechanism to a tornado or vortex that picks up objects from the ground. The eddy effect is created by a rotor within the pump that is located above the intake. The pump is attached to a flexible pipeline and can be suspended from a barge-mounted crane or ladder. By virtue of the negative pressure caused by the vortex in the pump, the system is essentially leak-proof. The Eddy pump system used for environmental dredging is designed for easy transportation and with a unique spud system that allows great maneuverability. Pumps of various sizes (4-inch, 6-inch, 8-inch, and 14-inch) are available. On various demonstration projects, this pump dredged material at solids contents of 55% to 90% by weight at rates of 187 to 200 cy/hour and was used in widely varied bathymetric, environmental, and climatic conditions.

B.3.1.3 Dredging Screening Analysis

The environmental dredge technology screening matrix presented in Table B-2 provides descriptive, technology-specific information regarding the performance of each technology with regard to the following evaluation criteria, which were described in Section B.3.1.1:

- sediment resuspension;
- availability;
- site compatibility/technical feasibility;
- solids content;
- production rate; and
- past performance.

Table B-2 describes the advantages and disadvantages of each of the initially retained dredging technologies and identifies whether the technology was retained for further analysis as a part of the Terminal 4 Removal Action alternatives.

Sediment resuspension is an important factor in selecting dredge technologies. The contractor will generally select a dredging technology that enables it to meet water quality standards while maintaining production rates that meet other project requirements. The impact of production rate on site compatibility and general project requirements is discussed in detail in Appendix J, Section J.2. Water quality during dredging is discussed in Section J.3. Compatibility of the dredging technology with subsequent technologies, including transport and disposal, is an important criterion as well. Transport and disposal are greatly affected by the solids content of the dredged material. Mechanical dredging adds the least amount of water to the sediments to be dredged and would require the least amount of dewatering or use of drying agents. Mechanical dredging is therefore a likely candidate for alternatives that involve landfill disposal. However, mechanical dredging is also suitable for onsite disposal in a CDF and is not eliminated from the CDF disposal alternative. Dredging technologies other than mechanical dredging will likely add a relatively large amount of water to the sediment and will decrease its solids content. Sediments dredged using hydraulic cutterhead, hydraulic, pneumatic, or specialty dredges and pumps are typically suitable for pipeline transport, but would likely require a fair amount of dewatering in conjunction with other transport technologies. Pipeline transport would likely be used only in conjunction with onsite disposal in a CDF.

While the majority of dredges described in this appendix are generally technically feasible for portions of or the entire project site, availability of the dredges will play an important role in technology selection. Based on availability, the most likely candidates for the Terminal 4 Removal Action are mechanical clamshell and hydraulic cutterhead dredges. Both of these dredge types are widely available on the West Coast. While cutterhead dredges would likely be used only in conjunction with onsite CDF disposal, because of the high water content/low solids content of the dredged material, clamshell dredges could be used for both landfill and CDF disposal.

B.3.1.4 Dredging Screening Outcome

As shown on Table B-1, several dredging technologies were retained as potentially applicable for the Removal Action Area and are analyzed in more detail in Appendix J. These technologies are:

- mechanical dredging using open clamshell bucket;
- mechanical dredging using enclosed clamshell bucket; and
- hydraulic cutterhead dredging using a cutterhead dredge.

Clamshell and cutterhead dredges are considered the most likely candidates for the Terminal 4 Removal Action and were retained for detailed analysis as a part of the development of Removal Action alternatives (Appendix J). However, other technologies have not been ruled out (identified as “possible” in Table B-2) and may represent viable options depending on design considerations.

B.3.2 Transport

Transport technologies will be used in conjunction with dredging and disposal. Once the sediments have been dredged, they will be transported to an onsite or offsite disposal facility. Processing of the dredged material may consist of dewatering or solidification, depending on the disposal technology, and these technologies are described further in Section B.3.3.2.

Transport technologies commonly applicable to dredging projects are:

- truck transport;

- rail transport;
- barge transport; and
- pipeline transport.

B.3.2.1 Transport Evaluation Process

The evaluation criteria against which the transport technologies were screened are described below.

Protectiveness of the Public and Construction Personnel. The use of certain transport technologies may affect the health and safety of the public or the health and safety of construction personnel. Health and safety may be affected by impacts to air quality and traffic, by increased potential for vehicular accidents, by the need to rehandle contaminated sediments, and by the potential for spills.

Technical Feasibility. Technical feasibility is evaluated based on construction and operational considerations, compatibility with site conditions, compatibility with other technologies, and demonstrated performance.

Availability. The implementability of a technology is generally heavily dependent on the availability of equipment, personnel, and services.

The transport technologies were also evaluated for cost in a broad sense, i.e., low, moderate, or high.

Section B.3.2.3 applies this evaluation process to the screening of transportation technologies for potential inclusion in the development of Removal Action alternatives.

B.3.2.2 Transport Technology Types

This section describes each of the transport technology types. Table B-3 discusses the advantages and disadvantages of each as a part of the screening process.

Truck Transport

Truck transport of dredged sediment is generally used in conjunction with offsite disposal at a landfill. Truck transport would require construction of an onsite transload facility where the dredged sediments could be transferred from a barge or a stockpile to the trucks. Dredged sediments most often require some level of dewatering to achieve a moisture content that will preclude water drainage from the trucks during transport. Truck transport usually works best in combination with mechanical dredging, because mechanically dredged material contains less water than hydraulically dredged material and needs less dewatering.

The dredged material would likely be placed in lined roll-off boxes or containers, because additional free water could be generated during transport as a result of vibration. For purposes of the EE/CA, it is assumed that each truck would have a capacity of 30 tons. An established truck route from Terminal 4 to Interstate 5 follows Lombard Boulevard to Burgard Road to Columbia Boulevard and then directly to I-5. For purposes of this technology screening, it is assumed that the distance from Terminal 4 to a landfill suitable to accept this material is approximately 120 miles. It would probably take five to seven hours to load a truck, take the material to a landfill, and return to Terminal 4. Truck transport is heavily influenced by traffic, weather, and road conditions, which may affect travel time and thus turnaround time. It is unlikely that a truck would be able to make more than one trip per day. The rate at which material is hauled offsite by truck must meet the requirements set by dredging production, i.e., the material must be hauled offsite quickly enough to avoid shutdown or delay of the on-water operations. If, based on dredging productivity, the cycle time required to fill one truck is less than 10 minutes, loading of trucks likely becomes a challenge. In addition, simply obtaining enough trucks to keep up with the dredge production rate would be difficult. Trucking can generally be used in combination with other transport technologies, if trucking alone cannot keep up with dredge production.

Rail Transport

Because Terminal 4 has rail access, rail transport is a viable transport option for offsite disposal of dredged sediment at a landfill. Rail transport should generally work well in conjunction with mechanical dredging, but will work less well in conjunction with hydraulic dredging. Mechanical dredging adds significantly less water to the sediments than does hydraulic dredging. Hydraulically dredged material would likely require significant material processing, such as dewatering or solidification, prior to transport. The dredged sediment may be placed in lined railcar boxes (containers) or gondolas. Railcars comprised of buggies to carry containers have a capacity of 90 tons, while gondolas have a capacity of 105 to 115 tons. Several USEPA-approved landfills in Oregon and Washington have rail access. For the purposes of the EE/CA, it is assumed that it will be necessary to construct a transload facility at the head of Slip 1.

Barge Transport

Two USEPA-approved landfills located on the Columbia River have direct barge access and thus can be accessed from Terminal 4. The barges would be loaded during dredging without rehandling of the dredged sediments. A tugboat would be required to move the barges on the Columbia River to the landfill. A similar disposal project has been successfully completed in which approximately 20,000 cy of dredged material was transported by barge from Portland to a landfill in Klickitat County, Washington. The travel time for each barge was approximately one day each way. The barges had capacities of about 5,000 cy, although most barges are smaller and can typically carry up to 3,000 cy of material. In general, barge transport is relatively slow and the contractor would have to supply several barges to allow dredging to continue while full barges traveled to and from the landfill.

Barge transport is often used in conjunction with hydraulic transfer. At Terminal 4, barge transport to deliver dredge material to a possible CDF would have to be coordinated with other vessel traffic and thus the use of bottom dump barges is not likely.

Pipeline

Pipeline transport could be used in conjunction with onsite disposal in a CDF. Pipeline transport is typically not applicable to offsite disposal because of the long distance that must be traveled to reach USEPA-approved landfills. To allow pipeline transport, the material to be transported generally needs to have a fairly low solids content (i.e., the material should be a slurry) so that pumps can move the material through the pipes. Therefore, hydraulic dredging works well in conjunction with pipeline transport. Mechanical dredging can also be coupled with hydraulic transport of the dredged sediment whereby additional water is mixed with the sediment to achieve a slurry that can be pumped. Hydraulic, hydraulic cutterhead, pneumatic pump, and high-solids pump dredges are generally all compatible with pipeline transport, although it may be necessary to use booster pumps if pipeline lengths exceed limitations of the main dredge pump.

B.3.2.3 Transport Screening Analysis

The screening placed emphasis on the compatibility of a technology with the conditions at Terminal 4 and compatibility with other technologies. The transport technology screening matrix presented in Table B-3 provides descriptive, technology-specific information regarding the performance of each technology with regard to the following evaluation criteria, which are described in Section B.3.2.1.:

- protectiveness of the public and construction personnel;
- technical feasibility;
- availability; and
- cost, broadly expressed as low, moderate, or high.

B.3.2.4 Screening Outcome

Generally, all four transport technologies are feasible and none of the technologies was eliminated from consideration for the Terminal 4 Removal Action. However, if the dredged material is disposed of in an onsite CDF, pipeline transport is the primary applicable transport technology. This could be accomplished by utilizing either hydraulic dredging or mechanical dredging with the addition of water to the dredged sediment to form slurry suitable for pipeline transport.

B.3.3 Treatment

This section summarizes the information used to screen sediment treatment technologies to determine their appropriateness for inclusion in the development of Removal Action alternatives. As stated in USEPA guidance, “whenever practicable, the alternatives selection process should consider the CERCLA preference for treatment over conventional containment or land disposal approaches to address the principal threat at a site” (USEPA, 1993). However, USEPA guidance also states that “Removal actions, however, cannot conform entirely to requirements for remedial actions because of site-related time constraints and statutory limits on remedial actions.” For this reason, “only the most qualified technologies that apply to the media or source of contamination should be discussed in the EE/CA” based on proven treatment technologies that have been “selected in the past at similar sites for similar contaminants” (USEPA, 1993).

Sediment treatment technologies are currently under development through pilot and demonstration projects with the USEPA and state departments of transportation and environmental protection. Although there are several proven sediment treatment technologies, few, if any, are commercially available at a cost that can compete with the cost of onsite disposal or upland disposal at a USEPA-approved landfill.

B.3.3.1 Treatment Evaluation Process

The screening of sediment treatment technologies was based on a review of current literature, discussions with experts in the field, and interviews with sediment treatment technology vendors. Although a number of sediment treatment technologies exist in concept, the screening focused on those that have undergone pilot and/or demonstration projects or have been used successfully and are associated with a financially viable vendor. The process consisted of:

- Screening technology process options and vendors through a telephone survey of vendors.

- Determining whether any treatment technologies are suitable for inclusion in the development of Removal Action alternatives on the basis of commercial availability, suitability of the end product, and cost.

Sections B.3.3.3 and B.3.3.4 apply this evaluation process to the screening of treatment technologies for potential inclusion in the development of Removal Action alternatives.

B.3.3.2 Treatment Technology Types

Consistent with USEPA guidance, "only the most qualified technologies that apply to the media or source of contamination" and that have been "selected in the past at similar sites for similar contaminants" (USEPA, 1993) were reviewed. During prescreening on the basis of that guidance, the following technology types were eliminated from consideration:

- Dewatering and stabilization were not screened as treatment technologies because reducing the toxicity of contaminants is not their primary purpose. Rather, dewatering and stabilization are typical steps in many sediment treatment technologies to improve the suitability of sediment for certain kinds of handling. Dewatering and stabilization are therefore discussed separately in Section B.3.4.2.2.

- In addition, in-situ treatment technologies were not included in the screening because they are in the early stages (conceptual level) of development. Research on in-situ technologies for treating or stabilizing contaminants is ongoing, but these technologies have not yet been successfully applied in a large-scale field situation.

The technology types that were screened are:

- thermal treatment;
- extraction;
- chemical treatment;

- biological/bioremediation; and
- immobilization.

Each of these is briefly summarized below.

Thermal Treatment

Thermal treatment technologies use heat as the primary mechanism for removal/volatilization and/or destruction of chemical contamination in sediments. Several common types of thermal treatment processes are described below.

Drying Kiln Technology. This technology converts contaminated dredge sediments into construction-grade cement. Dredged wet sediment is off-loaded from a barge via a clamshell excavator or other means and temporarily deposited into a storage area. From the storage area, the sediment is put through a scalper to remove oversized objects. The sediment is dried using thermal energy recovered from hot flue gases. The dried sediment is then blended with suitable modifiers and screw fed into the melter. In the melter, the sediment-modifier mixture is subject to temperatures in the range of 2,400^{o}F to 2,600^{o}F (1,300^{o}C to 1,400^{o}C) by combustion of natural gas with air and/or oxygen. This temperature is sufficient to reduce the mixture to a homogeneous melt. All non-volatile heavy metals originally present in the sediment are incorporated into the melt matrix via a molecular replacement mechanism. The molten material moves through the kiln and exits by flowing over a weir. The molten material then falls through a plenum through high-pressure streams of water, which immediately quench and granulate the melt. The granulated melt is used as an ingredient in the manufacture of concrete for general construction purposes.

Vitrification. Vitrification is an extremely high temperature thermal treatment process that produces a glass-like product. The sediment is screened and the coarse fraction rinsed with water. The fine fraction is sent to an agglomerations stage, where lime and a flocculent agent are introduced. The fresh water from the coarse rinse is introduced and the material is sent to a dewatering stage to reduce the moisture content. The contaminated sediment is sent to a plasma melter, where a flux of high-temperature combustion agents and air is introduced prior to injection in the melter. The reactor is operational at temperatures between 18,000^{o}F and 25,000^{o}F (10,000^{o}C and 14,000^{o}C). Organic constituents are destroyed virtually immediately and metals are incorporated (melted) into the vitrified output. The inorganic portion in the melter is transformed into a vitrified glass matrix, which is essentially inert and can be disposed of or used to make construction materials, e.g., tiles, bricks, aggregate, and rock wool.

Incineration. Incineration is a controlled high-temperature process that uses combustion to destroy contaminants of concern, resulting in reduction in volume and/or toxicity of the contaminated medium. Contaminated sediments are heated in a rotary kiln or multiple-hearth furnace to an operating temperature greater than 1,800^{o}F to 2,000^{o}F (980^{o}C to 1,100^{o}C). The manufacture of lightweight aggregate via the rotary kiln process is based on the conversion of feedstock solids into a partially molten (pyro-plastic) state at the same temperature that bloating gases begin to evolve. The plasticity of the substance is controlled by the amount of flux compounds reacting with silicon dioxide (the predominant mineralogical component) to form a complex compound matrix that further binds and immobilizes the various inorganic components. The heat-induced physical expansion process yields the desired end product, lightweight aggregate. By exposing the sediment material to the temperatures within the burning zone of the kiln, the organic constituents are thermally desorbed and destroyed. Incineration does not destroy metals. Mercury volatilizes and must be removed from stack gases. Other metals remain in the sediment and must be disposed of.

Thermal Desorption. Thermal desorption physically separates volatile and semivolatile compounds from sediments by heating the sediment to temperatures ranging from 190^{o}F to 1,000^{o}F (90^{o}C to 540^{o}C). Water, organic compounds, and some volatile metals are vaporized by the heating process and are subsequently condensed and collected as liquid, captured on activated carbon, and/or destroyed in the afterburner. An inert atmosphere is usually maintained in the heating step to minimize oxidation of organic compounds and for thermal desorption. Residuals from this process, which might include liquids, solids, or contaminated activated carbon, must be disposed of. This technology will not treat metals.

Extraction Technology

Extraction treatment technologies primarily involve unit operations in which change is brought about by means of or through the application of physical forces. Separation technologies, such as gravity separation or filtration, are examples of physical treatment technologies.

Soil Washing. Soil washing is a physical/chemical process that reduces the volume of soil material requiring further treatment and/or disposal by separating and/or removing organic contaminants that adhere to organic matter and fine particles within a soil matrix. The process is designed to decontaminate fine-grained (silt and clay) sediment particles by isolating individual particles and removing the adsorbed contaminants along with the naturally occurring organic material coating each particle. Depending on the soil being processed, soil washing may be effective for treating organic and inorganic compounds. The affected soils are subject to a multi-stage physical separation and washing system in which standard soil separation technologies (e.g., cyclone) and surfactants are used to separate the contaminants and the finer particles from the coarser soil materials. The wash stream containing most of the contamination then undergoes an additional treatment process. Decontaminated soils are mixed with amendments to create a manufactured soil product or other product suitable for beneficial uses.

Chemical Treatment

Chemical treatment technologies involve unit operations in which change is brought about by means of or through chemical reaction. Chemical unit processes are usually used in conjunction with physical processes to enhance contaminant removal, immobilization, or degradation. Chemical treatment techniques extract, destroy, or alter contaminants in dredged material with chemical solutions. Chemical treatment technologies involve mixing chemical additives with sediments or with a sediment slurry. Chemical treatments may destroy specific contaminants completely or partially, in which case the chemical treatment may be used to optimize process conditions for other (subsequent) treatment processes.

Chemical Oxidation. Chemical oxidation involves the use of chemical additives to transform, degrade, or immobilize organic wastes. Oxidizing agents most commonly used (singly or in combination with ultraviolet light) are ozone, hydrogen peroxide, peroxone, potassium permanganate, calcium nitrate, and oxygen. Oxidation is used to transform or break down compounds into less toxic, mobile, or biologically available forms. This process is applicable to organic compounds, but not to inorganics.

Biological/Bioremediation Technologies

Biological/bioremediation technologies are managed or spontaneous processes in which microbiological processes or plants (phytoremediation) are used to degrade or transform contaminants to less toxic or non-toxic forms, thereby remedying or eliminating environmental contamination.

Microorganisms depend on nutrients and carbon to provide the energy needed for their growth and survival. Degradation of natural substances in sediments provides the necessary food for the development of microbial populations in these media. Bioremediation technologies harness these natural processes, promoting the enzymatic production and microbial growth necessary to convert the target contaminants to non-toxic end products. Many of the more persistent contaminants in the environment, such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs), are resistant to microbial degradation because of (1) the compound's toxicity to the organisms, (2) preferential feeding of microorganisms on other substrates, (3) the microorganism's lack of genetic capability to use the compound as a source of carbon and energy, or (4) unfavorable environmental conditions in the sediment for propagating the appropriate strain of microorganisms.

Phytoremediation uses root systems of plants to collect contaminants, most commonly metals. Plants are grown on top of the sediment and harvested for use or disposed of once the plants have absorbed the contaminants.

Bio-slurry Process. Bio-slurry reactors are best suited to treating fine-grained materials that are easily maintained in suspension. In a bio-slurry system, the sediment-water slurry is continuously mixed with appropriate nutrients under controlled conditions in an open or closed impoundment or tank. The most common form of aerobic treatment involves adding air or another oxygen source. Contaminants with potential for volatilization during the mixing and/or aeration process can be controlled using emission control equipment. Once the treatment period is complete, the solids may be separated from the water and disposed of separately. The bio-slurry process is effective for organic compounds, but not for inorganics.

Immobilization (by Fixation or Solidification)

Immobilization is intended to lock contaminants in the dredged sediment by either chemically binding the contaminants to solid particles (fixation) or physically preventing the contaminants from moving (solidification) when placed in a disposal site. In some cases, a combination of physical and chemical immobilization is used. Solidification is a technology that immobilizes contaminants in the sediments while potentially improving the handling characteristics of the material. Solidification normally results in a net volume increase in the treated materials and changes in their physical properties. Treated materials may still require disposal in an appropriate facility. Solidification does not reduce the concentrations of contaminants but reduces the mobility of the contaminants and renders them inaccessible to potential receptors.

Physical Stabilization. Physical stabilization changes the engineering properties of the sediment to form a solid material (e.g., a cement matrix) and reduces the availability of the contaminants. Solidification processes may also reduce contaminant losses by binding the free water in dredged material into a hydrated solid. Binders used to immobilize contaminants in sediments include cements, pozzolans, and thermoplastics.

B.3.3.3 Treatment Technology Process Options and Vendors

The treatment technologies described above exist as theoretical approaches to sediment treatment. To determine "only the most qualified technologies that apply to the media or source of contamination" and that have been "selected in the past at similar sites for similar contaminants" (USEPA, 1993), current literature and websites on sediment treatment technologies were reviewed to develop a list of technology process options and vendors. In addition, telephone interviews were conducted with the following experts in the treatment of contaminated sediments:

- Scott Douglass, Dredging Manager, New Jersey Department of Transportation, Office of Maritime Resources; and

- Eric Stern, USEPA Regional Contaminated Sediments Program Manager.

Both Mr. Douglass and Mr. Stern are intimately involved with pilot and demonstration projects for a variety of sediment treatment technologies in the New York/New Jersey area. The New Jersey Department of Transportation's Office of Maritime Resources (NJDOT/OMR) is the national leader in the field of promoting pilot and demonstration projects of sediment treatment technologies, in part because the region must deal with a large volume of dredged material (several million cubic yards annually). NJDOT/OMR works closely with USEPA to evaluate new sediment decontamination technologies with the goal of providing new management opportunities for navigational dredged material. NJDOT/OMR initiated the ongoing Sediment Decontamination Technology Demonstration Program to evaluate sediment treatment technologies and to foster the startup of commercial-scale dredged material decontamination facilities that produce value-added products from harbor sediments.

Based on information from these sources, the following technologies and vendors were identified for further analysis to determine whether they are applicable to the Terminal 4 Removal Action:

Technology Type	Technology Process Option	Vendor
Thermal	Cement-Lock™ technology	Gas Technology Institute (GTI)
Thermal	Plasma pyrolysis vitrification	Solena Group
Thermal	Rotary kiln	Bay Cycle
Thermal	Desorption	RemTech
Thermal	Vitrification	Minergy Corporation
Extraction	Soil washing	BioGenesis
Chemical	Oxidation/stabilization/solidification	Harbor Resource Management Group

B.3.3.4 Treatment Screening Analysis

Vendors were contacted by telephone and told that BBL was calling on behalf of a confidential client evaluating the current status of sediment treatment technologies. The vendors were provided with a sediment profile for sediments that may be dredged in the Terminal 4 Removal Action. The sediment profile contained chemistry data (constituent minimum, maximum, and average) for surface sediment, under-pier sediment, and subsurface sediment, as well as data on physical parameters such as total organic carbon, percent solids, and grain size. The COPCs were identified as:

- lead;
- zinc;
- PAHs;
- PCBs; and
- DDT.

The vendors were told that the proposed dredge prism would comprise silts and silty sands with a moisture content ranging from 50% to 150% (by weight). Table B-4 summarizes the sediment chemistry and physical parameters of the possible dredge prism provided to the venders. Vendors were told that an estimated 200,000 cy may be dredged.

Eleven questions were posed to each vendor; the questions related to the applicability of their treatment technology to Removal Action Area sediments, facility operating and development parameters, beneficial reuse and waste products, permitting and regulatory issues, and costs. The results from the telephone surveys are summarized in Table B-5 and discussed in the next section.

B.3.3.5 Treatment Screening Outcome

Based on the results of the telephone survey, none of the treatment technologies was retained for inclusion in the development of Removal Action alternatives. This conclusion was based on the following:

- Seven technology types offered by seven different vendors were evaluated. Of those seven, only plasma pyrolysis, desorption, and vitrification were both commercially available and had potential applicability to the Removal Action Area sediments.

- The vendors of the vitrification and plasma pyrolysis technologies have no interest in a one-time project with the volume of sediment available for treatment at Terminal 4. The vendor of the desorption technology requires a parallel need for onsite or offsite fill material.

- The Terminal 4 project lacks a need for significant onsite fill or offsite fill for construction material, as required by the vendor of the desorption technology. (Although construction of a CDF would require fill material, a CDF would not be necessary for disposal purposes if sediment treatment were implemented, and there is no other currently identified need for such fill.)

- Processing of the dredged material would take a significant amount of time (the shortest time frame is almost 1 year), which would significantly extend the project's duration, since treatment could not occur at the same rate as dredging.

- The end products of treatment processes are not currently marketed in Oregon. Without a market in which the end products are approved for use, the end products present a disposal issue. Gaining approval to market the end products would require a regulatory process.

- The cost of the treatment technologies is high, typically as much as two to three times the cost of onsite or offsite disposal, and the end product must still be disposed of.

- In addition, it is not cost-effective to construct a treatment facility for the relatively small volume of dredged sediment from the Removal Action Area. For treatment technologies to be economical, a minimum volume of 100,000 cy per year over a 10- to 20-year period (i.e., 1 to 2 million cy) is typically required. The volume of dredged sediment from the Removal Action Area will be approximately 10% to 20% of the necessary volume for cost-effective treatment.

- The Terminal 4 Removal Action is a relatively small project and would not provide the technology vendors with a long-term source of dredged material that would justify their capital investment.

  It is plausible to assume that if the volume of sediment to be treated were to increase, certain treatment technologies could become economically feasible. However, at this point there is no good information available to ascertain the volume of sediment available from other sites, the potential chemical components associated with such sediments, or when such sediments might become available for treatment. Furthermore, it is anticipated that most of the sediments are contaminated by multiple chemicals, which likely would require the use of multiple treatment technologies.

  Therefore, it is expected that even if sediments were sent to a central treatment facility from all sites in Portland Harbor, a wide array of treatment technologies would be required to handle the range of contaminants. Considering the present state of sediment treatment technologies, it is not expected that a “treat all” technology will become available, barring a technology breakthrough, within the timeframe of the Portland Harbor cleanup process.

In summary, no treatment technology was retained for inclusion in the development of Removal Action alternatives because the cost of treatment is relatively high, there is no Oregon market for the end product, and no vendor of a process with potential applicability to the Removal Action Area sediments was interested in pursuing a project of this limited size and duration.

B.3.4 Disposal

Two disposal technologies were evaluated for dredged sediments from Terminal 4: onsite disposal in a CDF and offsite disposal at a USEPA-approved landfill. In addition, the material handling options of dewatering and stabilization are described, because these technologies may be needed to allow disposal at an offsite facility. The material handling options were not screened, as both are possible support technologies for offsite disposal.

B.3.4.1 Disposal Technology Evaluation Process

The two disposal options were evaluated against conditions at Terminal 4 to determine whether they are feasible and should be included for possible detailed analysis in the development of Removal Action alternatives. The Terminal 4 conditions important for the screening process are:

- sufficient area for developing a CDF (onsite disposal evaluation only); and
- appropriately licensed facilities within a reasonable distance from the Removal Action Area (offsite disposal only).

The materials handling options are described in Section B.3.4.2 below but are not screened because these are not stand-alone technologies and would be used in conjunction with offsite disposal as needed.

B.3.4.2 Disposal and Materials Handling Technology Types

B.3.4.2.1 Disposal

This section describes the two types of disposal technologies available: onsite disposal in a confined disposal facility and offsite disposal at a licensed landfill facility.

Onsite Disposal. Onsite disposal involves the design, construction, and monitoring of a CDF. A CDF is an engineered disposal structure for permanently containing dredged material in a nearshore environment. Confinement berms or dikes enclose the disposal area below the surface of the adjacent surface waters, thereby isolating the dredged sediment from adjacent waters. Confined disposal in a CDF is a proven technology that isolates contaminants from the aquatic environment and ensures protection of human health and the environment. CDFs are designed and constructed to withstand floods and earthquakes. There is sufficient space at Terminal 4 to construct a CDF is Slip 1 is eliminated and the CDF is constructed within the former slip.

Over the last 20 years, CDFs have been successfully designed and constructed at many other Superfund sites around the country and within USEPA Region 10. There are currently five successful CDFs in Washington's Puget Sound area. Basic characteristics of the five Puget Sound CDFs are summarized below.

Name of CDF	Owner	Construction Dates	Capacity	Current Status
Milwaukee Waterway Fill, Tacoma, WA	Port of Tacoma	1993 to 1995	2.6 million cy	Formed part of an existing marine container cargo facility. Functioning as designed.
Eagle Harbor, Bainbridge Island, WA	Washington Department of Ferries	1997	20,000 cy (approx)	Developed for use as a ferry maintenance facility. Functioning as designed.
St. Paul Waterway,	Simpson Tacoma Kraft Company	2003 to present; filling is	650,000 cy (approx)	Accepting sediment from the Thea Foss Waterway Superfund site.

Tacoma, WA		ongoing		
Slip 1 CDF, Tacoma, WA	Port of Tacoma	2002 to present; filling is expected to be completed by 2004 year-end	1 million cy (approx)	Accepting sediment from multiple users including the outer Hylebos Waterway Superfund site, Middle Waterway Superfund site, and other sites.
Terminal 91, Seattle, WA	Port of Seattle	Completed 1985	600,000 cy (approx)	In use as a marine terminal and environmental monitoring is complete. Functioning as designed.

To increase the long-term effectiveness of CDFs, certain institutional controls may also be implemented. These include:

- Updating engineering baseline maps to include the CDF boundaries.

- Update/include provisions in tenant leases, as applicable, formalizing notification and approval procedures for any planned construction projects or changes in operations to ensure the integrity of the CDF is maintained. Provisions also include requirement of access to areas, as needed for monitoring and maintenance.

- Deed notifications or easements on the property that would limit types of future development allowed on the CDF and prohibit intrusion into CDF at a certain specified depth.

Offsite Disposal. Any upland landfill that has received USEPA approval to accept material of the type to be dredged from the Removal Action Area can be used for the offsite disposal component of a Removal Action alternative. Several appropriately licensed landfills are within 120 miles of the Removal Action Area; therefore, offsite disposal of dredged sediments is feasible.

Note that some regional landfills have taken steps to gain regulatory approval to accept contaminated sediments that contain free liquids, i.e., to waive a requirement that the material pass a paint filter test. Because the sediment would not have to be dewatered, such landfills may offer advantages related to time, cost, and convenience and for that reason should be considered as offsite disposal locations for dredged material from the Removal Action Area.

B.3.4.2.2 Materials Handling Technologies

Many landfill facilities have moisture content requirements that would require that the sediment be dewatered or stabilized prior to disposal, which is relevant if offsite disposal is retained as a feasible disposal technology. Dewatering and stabilization technologies are described below.

Dewatering. In the Pacific Northwest, dredged sediment is typically dewatered using a gravity dewatering system, in which water is pushed out of the material by the material's own weight. A gravity dewatering system is expected to be sufficient to meet the needs of the Terminal 4 Removal Action if dewatering is necessary. However, if necessary, mechanical dewatering may be used to process the sediment in order to achieve a moisture content suitable for disposal at an offsite commercial landfill. The water generated would be collected, tested, and discharged according to the substantive requirements of the Clean Water Act.

Stabilization. Under certain circumstances to meet landfill requirements for moisture content, dredged material will require stabilization through the addition of a drying agent. Typical drying agents include clarifier solids, fly ash, lime, and cement. Note that while the addition of a drying agent reduces or eliminates free liquids, it also adds to the weight of the material to be disposed of.

There are certain landfills permitted to accept free liquids, which therefore present a greater flexibility with respect to the amount of dewatering and/or stabilization. However a certain amount of dewatering will unavoidably occur as part of the handling of the dredged sediment thus necessitating the introduction of technologies associated with the collection, handling, treatment and discharging of the decant water.

The Terminal 25 sediment transload facility in Seattle handles sediment removed by mechanical dredging and transfers it to railcars to deliver waste to Roosevelt landfill, which accepts free-liquids. The Terminal 25 facility has a complex decant water collection, treatment and discharge system consisting of berms, sumps, pumps, piping and treatment equipment.

Additional dewatering and/or stabilization could also be necessitated, e.g., to reduce risk of in-transport spillage or leakage as an added measure to protect the public and the environment.

B.3.4.3 Screening Analysis and Outcome

The disposal facilities were screened by evaluating conditions at Terminal 4 (onsite disposal) or regionally (offsite disposal) as described in Section B.3.4.1. The results of the evaluation indicate that there is sufficient space to construct a CDF in Slip 1; therefore, onsite disposal was retained as a possible technology for the development of Removal Action alternatives. Additionally, appropriately licensed landfills are present within a reasonable distance from the Removal Action Area; therefore, offsite disposal (and its supporting materials handling technologies) was also retained for further analysis in the development of Removal Action alternatives.

B.4 Summary of Technology Screening

This appendix to the EE/CA report presented the results of the technology screening conducted to identify technologies potentially applicable to the Terminal 4 Removal Action. The screened technologies are monitored natural recovery; sediment capping; sediment dredging; dredged sediment transport; dredged sediment treatment; and dredged sediment disposal. Based on the analysis summarized here, most of these technologies were found to be effective, implementable, and applicable to the characteristics of Terminal 4 in whole or in part. In particular:

- Monitored natural recovery was found to be feasible at portions of Berth 401, Wheeler Bay, and Slip 1 and at the North of Berth 414 subarea.

- Capping was found to be feasible for both slips. The types of caps that might be needed to control erosion on steep slopes, such as concrete mattresses, were retained for further consideration during the design phase. Sand or gravel caps were retained for further consideration in parts of the Removal Action Area where the slopes are less steep and areas are less exposed to hydraulic forces and erosional impacts. Absorbent caps were not retained, because the site conditions may not necessitate their use.

- Dredging was found to be feasible for both slips. The specific technology types with greatest applicability to conditions at Terminal 4 are mechanical dredging using an open clamshell bucket, mechanical dredging using an enclosed clamshell bucket, and hydraulic cutterhead dredging using a cutterhead dredge.

- The transport technologies of truck, rail, barge, and pipeline are all feasible and none of the technologies was eliminated from consideration for the Terminal 4 Removal Action. However, if the dredged material is disposed of in an onsite CDF, pipeline transport from Slip 3 or from a barge would likely be used depending on the type of dredging.

- Treatment was not found to be feasible for the conditions prevailing at Terminal 4. No treatment technology was retained for inclusion in the development of Removal Action alternatives because the cost of treatment is relatively high, there is no Oregon market for the end product, and no vendor of a process with potential applicability to the Removal Action Area sediments was interested in pursuing a project of this limited size and duration. Therefore, sediment treatment technologies were not considered in the development of Removal Action alternatives.

- Both offsite disposal at a USEPA-approved landfill and onsite disposal in a CDF were found to be feasible and were considered in the development of Removal Action alternatives. Dewatering and stabilization with a drying agent were retained as materials handling technologies that may be considered to facilitate transport and disposal of dredged sediment.

B.5 References

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Table B-1
Results of Prescreening of Dredging Technologies

Technology	Retained for further screening?	Rationale
Hopper	no	Equipment is too large, prone to cause resuspension and lacks vertical and horizontal accuracy needed to address site conditions. Developed for and extensively used in port and waterways navigational dredging. Not used in environmental applications.
Dustpan	no	Equipment is too large, prone to cause resuspension and lacks vertical and horizontal accuracy needed to address site conditions. Developed for and extensively used in river channel navigational dredging. Not used in environmental applications.
Bucket ladder	no	Equipment is too large and prone to cause resuspension and lacks vertical and horizontal accuracy needed to address site conditions. Developed for and extensively used in gravel and sand mining, and not used in environmental applications.
Drag-line	no	Equipment is too large and prone to cause resuspension and lacks vertical and horizontal accuracy needed to address site conditions. Developed for and extensively used in surface mining applications, and not used in environmental applications.
Dry excavation	no	Procedure requires dewatering the entire area of extent of sediment contamination. Considering the depth of water at the site, the time required to implement the technology, dewatering is regarded impractical.
Open Clamshell Bucket	yes	Widely used in environmental dredging applications. Can achieve good vertical and horizontal accuracy with relatively high resuspension. Compatible with site conditions.
Enclosed Clamshell Bucket	yes	Widely used in environmental dredging applications. Can achieve good vertical and horizontal accuracy with relatively low resuspension. Compatible with site conditions.
Barge-Mounted Excavator with Conventional Bucket	yes	Can achieve relatively good vertical and horizontal accuracy with little resuspension. Specifically developed for environmental dredging. Little amount of documented production level past performance is available, and suitable for shallow (<25ft) dredging.
Barge-Mounted Excavator with Bucket-Closing Mechanism	yes	Can achieve relatively good vertical and horizontal accuracy with moderate resuspension. Specifically developed for environmental dredging. Documented past performances available, but suitable mainly for shallow (<25ft) dredging
Cutterhead	yes	Widely used in environmental dredging applications. Can achieve good vertical and horizontal accuracy with relatively low resuspension and high production rates.
Horizontal Auger	yes	Widely used in environmental dredging applications. Can achieve good vertical and horizontal accuracy with relatively low resuspension and high production rates.
Plain Suction	yes	Widely used in environmental dredging applications. Can achieve good vertical and horizontal accuracy with relatively low resuspension.
Diver-Assisted Hydraulic Suction Dredge	yes	Widely used in environmental dredging applications. Can achieve good vertical and horizontal accuracy with relatively low resuspension.
Oozer Pump	yes	Widely used in environmental dredging applications. Can achieve good vertical and horizontal accuracy with relatively low resuspension.
Pneuma Pump	yes	Widely used in environmental dredging applications. Can achieve good vertical and horizontal accuracy with relatively low resuspension.
Toyo Pump	yes	Used in mining, pond cleanout and sometimes in environmental dredging applications. Can achieve good vertical and horizontal accuracy with relatively low resuspension and high production rates.
Eddy Pump	yes	Developed specifically for environmental dredging applications. Can achieve good vertical and horizontal accuracy with relatively low resuspension. Number of documented past project performance is available.

Table B-2
Environmental Dredge Technology Screening Matrix

Dredge Technology	Sediment Resuspension	Availability	Site Compatibility / Technical Feasibility	Percent Solids	Production Rate	Past Performance	Retained?	Rationale
Open Clamshell Bucket	High due to sloughing of cut, washout and spillage from open bucket, etc.	Widely available on West Coast through a relatively large number of contractors	Generally compatible with site characteristics; slope dredging possible, but at low efficiency; debris can cause problems and increase resuspension. Higher precision than excavators.	Near in-situ.	Rates for 5- to 10-cy buckets range from about 75 to 300 cy/hr. Larger buckets are available up to about 60 cy and may produce 600+ cy/hr. Production is typically less on slopes (40 to 100 cy/hr). May be difficult or unable to dig through hard sediments.	Used widely in U.S.	Yes	Widely Available, well established technology that is generally compatible with site conditions if offsite disposal is the selected disposal technology.
Enclosed Clamshell Bucket	Low to moderate. Up to 25 to 70% reduction in resuspension compared to open clamshell.	Barge-mounted cranes widely available. Enclosed buckets are available through US based manufacturers (e.g. Cable Arm Inc.).	Generally compatible with site characteristics; slope dredging possible, but at low efficiency; debris can cause problems and increase resuspension. Higher precision than excavators.	Near in-situ.	Rates for 5- to 10-cy buckets range from about 75 to 300 cy/hr. Larger buckets are available up to about 60 cy and may produce 600+ cy/hr. Production is typically less on slopes (40 to 100 cy/hr).	Evaluation by USACE in 1982 showed significant reduction in turbidity.	Yes	Similar or slightly lower availability as Open Clamshell Bucket, well established technology generally compatible with site conditions if offsite disposal is the selected disposal technology. Lower resuspension than Open Clamshell Bucket.
Barge-Mounted Excavator with Conventional Bucket	High. Similar to open clamshell.	Some available in California.	Can achieve only limited dredge depth (<25 feet); fairly good debris handling capabilities; slope dredging possible, but likely inefficient. Higher precision than cable-operated clamshells.	Near in-situ.	Production rates are likely slightly lower than crane operated clamshell; dependent on bucket size.	An instrumented excavator was used to dredge 162,000 cy of PAH contaminated sediments in Bayou Bonfouca, LA.	Possible	Limited availability and not as compatible with site conditions as and slower production rates than Cutterhead, Open and Enclosed Clamshell Bucket dredges. However, retained as possible because of proven past performance.
Barge-Mounted Excavator with Bucket-Closing Mechanism	Low to moderate. Less resuspension as compared to open clamshell and conventional excavator.	Availability may be very limited.	Can achieve only limited dredge depth (<25 feet); debris may cause difficulty associated with closing mechanism; slope dredging possible, but likely inefficient. Higher precision than cable-operated clamshells.	Near in-situ.	Production rates are likely slightly lower than crane operated clamshell; dependent on bucket size.	Visor Grab was tested for Environment Canada's Great Lakes project. Additional testing may be needed.	No	Limited availability; not as compatible with site conditions as Open and Enclosed Clamshell Bucket; production rates are slower; performance not well established.
Cutterhead	Low to moderate. Less resuspension than open-bucket mechanical dredges, but dependent on dredge design and operation.	Widely available on West Coast.	Generally compatible with site characteristics; slope dredging may be difficult and inefficient with cutterhead attached; relatively poor debris handling capabilities.	5% to 20% by weight	Rates for 6- to 12-inch pumps range from about 25 to 120 cy/hr. Larger pumps are available up to about 30-inches and may produce 1000+ cy/hr.	Used widely in the U.S. for maintenance and environmental dredging (e.g. Sitcum Waterway, Tacoma, WA).	Yes	Lower resuspension than Open Shell Bucket; widely available, well established technology; compatible with site conditions; high production rates. Would need a CDF onsite to be viable due to high water content of dredged material.
Horizontal Auger	Low to moderate. Less resuspension mechanical dredges and possibly less than cutterhead dredge.	Some available in Oregon and California.	Dredge depth limited to 15 to 30 feet; Slope dredging difficult and inefficient; relatively poor debris handling capabilities.	5% to 20% by weight	Rates for 6- to 12-inch pumps range from about 25 to 120 cy/hr.	Developed in the U.S. and used on several projects (e.g., Cold Spring, NY)	possible	Not widely available in this area. However retained as possible because it has low to moderate resuspension (similar to Cutterhead) and is a widely established technology, is compatible with site conditions. Would need a CDF onsite to be viable due to high water content of dredged material.
Plain Suction	Low to moderate; no mechanical action to dislodge material.	Few available in California.	Better suited for smaller dredge volumes; slope dredging possible at lower efficiency.	5% to 20% by weight	25 to 120 cy/hr.	"Matchbox" dredge was used in the Calumet Harbor demonstration project by the Waterways Experiment Station.	possible	Limited availability and better suited for smaller dredge volumes. However, retained as possible because it might be useful technology for slope dredging.
Diver-Assisted Hydraulic Suction Dredge	Low due to precision, small size of dredge head, and slow operation.	Availability likely very limited.	May be well suited for certain areas such as areas with limited access (e.g. between piles); generally not well suited for large volumes.	<5% by weight	15 to 30 cy/hr.	Used for removal in smaller areas (e.g., Manistique River, MI; removal of 8,000 cy of PCB contaminated sediments)	possible	Very limited availability and only useful for limited dredge volumes. However retained as possible because it may be suitable for limited high slope areas.
Oozer Pump	Low. However, debris can clog pump causing increased resuspension.	Likely not available in the US.	Generally compatible with site characteristics; slope dredging would probably be difficult; debris can cause problems and increase resuspension.	25% to 80% by weight	40 to 300 cy/hr.	Used extensively in Japan.	No	Likely not available in the U.S.
Pneuma Pump	Low. However, debris can clog pump causing increased resuspension.	Not widely available. (Has been used in Pacific NW)	Generally compatible with site characteristics; slope dredging would probably be difficult; debris can cause problems and increase resuspension.	25% to 80% by weight	40 to 300 cy/hr.	Duwamish River, Seattle, WA, 1976, PCB cleanup, very low turbidity.	No	Limited availability and high water content would require significant dewatering or stabilization prior to offsite disposal.
Toyo Pump	Low	Not widely available (has been used in Pacific NW)	Generally compatible with site characteristics; slope dredging is probably feasible, but not without difficulty; can handle up to 5-inch rock.	Up to about 70% by weight	30 to 200 cy/hr.	Used to remove 32,000 cy of highly contaminated sediments from the Hylebos Waterway in Tacoma, WA.	No	Limited availability and high water content would require significant dewatering or stabilization prior to offsite disposal.
Eddy Pump	Low	Not widely available. (Has been used in Pacific NW)	Generally compatible with site characteristics; slope dredging is probably feasible, but not without difficulty; can handle up to 5-inch rock. Suitable to pump slurry over relatively long distances.	Up to about 70% by weight	100 to 300 cy/hr.	Has been used on several environmental dredging projects e.g. removing 50,000 cy sediment in Sarnia, ONT.	No	Limited availability and high water content would require significant dewatering or stabilization prior to offsite disposal.

Table B-3
Transport Technology Screening Matrix

Transport Technology	Protectiveness of Public and Construction Personnel	Technical Feasibility	Availability	Cost	Retained?	Rationale
Truck	Accidents during rehandling possible; truck traffic on site and off site increases potential for accidents; exhaust fumes affect air quality; spills and leakage possible, but generally preventable.	Generally feasible; capacity may be exhausted during high dredge production (consider combination with other transport technologies) requires on-site transload facility.	Generally available, but may require large number of trucks if trucking is used by itself (may have to combine with other transport technologies)	Relatively high cost compared to other technologies.	Yes	Generally feasible and available; however is most costly option and may not have the capacity of meeting dredge production rates. Retained because it may be needed to supplement other technologies or if other technologies are not available at the time of the action.
Rail	Generally fairly safe transport technology; accidents during rehandling possible; spills and leakage possible, but generally preventable.	Requires on-site transload facility; would need to construct additional rail spurs if Kinder Morgan facility is not available for use.	Widely available. Terminal 4 has rail access and many offsite disposal facility also have rail access.	Moderate, smaller than truck transport unless construction of additional rail spurs is required.	Yes	Feasible if an on-site transload facility can be constructed.
Barge	Rehandling required at transload facility; accidents during transport unlikely; minimal impact to air quality	Compatible with site conditions and other technologies.	Generally available, but could be problematic depending on other on-going projects at the time of construction.	Probably comparable to rail transport. Capital cost can be high if the contractor needs to purchase barges in case there are not rentals available.	Yes	Feasible and available.
Pipeline	No rehandling; dredged material is pumped directly to disposal point in CDF; virtually no air quality impacts.	Highly feasible in conjunction with on-site disposal and hydraulic dredging (or similar). However, not practicable with off-site disposal or with mechanical dredging.	Pipeline is widely available.	Low.	Yes	Feasible with onsite disposal.

Table B-4
Summary Statistics for Dredge Prism Sediment

Compounds	Maximum Detected Concentration (a)	Minimum Detected Concentration (a)	Average Detected Concentration (b)
Metals (mg/kg)			
Arsenic	15.1	0.90	3.58
Cadmium	4.44	0.047	0.562
Chromium	33.2	7.11	19.1
Copper	72.4	9.30	29.4
Lead	681	2.08	54.7
Mercury	0.273	0.009	0.0638
Nickel	29.9	9.21	19.5
Selenium	2.58	0.04	0.15
Silver	1.46	0.02	0.24
Zinc	768	30.4	120
Semivolatile Organics (ug/kg)			
Total PAHs (c,d)	602,953	12.4	17,901
Pesticides (ug/kg)			
Σ DDTs (c,e)	186	1.19	13.7
PCBs (ug/kg)			
Total PCBs (c,f)	1,320	26.2	91.0
Petroleum Hydrocarbons (mg/kg)			
Diesel Range Organics (DRO)	580	9.10	101
Residual Range Organics (RRO)	1,200	5.90	258
Gasoline Range Organics (GRO)	7.30	1.40	2.02
Conventionals (percent)			
Total organic carbon	3.71	0.04	1.11
Total solids	92.2	45.0	67.3
Grain Size (percent passing by weight) (g)			
Gravel No. 3/4" (19.0 mm)	100	96.4	100
Gravel No. 3/8" (9.50 mm)	100	96.2	99.8
Gravel, Medium No. 4 (4.75 mm)	100	96.2	99.8
Gravel, Fine No. 10 (2.00 mm)	100	96.2	99.7
Sand, Very Coarse No. 20 (0.850 mm)	100	93.1	98.8
Sand, Coarse No. 40 (0.425 mm)	99.9	49.8	83.3
Sand, Medium No. 60 (0.250 mm)	99.6	7.30	58.7
Sand, Fine No. 140 (0.106 mm)	98.4	2.27	49.2
Sand, Very Fine No. 200 (0.0750 mm)	95.7	2.13	46.1
Silt (0.074 mm)	92.5	0.68	40.4
Clay (0.005 mm)	53.8	0.31	17.7
Clay (0.001 mm)	38.0	0.18	8.05

a. The maximum and minimum detected concentrations are calculated on all data (detected and not detected results). For not detected results, half of the detection limit was used for the calculation.
b. The average detected concentration calculation includes all data (detected and not detected results). For not detected results, half of the detection limit was used for the calculation. The average is the average of sample results; it does not account for the volume of dredged material associated with each sample.
c. Total concentrations are calculated using all the data (detected and not detected results). For not detected results, half of the detection limit was used for the calculation.

d. Swartz, 1999, which MacDonald et al., 2000a references as the source of the PAH screening levels, describes the total PAH criteria as the sum of the following polycyclic aromatic compounds: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, and benzo(a)pyrene.
e. Σ DDTs criteria represent the sum of the following compounds: 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, and 4,4'-DDT.
f. MacDonald et al., 2000b, which MacDonald et al., 2000a references as the source of the PCB screening levels, does not describe which individual Aroclors make up the total PCB criteria. It was assumed that total PCBs consisted of all the Aroclors that were analyzed for (Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, Aroclor 1260, Aroclor 1262, and Aroclor 1268).
g. Grain size analysis was performed by sieve and hydrometer (ASTM D 422). There were occasional calibration discrepancies between the sieves and hydrometer which are inherent in the method. These discrepancies occasionally resulted in an increase in the percent passing fraction between very fine sand and silt. As these discrepancies are inherent in the method, the data are considered acceptable for use.

Table B-5 Identification and Screening of Potentially Applicable Sediment Treatment Technologies

Technology Type:	Thermal
Technology Process Option:	Cement-Lock Technology
Vendor:	Gas Technology Institute (formerly ENDESCO Clean Harbors, LLC) – Mike Mensinger Senior Chemical Engineer*
Is this technology applicable to the sediment profile (contaminants, concentrations and volume)?	Yes. Have treated sediments with higher concentrations (New Town Creek project). Destruction and removal efficiency ranges (based on pilot-scale facility) from >99.13 % (Total TCDD/F - TEF basis) to >99.99 (PCBs)[1]
Does the vendor take title to the sediments once the material arrives at their facility?	Yes.
Is this treatment process currently commercially available?	No. Only equipment available is in New Jersey at a demonstration project.
What is the facility throughput (hourly basis)?	System is modular. For demonstration project, one module treats 1 cy/hour. Can increase throughput by use of oxygen enrichment or add additional modules. A production-scale facility is anticipated to process almost 13 cy/hour.
What waste products are generated?	Any large pieces of debris removed by the dredging operation are landfilled. Spent carbon is sent to a recycler.
What if (any) end product is produced? Is there a market for the end product? If, yes what is the market and are there any contractual arrangements?	Eco-Melt is the end product and is similar to a granulated blast furnace slag. Uses include blending with Portland cement. No contract for sale of Eco-Melt.
Has DEQ or other regulatory agency been involved with evaluating beneficial uses of the end product?	No. Gas Technology Institute. has not worked with any agencies in Oregon.
How much land is required to construct the facility?	7 acres for 100,000 ton/year module. Depends on dredging schedule and how many acres required for storage.
What types of permits have been required to construct the facility?	Air permit, building permit.
What is the per ton cost for the treatment once the dredged material has arrived at the facility?	Couldn't give a number for 200,000 cy project. Small project has high fixed costs.
What if the minimum volume of dredged material needed to develop an economically viable treatment facility?	Unlikely to be interested in a 1 time project of 200,000 cy. $25 Million investment for one module. Looking for long term situation with a minimum of 100,000 cy/year for 10 to 20 years.

* Mike Mensinger was interviewed via telephone on September 9, 2004.
1 Rehmant, A, Anthony Lee, Michael C. Mensinger, and Anil BGoyal, 1999. Cement-Lock™ Technology for Decontaminated Dredged Estuarine Sediments Phase II: Pilot-Scale Studies, March 24, 1999.

Table B-5 Identification and Screening of Potentially Applicable Sediment Treatment Technologies

Technology Type:	Thermal
Technology Process Option:	Plasma Pyrolysis Vitrification System
Vendor:	Solena Group (formerly Global Plasma Treatment) – Dennis Miller Chief Scientist/Vice President*
Is this technology applicable to the sediment profile (contaminants, concentrations and volume)?	Yes. Have treated more contaminated material. Destroy organics at 99.99999%. Technology is used for a variety of waste streams including contaminated scrap metal, municipal solid waste, rice husks, lignite, cruise ship wastes. Experience with just sediments limited.
Does the vendor take title to the sediments once the material arrives at their facility?	Solena Group provides the technology license to a company that owns/operates a facility. Ownership of the sediment is the responsibility of the owner/operator.
Is this treatment process currently commercially available?	Yes. The technology is in use in the United State and around the world.
What is the facility throughput (hourly basis)?	Depends.1 to 40 tons/hour. Average is about 20 tons/hour. Will run 24 hours/day 7 days/week.
What waste products are generated?	None.
What if (any) end product is produced? Is there a market for the end product? If, yes what is the market and are there any contractual arrangements?	Synthesis gas and vitrified slag. Synthesis gas cleaned and used for electricity generation with gas turbines. Vitrified slag can be made into a variety of products including bricks, tile, or sand. Contracts are negotiated by owner/operator not Solena Group.
Has DEQ or other regulatory agency been involved with evaluating beneficial uses of the end product?	Solena Group has not worked with any agencies in Oregon.
How much land is required to construct the facility?	7 acres and possibly more for storage of dredged material.
What types of permits have been required to construct the facility?	Air permit, building permit. Not clear how regulated in Oregon.
What is the per ton cost for the treatment once the dredged material has arrived at the facility?	Would need to conduct feasibility study to provide costs. Have not calculated costs for such a small amount of sediment. For a one time project, not worth evaluating.
What if the minimum volume of dredged material needed to develop an economically viable treatment facility?	Not interested in dredged material from one project. Want minimum volume of 500,000 tons/year (volume after dewatered) for at least 15 years. For small facility, capital investment is $40-80 million.

* Dennis Miller was interviewed via telephone on September 17, 2004.

Table B-5 Identification and Screening of Potentially Applicable Sediment Treatment Technologies

Technology Type:	Thermal
Technology Process Option:	Rotary Kiln
Vendor:	Bay Cycle (formerly JCI/Upcycle) – Rudy Maes Director of Technical Development
Is this technology applicable to the sediment profile (contaminants, concentrations and volume)?	Yes. Would want sediment quality information on other pesticides and dioxins and furans. If these constituents are present in significant concentrations, thermal oxidizer would be needed. Data on percent destruction is confidential. Data on removal efficiency is required as part of air permitting.
Does the vendor take title to the sediments once the material arrives at their facility?	Yes.
Is this treatment process currently commercially available?	Not yet. It is expected to be commercially available in 6 to 12 months.
What is the facility throughput (hourly basis)?	20 tons/hour. Will run 24 hours/day 7 days/week.
What waste products are generated?	Air emissions and if pre-treatment required waste water.
What if (any) end product is produced? Is there a market for the end product? If, yes what is the market and are there any contractual arrangements?	Light weigh aggregate (similar but lighter than gravel) that is used in the construction industry. There is a market for light-weight aggregate. Same existing customer base as recycled concrete, recycled asphalt and other construction/demolition material. Contracts in these existing markets are used to sell light-weight aggregate.
Has DEQ or other regulatory agency been involved with evaluating beneficial uses of the end product?	Bay Cycle has not worked with any agencies in Oregon.
How much land is required to construct the facility?	A minimum of 3 ½ acres is needed. The building and associated covered area is 2 ½ acres plus 1 acres of outside area. Depending on the dredging program more area for storage would be needed.
What types of permits have been required to construct the facility?	Air permit, water discharge permit possible, building permit.
What is the per ton cost for the treatment once the dredged material has arrived at the facility?	$100-$150/ton.
What if the minimum volume of dredged material needed to develop an economically viable treatment facility?	50,000 tons.

* Rudy Maes was interviewed via telephone on September 13, 2004. Clarification on information was obtained via an email dated 9/13/04.

Table B-5 Identification and Screening of Potentially Applicable Sediment Treatment Technologies

Technology Type:	Thermal
Technology Process Option:	Desorption
Vendor:	RemTech – Keith Carpenter President
Is this technology applicable to the sediment profile (contaminants, concentrations and volume)?	Yes. May need pre-treatment for metals including possible stabilization. May need review of any restricted beneficial uses due to metal content. Most work on drilling muds which is similar to dredged sediment. Data on percent removal required as part of air permitting. Data on percent removal was not provided during the telephone interview or in response to follow-up email.
Does the vendor take title to the sediments once the material arrives at their facility?	No. RemTech does not take title at a temporary site. RemTech has a fixed facility in Spokane and if the material is processed there, RemTech takes title to the sediment
Is this treatment process currently commercially available?	Yes.
What is the facility throughput (hourly basis)?	40 tons/hour. Will run 24 hours/day 7 days/week.
What waste products are generated?	Air emissions, waste water and spent carbon/organo clay.
What if (any) end product is produced? Is there a market for the end product? If, yes what is the market and are there any contractual arrangements?	"Clean" dredge material suitable for use in a capping project, on-site fill or stock pile for beneficial use. No contracts are in place. Beneficial use is negotiated on a project by project basis.
Has DEQ or other regulatory agency been involved with evaluating beneficial uses of the end product?	Yes. RemTech has worked with DEQ on projects near Baker and in Coos Bay, Oregon. These projects were treatment of soils and the treated material was used on-site.
How much land is required to construct the facility?	Equipment requires about 1 acre. Additional acreage would be required for storage of dredged sediment and storage for treated sediment.
What types of permits have been required to construct the facility?	Air permit, building permit, and water discharge permit.
What is the per ton cost for the treatment once the dredged material has arrived at the facility?	$50-$75/ton.
What if the minimum volume of dredged material needed to develop an economically viable treatment facility?	40-50,000 tons.

* Keith Carpenter was interviewed via telephone on September 9, 2004.

Table B-5 Identification and Screening of Potentially Applicable Sediment Treatment Technologies

Technology Type:	Thermal
Technology Process Option:	Vitrification
Vendor:	Minergy Corporation – Bob Paulson Manager of Business Development*
Is this technology applicable to the sediment profile (contaminants, concentrations and volume)?	Yes. Treatment effectiveness for PCB 99.99995% (destruction), for metals 99.9% (not destroyed) and for Dioxins 99.9% (destruction).
Does the vendor take title to the sediments once the material arrives at their facility?	Negotiable as part of contract.
Is this treatment process currently commercially available?	Yes.
What is the facility throughput (hourly basis)?	Depends on site. No limitation for size. 80 cy/hour or more. 2,000 tons/day or more.
What waste products are generated?	Flue gases and condensate blow down
What if (any) end product is produced? Is there a market for the end product? If, yes what is the market and are there any contractual arrangements?	Glass aggregate that is used in asphalt, general construction, replacement for Portland cement, admixture in cements and concretes, road base material. Some contracts for use as road base material. Other uses do not have contracts.
Has DEQ or other regulatory agency been involved with evaluating beneficial uses of the end product?	Minergy Corporation has not worked with any agencies in Oregon.
How much land is required to construct the facility?	Depends on how the dredged program is managed. If year round generation of sediment, need 2 acres. If need to store large quantity, facility gets large.
What types of permits have been required to construct the facility?	Air permit, water discharge, possible solid waste permit, and building permit.
What is the per ton cost for the treatment once the dredged material has arrived at the facility?	Have not considered or developed costs for project as small as 200,000 cy. Not sure this is worth considering. Other options like landfill are cheaper. Client needs to place high value on destruction of material to eliminate liability.
What if the minimum volume of dredged material needed to develop an economically viable treatment facility?	750,000 cy.

* Bob Paulson was interviewed via telephone on September 9, 2004.

Table B-5 Identification and Screening of Potentially Applicable Sediment Treatment Technologies

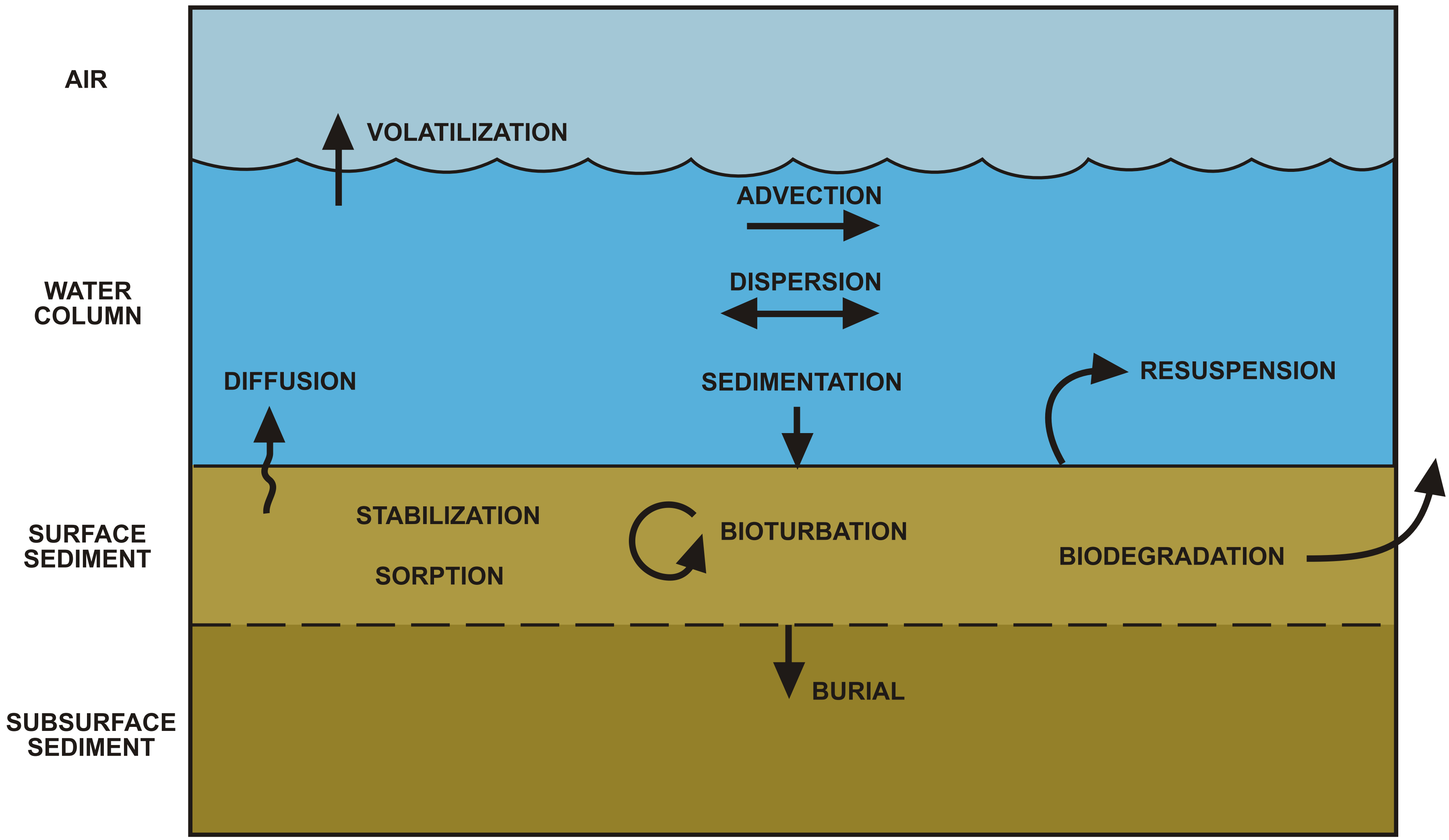
Technology Type:	Extraction
Technology Process Option:	Soil Washing
Vendor:	BioGenesis – John Sontag, P.E. Senior Program Manager*
Is this technology applicable to the sediment profile (contaminants, concentrations and volume)?	Yes. Would want a break down of specific PAHs. Percent removal ranges from 34% (individual PAH) to 92% (individual metal)[1].
Does the vendor take title to the sediments once the material arrives at their facility?	Yes.
Is this treatment process currently commercially available?	Almost. Looking for investors and want to license the technology. After New Jersey demonstration project, it will be more commercially available
What is the facility throughput (hourly basis)?	Commercial scale is 40 cy/hour. Will run 24 hours/day 7 days/week.
What waste products are generated?	Sludge is generated and comprises 1% of total incoming solids. Sludge contains metals precipitated out from sediment. Sludge is solid waste based on testing from pilot study.
What if (any) end product is produced? Is there a market for the end product? If, yes what is the market and are there any contractual arrangements?	Market and region dependent. In the northeast US, there is demand for topsoil so that is how the end product is marketed. In Venice, Italy, there is demand for manufactured brick so that is how the product will be marketed. Currently, there are no contracts for sale of the end product.
Has DEQ or other regulatory agency been involved with evaluating beneficial uses of the end product?	BioGenesis has not yet worked with anyone in Portland and does not have experience with the Oregon DEQ.
How much land is required to construct the facility?	Depends on how the dredging program is managed. Need five acres for treatment equipment and up to a total of an additional 25 acres if required to store all 200,000 cy at once.
What types of permits have been required to construct the facility?	Air permit, waterfront development permit (unload by barge), water discharge to river or sanitary sewer, building permit, possible solid waste permit for facility and consultation for beneficial use of product.
What is the per ton cost for the treatment once the dredged material has arrived at the facility?	$80-$100 cy.
What if the minimum volume of dredged material needed to develop an economically viable treatment facility?	There is not really a minimum—wouldn't want to rule anything out. Can do 200,000 cy but it will be expensive.

* John Sontag was interviewed via telephone on September 3, 2004. Clarification on information was obtained via emails dated 9/10/04 and 9/10/04.
1 BioGenesis Enterprises, Inc. and Roy F. Weston, 1999. BioGensis[SM] Sediment Washing Technology. Full Scale, 40 cy/hr, Sediment Decontamination Facility for the NY/NJ Harbor Region. Final Report on the Pilot Demonstration Project. December 1999.

Table B-5 Identification and Screening of Potentially Applicable Sediment Treatment Technologies

Technology Type:	Chemical
Technology Process Option:	Oxidation/Stabilization/solidification
Vendor:	Harbor Resource Management Group – Mike Behan – President*
Is this technology applicable to the sediment profile (contaminants, concentrations and volume)?	Appears to be. Would need more information about the chemical and physical properties of the dredged material. NJ pilot project focused on PAH reduction but also demonstrated reduction of PCBs, metals, and dioxins. To date, the treatment process has not focused on a mix of contaminants. The end use dictates the exact nature of the treatment. Percent reduction ranges from 20% for PCBs to 59.2 % for PAHs[1].
Does the vendor take title to the sediments once the material arrives at their facility?	Negotiable.
Is this treatment process currently commercially available?	Almost. Following successful completion of NJ demonstration project in the Spring 2005 expect the technology to be commercially available.
What is the facility throughput (hourly basis)?	25 cy/hour. Will run 12 hours/day.
What waste products are generated?	Waste water that is contained is shipped off-site for disposal at a permitted facility. Air emissions.
What if (any) end product is produced? Is there a market for the end product? If, yes what is the market and are there any contractual arrangements?	End product currently being used as fill material at the EnCap brownfield redevelopment project in East Rutherford, New Jersey. The East Rutherford site is permitted to take treated dredge material for various construction uses. Future plans included developing and marketing a manufactured soil product and possibly other materials. If fill is needed there is a market. No contractual arrangements but developed on a project by project basis.
Has DEQ or other regulatory agency been involved with evaluating beneficial uses of the end product?	Harbor Resource Management Group has not yet worked with anyone in Portland and does not have experience with the Oregon DEQ.
How much land is required to construct the facility?	Minimum 1 ½ acres for equipment and some storage. For NJ pilot project, processed material shipped the same day as it is processed. No need for large amount of storage. If needed to stock pile in-coming dredging material and treated sediment, more land would be required. Do not want to stock pile onsite. Prefer to stock pile treated sediment at end use site.
What types of permits have been required to construct the facility?	Air permit and possibly a wastewater permit if wastewater cannot be shipped off-site, building permit.
What is the per ton cost for the treatment once the dredged material has arrived at the facility?	For pilot projects, per ton cost is estimated at $200. Goal is to get to $60/ton.
What if the minimum volume of dredged material needed to develop an economically viable treatment facility?	Don't know at this point. Front end costs for mob and demob are considerable. Looking for 500,000 cy to 1,000,000 cy a year for fixed facility. Situation requires "value" put on contaminant reduction so material can be used in commercial construction.

* Mike Behan was interviewed via telephone on September 14, 2004.
1 NUI Environmental Group, 2002. Sediment Decontamination Demonstration Project Final Pilot Study Report, February 2002.



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TERMINAL 4 EARLY ACTION
EE/CA REPORT

MONITORED NATURAL RECOVERY PROCESSES WHEN SOURCES ARE CONTROLLED

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B-1