APPENDIX F

UPDATED BANK STABILIZATION ALTERNATIVES ANALYSIS (UPDATE OF 2003 REPORT)

GASCO SITE

PORTLAND HARBOR, OREGON

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ACB	Articulated Concrete Block
bgs	below ground surface
BMU	Bank Management Unit
BTEX	benzene, toluene, ethylbenzene, and xylene
CCS	Cellular Confined Systems
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
City	City of Portland
COPC	Chemicals of Potential Concern
DEQ	Oregon Department of Environmental Quality
DSL	Oregon Department of State Lands
EPA	Environmental Protection Agency
FAMM	Fuel And Marine Marketing
FEMA	Federal Emergency Management Agency
FS	Feasibility Study
GWFFS	Groundwater Focused Feasibility Study
JSCS	Joint Source Control Strategy
LWD	Large Woody Debris
LWG	Lower Willamette Group
MOU	Memorandum of Understanding
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OHWL	Ordinary High Water Line
OLWL	Ordinary Low Water Line
ORS	Oregon Revised Statutes
PAH	polycyclic aromatic hydrocarbons
RA	Risk Assessment
RAPP	Removal Action Project Plan
RCM	Reactive Core Mat
RI	Remedial Investigation
USACE	United States Army Corps of Engineers
EPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service

1 INTRODUCTION

In a letter dated January 22, 2003, the Oregon Department of Environmental Quality (DEQ) requested that NW Natural perform a focused evaluation of stabilization methods and develop alternatives to prevent the release of potentially contaminated riverbank soils at the Gasco site to the Willamette River located in Portland, Oregon (Figure 1). In accordance with this request, NW Natural submitted a bank stabilization evaluation report for DEQ's review in June 2003. Because NW Natural has yet to receive comments on the submittal, the purpose of this report is to update the 2003 submittal as necessary to incorporate existing information into the evaluation of potential bank stabilization alternatives and identify the preferred bank stabilization method to be incorporated into the Groundwater Focused Feasibility Study (GWFFS). The bank stabilization discussed herein is intended as an interim action that could become a permanent remedy for shoreline stabilization of soils pending future agency approval.

1.1 Project Background

The Gasco site has been impacted by historical industrial operations, which included oil gas production, creosote formulation, petroleum handling and shipping, and pencil pitch/coal tar pitch handling and transportation. The upland primary constituents of concern in soil and groundwater are polycyclic aromatic hydrocarbons (PAHs), and benzene and xylene (of the benzene, toluene, ethylbenzene, xylene [BTEX] monocyclic aromatic hydrocarbons), and cyanide. The highest concentrations of the organic constituents generally occur in areas with tar and oil residues. The nature and extent of upland contamination is described in Hahn (2007). The nature and extent of sediment contamination near the upland Site is described in Anchor Environmental (2005) and the Lower Willamette Group's (LWG) Round 2 Report (LWG 2007), respectively.

Since submittal of the document in 2003, the Site has continued to undergo a site Remedial Investigation (RI) and Feasibility Study (FS) under the Voluntary Cleanup Program to determine the extent of unacceptable soil and groundwater risk at the Site and to determine the most appropriate methods for cleanup at the Site. Following the 2003 submittal of this document, the following additional documents have been submitted to DEQ and/or United States Environmental Protection Agency (EPA) regarding environmental quality on the Site or in the adjacent Willamette River:

- Final Draft Remedial Investigation Report (Hahn 2007) – This RI report provides a description of Site hydrogeologic and contaminant characterization results based on the RI activities completed at the Site through 2005.
- Removal Action Project Plan (Anchor 2005) – Prepared under an Administrative Order on Consent with the EPA. Provides plans and design documents for implementation of EPA's selected remedy for conducting a non-time-critical removal of a tar body at the surface of the nearshore sediment adjacent to the Site. Contains sediment quality information gathered adjacent to the Site to support the removal action design.
- Final Phase 1 Field Sampling Approach – Gasco Siltronic Groundwater Source Evaluation (Anchor 2006a) – Developed to meet DEQ's request for more information related to contaminated groundwater along the shoreline of the Gasco and Siltronic properties and to perform a preliminary assessment of subsurface conditions for a potential vertical barrier. Provides the sampling rationale and general field data collection procedures for this investigation. Screens upland shoreline groundwater information consistent with the Final Joint Source Control Strategy (JSCS) document for Portland Harbor (DEQ and EPA 2005) and reviews offshore surface and subsurface sediment chemistry data collected in the area by the Lower Willamette Group (LWG), NW Natural, and Siltronic Corporation.
- Gasco Source Control Data Gaps Evaluation (Anchor 2006b) – Formally establishes the source control status of the Site, relative to the JSCS process, and identifies data gaps in existing information relevant to the JSCS process.
- Baseline Level III Ecological and Human Health Risk Assessment Report (Anchor 2003) – Completed the risk assessment process for the upland Site. DEQ has not completed its review of this document.

1.2 Project Objective

This document is primarily focused on bank stabilization measures that can be implemented on an interim basis to control potential erosion of the banks. These interim measures could become a permanent remedy for shoreline stabilization of soils pending agency approval. The actions recommended herein should be consistent with the upland removal actions identified in the GWFFS and also with the final upland or in-water remedy(ies), to the extent that these remedies can be anticipated.

1.3 Applicable Regulations

Bank stabilization activities may be required to comply with several federal, state, and local regulations, or the substantive requirements of these regulations. These requirements should be considered in the evaluation of bank stabilization alternatives. Under Oregon Revised Statutes (ORS) 465.315, the project need only comply with the substantive requirements state and local permits, while the permits themselves can be waived. Applicable regulations are described below and have not changed since the 2003 submittal. It is important to note that the bank stabilization will require a permitting process to comply with substantive requirements, but this will not affect timing for the groundwater barrier wall construction discussed in the GWFFS. As discussed in the GWFFS, these upland source controls can proceed independently of the bank stabilization measures. There are some reaches of the shoreline where subsequent bank stabilization measures could interfere with groundwater source control measures already in place, such as extraction wells, vertical barrier, or monitoring wells. These potential overlap areas will be dealt with during the design phase of the groundwater source control measures, so that future bank stabilization activities can be integrated without interfering with the in-place groundwater source control measures.

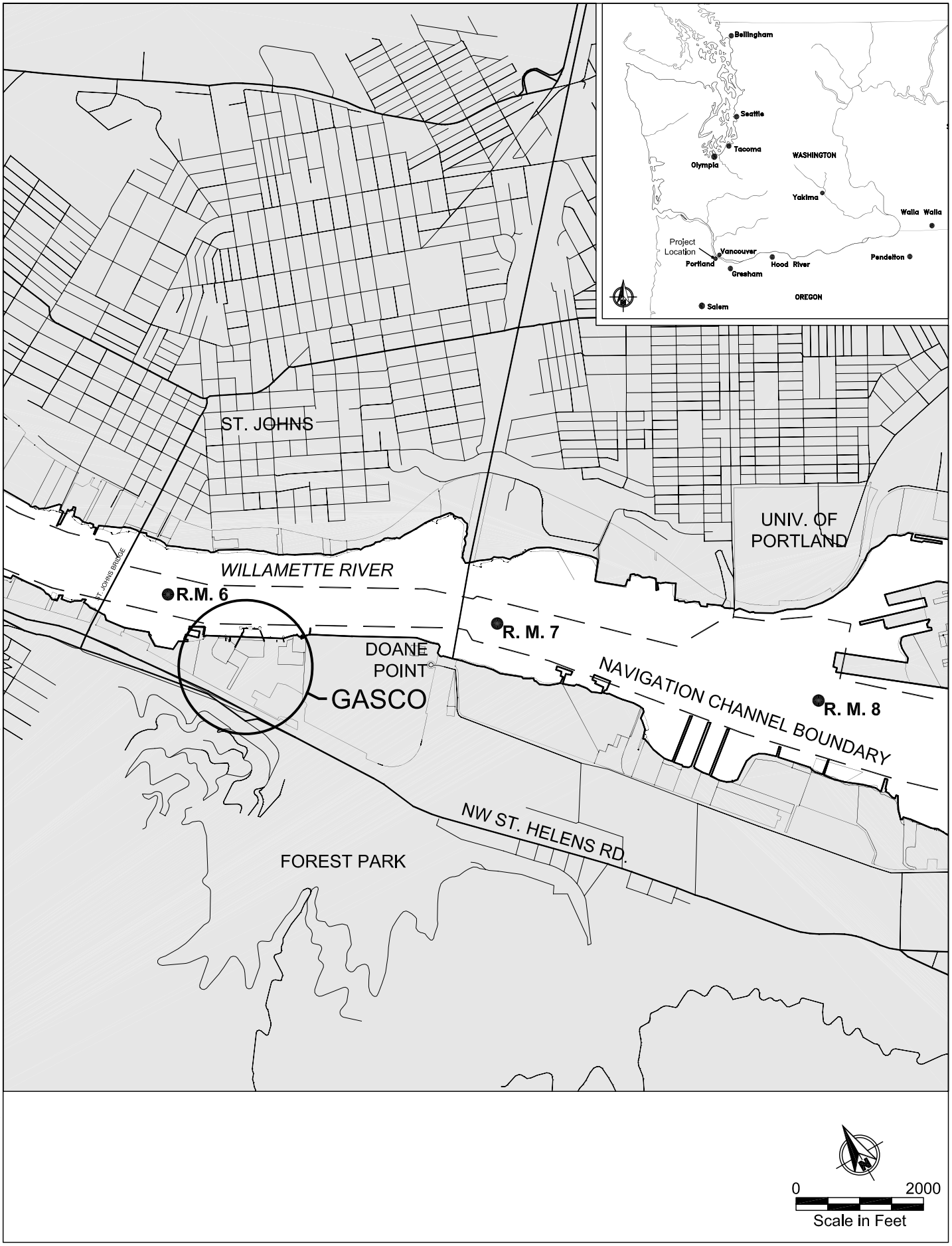

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Figure 1
Vicinity Map
Northwest Natural "Gasco" Site

1.3.1 EPA/DEQ: Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

EPA and DEQ are overseeing the in-water RI/FS and source control activities, respectively, for the Portland Harbor Superfund site. The framework for management coordination between DEQ and EPA on the Portland Harbor site is outlined in a Memorandum of Understanding (MOU) dated February 8, 2001. The MOU designates EPA as lead agency for in-water sediment work (and support agency for uplands source control), and DEQ as lead agency for upland source control (and support agency for in-water work). This bank stabilization analysis is being conducted under DEQ oversight to evaluate potential sources of erosion to the Willamette River and will be submitted to DEQ for review and approval of the preferred alternative.

1.3.2 USACE: Section 10 and Section 404 Permits

Work around navigable waters such as the Willamette River triggers a joint permit under Section 10 of the Rivers and Harbors Act, and Section 404 of the Clean Water Act. Section 10 requires approval of work in or over navigable waters, including excavation work. These permits apply to work conducted below the ordinary high water mark. Section 404 requires approval of work that may discharge fill material into waters of the nation. Depending upon the final alternative selected, this project may fall under the substantive requirements of a Nationwide General Permit or an Individual Permit. The permit contact will be United States Army Corps of Engineers (USACE), Portland District, Permitting Section for Multnomah County.

1.3.3 DEQ: Section 401 Water Quality Certification and NPDES Stormwater General Permit #1200-C

In addition to its role in source control, DEQ also has the authority to require permits to protect water quality under the Clean Water Act. Grading activities affecting greater than 1 acre of land above the ordinary high water mark will trigger the need for a National Pollutant Discharge Elimination System (NPDES) Stormwater General Permit #1200-C to provide erosion control to prevent sediments from entering waters of the state. This permit requires submittal of an Erosion and Sediment Control Plan prior to work. DEQ also reviews projects that require Federal Section 10 and Section 404 permits, and issues Section 401 Water Quality Certifications for such projects.

1.3.4 DEQ: Oregon Cleanup Statutes and Rules (ORS 465.003 to 465.034 and OAR 340-122)

State statutes and rules include a process for an RI to determine the extent of contamination an FS to determine cleanup alternatives for contaminated sites. The upland soil and groundwater at the Gasco Site is currently being evaluated through an RI/FS process.

1.3.5 NOAA Fisheries/U.S. Fish and Wildlife Service (USFWS): Endangered Species Act

When a federal permit application is submitted, and a listed threatened or endangered species is present in the action area, the federal agency must comply with the Endangered Species Act. The agency must make a determination as to whether the action may affect threatened and endangered species or critical habitat. If the agency determines that the action is not likely to adversely affect the species or habitat, NOAA/USFWS provides concurrence with their determination. If the action is likely to adversely affect the species or critical habitat, NOAA/USFWS requires a formal Section 7 consultation and prepares a biological opinion before the permit can be issued.

1.3.6 City of Portland: Floodplain Permits

The City of Portland (City) regulates construction in flood hazard areas that may cause increased flood height and velocity. Floodplain permits must be obtained for any construction, including grading, and require that no net filling occurs in flood management areas (cut must be greater than or equal to fill). Material that may block the floodway, such as riprap, may be replaced if it has eroded away; however, placement of additional material may trigger a hydraulic analysis, which may require a review by the City. However, there may have been some changes to this authority in recent years, and this would need to be explored more during design and permitting.

1.3.7 City of Portland: Greenway Permits

Under its greenway regulations, required by ORS 390.310 and 390.368, the City of Portland requires that a vegetated corridor ("greenway setback") be established along the Willamette River whenever there are changes to the land in a greenway overlay

zone. It appears that excavation as a result of bank stabilization may be sufficient to trigger the greenway regulations. Specifically, since the work will be within 75 feet landward of the top of the bank in a river industrial zone, the review process is triggered. A 25-foot setback is required from the top of the bank; however, the planting standards are somewhat flexible and may allow for unplanted areas within this area. Also, the City will consider an adjustment to the standards to allow for unplanted areas if these are mitigated for in other, wider areas.

1.3.8 City of Portland: Clearing and Grading Permits

Under Title 24, clearing permits are required in greenway overlay zones, and grading permits are required in most instances.

1.3.9 City of Portland: Erosion Control Permits

Under Title 10, the City requires erosion control permits to control the creation of sediment. The permit application is to be submitted with an Erosion, Sediment, and Pollutant Control Plan.

1.3.10 DSL: Removal Fill Permits

Streambank stabilization projects are usually subject to the Oregon Department of State Lands' (DSL) Removal Fill Rule, unless they are above the ordinary high water line (OHWL). Some of the proposed alternatives will not require work below the OHWL, and will therefore fall outside of DSL's jurisdiction. Where stabilization or buttressing of the toe is required, however, alternatives will extend below the OHWL, and the substantive requirements of a DSL permit will need to be met. Some alternatives also include flow deflection using barbs or large woody debris (LWD), work which is also typically done below the OLWL and will trigger DSL jurisdiction. The DSL permit is applied for jointly with the above-referenced USACE Section 10 and Section 404 permits.

2 BANK MANAGEMENT UNITS

The Gasco shoreline was divided into five Bank Management Units (BMUs) for the 2003 submittal, as shown on Figure 2 and described below. The BMUs represent sections of the Site shoreline with relatively similar physical, chemical, biological, and land use characteristics. Within each BMU, a consistent bank stabilization technique may be applied. These BMUs are still considered applicable, given that the existing Site conditions and present and anticipated future land use characteristics have not changed substantially. During the design process, methods will be developed so that construction of the vertical barrier wall and installation of groundwater extraction wells will be compatible with subsequent shoreline stabilization in each of the BMUs.

2.1 Delineation Criteria

The five BMUs (BMU-1 through BMU-5) were delineated on the basis of the following criteria:

- **Site Operations.** This criterion considers the nature of Site industrial operations, water-dependent use requirements, and boundaries of tenant lease areas. No changes have occurred since the 2003 submittal.
- **Site Structures**. This criterion considers the location and orientation of piers, docks, pipelines, storm drains, and other structures. No changes have occurred since the 2003 submittal.
- **Bank Morphology**. This criterion describes the conditions, materials, and slope of the bank; degree and type of vegetation; field evidence of sloughing; etc. The only observable change in bank morphology since 2003 is within a small area of BMU-2 where a portion of the nearshore sediments was removed along the sediment bench at the base of the shoreline slope. A pilot engineered cap was also placed here as part of the EPA Early Action tar body removal. This change is discussed below.
- **Bank Contamination**. This criterion describes the magnitude and extent of soil contamination on or adjacent to the bank. Such contamination could present a risk of release to the river during bank stabilization activities, either during or after construction. Since 2003, additional nearshore bank soil characterization was conducted to support the design of the EPA Early Action tar body removal. This additional information is discussed below. In addition, the Phase 1 offshore

groundwater borings were along the base of the shoreline slope, but do not generally represent bank material that is addressed under this alternatives analysis.

Previously in the 2003 submittal, soil and groundwater concentrations were summarized from the upper 35 feet below ground surface (bgs) of shoreline borings and monitoring wells (i.e., above approximately 0 feet elevation [City of Portland datum]). However, as discussed in Section 7 of the GWFFS, upland source controls will likely include a groundwater pump and treat system and a vertical barrier cutoff wall along some portions of the shoreline to prevent the migration of groundwater and DNAPL, respectively, into the adjacent Willamette River. The elimination of potential groundwater seepage through the bank precludes the need to include a summary of the upland groundwater quality, so this discussion has been removed from this report. The focus is now placed on observed soil quality that may present a risk of release to the river in any eroding areas. It is important to note that deeper strata of soils are unlikely to be exposed through erosion or during bank stabilization activities, and are therefore are not discussed herein.

The entire shoreline of the Gasco Site and all five BMUs share a few key characteristics. A shallow shelf extends from the dredged navigational channel to the toe of the shoreline slope except in a small area where the tar body removal action occurred. This shelf is about 100 feet wide and very gently sloped (approximately 9H:1V). It acts to buttress the existing riprap armor on the shoreline and minimize undercutting and toe erosion. The steeper (designed at 2.5H:1V) shoreline slope in the tar body removal area was designed with a 12-inch cap layer overlain by a 6-inch armor layer. The armor layer was selected to be protective of erosion during a 25-year design flow event. The Year 1 monitoring of the pilot cap documented that the armor layer was protective over the flow conditions encountered since placement. The unique characteristics of the individual BMUs are discussed below.

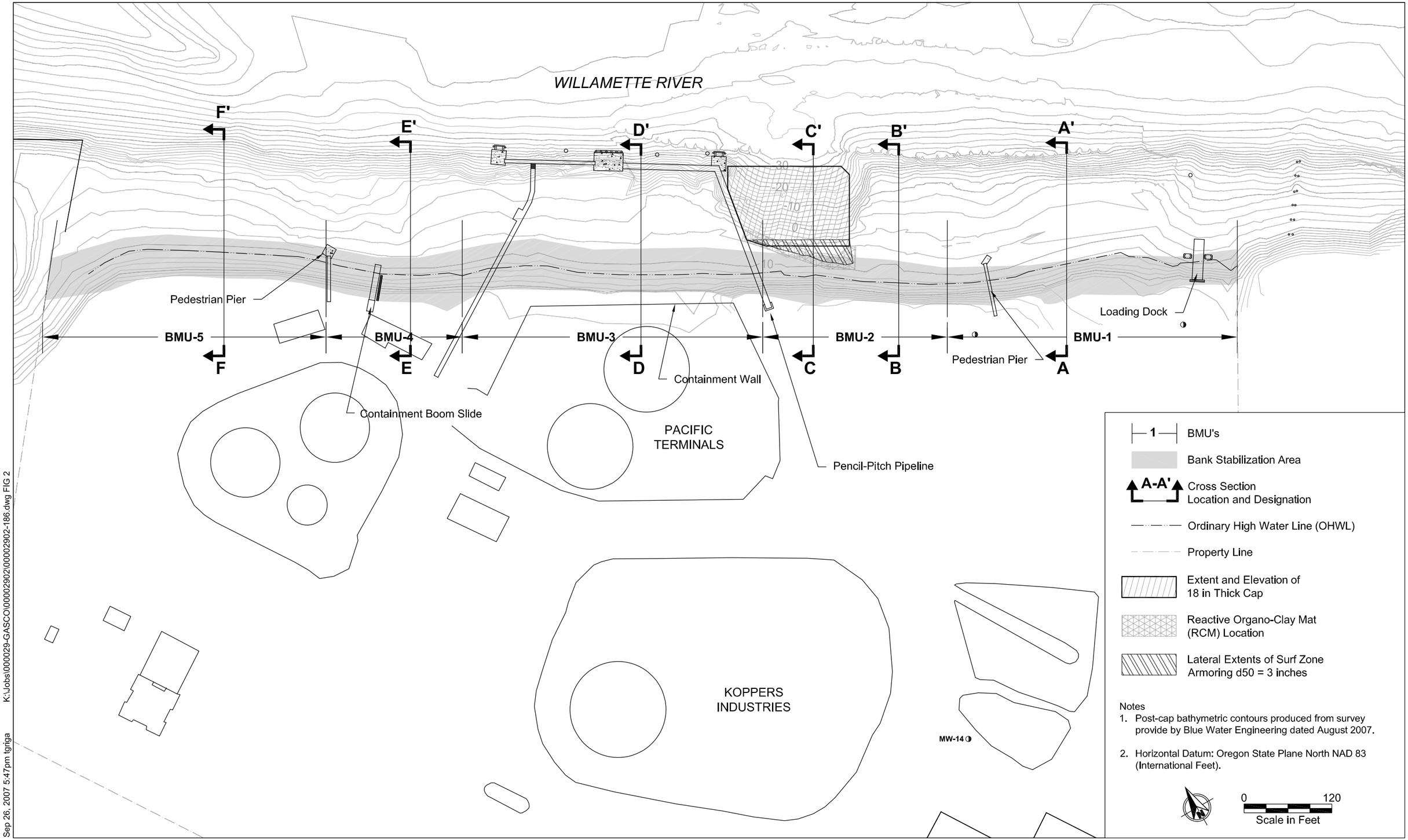

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Figure 2
Site and Cross Section Locations
Northwest Natural "Gasco" Site

2.2 BMU-1

BMU-1 extends from the upstream boundary of the Gasco site to the location of the primary Gasco stormwater outfall, covering approximately 390 feet of shoreline. An abandoned loading dock in disrepair is present on the upstream portion of this BMU, as well as a narrow pedestrian pier on the downstream portion. BMU-1, along with BMU-2, includes an upland area that may be leased in the future. If the lease is enacted, any shoreline uses will need to be integrated into the proposed shoreline stabilization and comply with Greenway regulations. We see no obstacles to such integration. Site conditions for BMU-1 are shown on Figure 3.

Figure 3 Existing Conditions Bank Management Unit 1 (looking upstream)

A complete description of the soil concentrations of chemicals of potential concern (COPCs) adjacent to BMU-1 is described in the *Gasco Source Control Data Gaps Evaluation for NW Natural* (Anchor 2006b).

During a 2003 site survey, the upper portion of the bank in this area (above +20 feet) was oversteepened, with some exposed soil escarpments. Slopes typically reached 1.5H:1V and

in some cases reached 1H:1V or more. The upper slope was covered primarily with Himalayan blackberry, Scot's broom, red elderberry, and blocky debris. Willow, black cottonwood, and Oregon ash trees were found near the top of bank. The lower slope including the toe appeared stable, and was armored with large rock (24 to over 36-inch), although armoring was somewhat inconsistent. General Site observations since 2003 indicate no significant changes of the shoreline vegetation, topography, or armoring. Prior to completing the design, it is anticipated that a shoreline survey will be conducted to update the existing vegetation types and potential erosional areas, if any.

2.3 BMU-2

BMU-2 extends downstream from the stormwater outfall (approximately 14-inch pipe outfall that discharges stormwater to the riverbank) to the upstream pipeline pier (pencil coal tar pitch pipeline), covering approximately 250 feet of shoreline. BMU-2, along with BMU-1, is adjacent to the upland area that may be potentially leased in the future. Site conditions for BMU-2 are shown on Figure 4.

Figure 4 Existing Conditions Bank Management Unit 2 (looking downstream)

The shoreline soils in BMU-2 contain the highest concentrations of COPCs on the Gasco bank. A complete description of the upland soil concentrations of COPCs adjacent to BMU-2 is described in the *Gasco Source Control Data Gaps Evaluation for NW Natural* (Anchor 2006b). As discussed in the 2003 submittal, these elevated concentrations are associated with tar globules and oily product at depth that likely accumulated in a topographic swale that drained the Former Tar Effluent Settling Pond Area. A description of the bottom of bank shoreline soil/sediment concentrations is provided in the Removal Action Project Plan (Anchor 2005).

Shoreline stabilization along BMU-2 will need to account for the presence of an installed organoclay geotextile below a portion of the extreme lower shoreline bank. During the tar body removal action construction, EPA provided NW Natural with a directed design change based on a request from DEQ. EPA specified the use of an organoclay product to cover the exposed dredge slope face along the nearshore dredge cut. Based on conditions at the Site, Anchor modified the design to include the use of a CETCO Organoclay Reactive Core Mat (RCM) across the entirety of the nearshore cut face. The RCM was then overlain by an armor layer to resist erosive forces in the surf zone. The Year 0 monitoring of the pilot cap in the removal action area has shown this armor layer to be protective of the erosive conditions encountered to date.

Shoreline stabilization in BMU-2 will need to work around the stormwater outfall and include features that prevent erosion from the discharge of the stormwater, should stabilization be needed in this portion of BMU-2.

During a 2003 site survey, the upper portion of the bank in this area (above +20 feet) was oversteepened, with consistently steep slopes reaching 1H:1V. The upper bank was covered primarily with Himalayan blackberry, Scot's broom, willows, big leaf maples, and blocky debris. The lower bank and toe of slope appeared to be relatively stable, but lacked consistent coverage of large rock. General Site observations since 2003 indicate no significant changes of the shoreline vegetation, topography, or armoring. Prior to completing the design, it is anticipated that a shoreline survey will be conducted to document the existing vegetation types and potential erosional areas, if any.

2.4 BMU-3

BMU-3 is the bank between the upstream (pencil coal tar pitch) pipeline pier and the downstream (fuel), pipeline pier, covering approximately 410 feet of shoreline. BMU-3 is located adjacent to Fuel and Marine Marketing's (FAMM's) aboveground petroleum storage tanks and containment area, and is largely protected from wake waves by the transfer dock. The containment area is defined by the freestanding concrete wall (Figure 5) that was undermined by floodwaters in 1996.

Figure 5 Existing Conditions Bank Management Unit 3 (looking downstream)

A complete description of the soil concentrations of COPCs adjacent to BMU-3 is described in the *Gasco Source Control Data Gaps Evaluation for NW Natural* (Anchor 2006b). Also, a portion of the tar deposit on the bank of BMU-2 extends beneath the pencil coal tar pitch pipeline into the upstream portion of BMU-3. This portion of the tar body was not removed during the early action removal due to a number of physical constraints. Outside of the drainage swale, there is no visible evidence of tar.

During a 2003 site survey, the top of the bank in BMU-3 was at a lower elevation compared to the rest of the shoreline, with relatively stable bank slopes between 4H:1V and 3H:1V.

However, there was a small escarpment, approximately 1 to 2 feet high, at the top of the bank near the tank containment wall. The bank in this area was comprised of sandy and gravelly fill material. Vegetation was mostly herbaceous weeds, grasses, and Scot's broom. The lower bank showed accretionary morphology including drift logs and a finer-grained gravel beach. The piers and dock appeared to dampen the river energy, allowing finer material to accumulate along this part of the shoreline. General Site observations since 2003 indicate no significant changes of the shoreline vegetation, topography, or armoring. Prior to completing the design, it is anticipated that a shoreline survey will be conducted to document the existing vegetation types and potential erosional areas, if any. Site conditions at BMU-3 are shown on Figure 5.

2.5 BMU-4

BMU-4 extends from the downstream (fuel) pipeline pier to a downstream pedestrian pier, covering approximately 185 feet of shoreline. This bank in this area has an emergency slide for deploying spill containment booms. BMU-4 is located next to FAMM office buildings; a second containment area with aboveground fuel storage tanks is located about 100 feet back from the top of the bank.

A complete description of the soil concentrations of COPCs adjacent to BMU-4 is described in the *Gasco Source Control Data Gaps Evaluation for NW Natural* (Anchor 2006b). No visible evidence of tar has been found in bank soils along this reach of the shoreline.

During a 2003 site survey, the top of the bank in BMU-4 was steeply graded at 2H:1V. The bank in this area was comprised of sandy and gravelly fill material. In general, the bank was well vegetated, with species such as red alder, willow, and beaked hazelnut, although intermittent bare patches were exposed indicating local areas of unstable soils. General Site observations since 2003 indicate no significant changes of the shoreline vegetation, topography, or armoring. Prior to completing the design, it is anticipated that a shoreline survey will be conducted to document the existing vegetation types and potential erosional areas, if any. Site conditions for BMU-4 are shown on Figure 6.

Figure 6 Existing Conditions Bank Management Unit 4 (looking upstream)

2.6 BMU-5

BMU-5 extends from the pedestrian pier to the downstream property boundary of the Site (boundary with U. S. Moorings); this BMU covers approximately 350 feet of shoreline. Beyond the pedestrian pier, no other waterfront structures are present. BMU-5 is located next to FAMM office buildings; a second containment area with aboveground fuel storage tanks is located about 100 feet back from the top of the bank.

A complete description of the soil concentrations of COPCs adjacent to BMU-5 is described in the *Gasco Source Control Data Gaps Evaluation for NW Natural* (Anchor 2006b). No visible evidence of tar has been found in bank soils along this reach of the shoreline.

During a 2003 site survey, the top of the bank in BMU-5 was steeply graded at 2H:1V. The bank was well vegetated and appears stable. The vegetation was primarily non-native Himalayan blackberry and Scot's broom. The toe was completely armored with large riprap. General Site observations since 2003 indicate no significant changes of the shoreline vegetation, topography, or armoring. Prior to completing the design, it is anticipated that a

shoreline survey will be conducted to document the existing vegetation types and potential erosional areas, if any. Site conditions for BMU-5 are shown on Figure 7.

Figure 7 Existing Conditions Bank Management Unit 5 (looking downstream)

3 EVALUATION CRITERIA

The bank stabilization alternatives were evaluated using the criteria of environmental protection, implementability, and relative cost, in general accordance with state guidance for conducting feasibility studies (DEQ 1998). Implementation risk was also considered in the evaluation.

3.1 Environmental Protection

This criterion includes both the long-term effectiveness of the bank stabilization technology to prevent soils from eroding into the Willamette River, as well as the feasibility of minimizing short-term risk of contamination during construction. In addition, all viable technologies must provide a threshold level of environmental protection that prevents ongoing releases of impacted soils to the river. For example, on some parts of the shoreline with oversteepened slopes and relatively high chemical concentrations, a "no action" alternative does not meet the threshold level of protection. The criteria are described below:

- **Effectiveness.** The effectiveness criterion considers the ability of a bank stabilization technology to provide long-term environmental protection and prevent releases of COPCs to the Willamette River. The primary means of control is physical stabilization of the slope to prevent erosion of impacted soil into the adjacent river. An effective technology must be able to withstand scour and erosion, which may destabilize banks and possibly expose buried contamination. In addition, a bank that is stabilized with organic rich material, such as topsoil, and rooted with vegetation may help to contain certain COPCs via chemical adsorption.
- **Implementation Risk**. The objective of this criterion is to minimize short-term risks to the environment associated with bank stabilization construction activities. Impacted soil and groundwater, especially soil and groundwater containing visible tar or oil, may be exposed by excavating certain parts of the bank, creating a risk that COPCs may be released to the Willamette River, including its water, sediments, and habitat. Although such impacts should be avoided, in some cases it may be determined that a short-term environmental risk is acceptable in order to gain long-term environmental protection.

A low score for environmental protection indicates a higher level of risk that the proposed solution may fail such that a release of COPCs may occur over the life of the project. This

higher risk would be associated with a technology that has not been used for a long period of time or is more experimental. A moderate score indicates an acceptable level of risk over the life of the project with relatively low risk of contamination during construction. A high score indicates the alternative has an exceptional lifespan and it addresses the root cause of instability, usually high velocity currents or undercutting of the slope.

3.2 Implementability

The implementability criterion considers a number of factors that affect the practicability of constructing a particular bank stabilization alternative. These factors include the following:

- **Operational Constraints.** Waterside operations must not be compromised by the stabilization action. In particular, the integrity of adjacent structures must not be undermined by excessive removal of the bank. "Line-of-sight" requirements and other safety concerns associated with waterside operations must also be accommodated.
- **Consistency with Final Remedial Actions.** The proposed bank stabilization action must be consistent with the final upland and in-water remedies, to the extent these final remedies can be anticipated, as well as any proposed early actions associated with the Portland Harbor Superfund site, or other interim removal actions.
- **Permittability.** This factor considers the ease by which a bank stabilization action may be permitted, or fulfill the substantive requirements of a permit as provided by ORS 465.315. For example, a permittable stabilization alternative should not affect the river floodway (evaluated on the basis of cut and fill balance). It should be able to accommodate a sufficient vegetated buffer zone to satisfy the City of Portland greenway regulations. All else being equal, an alternative that promotes creation and improvement of aquatic habitat, particularly habitat critical to threatened or endangered salmonid stocks, would be preferred.
- **Consistency with Current and Future Land Use.** A stabilization alternative should not conflict with existing or anticipated future land use, especially water-dependent land use. For example, heavy industrial waterfront usage may conflict with the use of shallow, bioengineered slopes and wide riparian buffer zones.

A low score for implementability indicates a potential conflict with future cleanup actions, Site operations, and/or a difficult alternative in terms of permitting. A moderate score

applies to alternatives that may compromise Site uses slightly, or that might require some mitigation to permit. A high score indicates an alternative is consistent with the Site's final remedy, to the extent known, and should not present obstacles to Site operations and/or permitting.

3.3 Cost

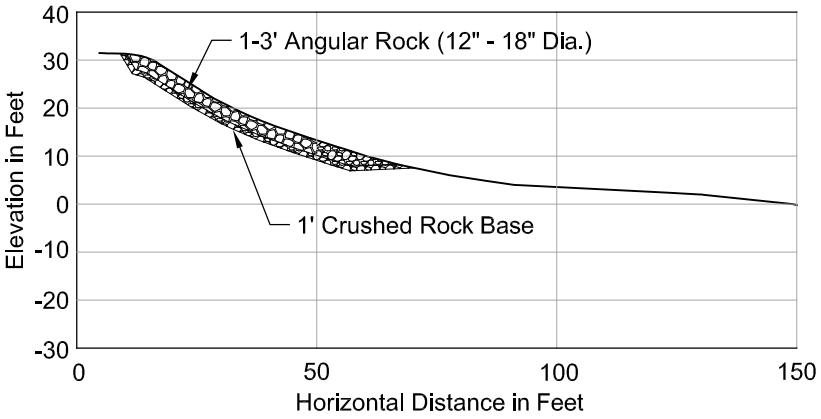
The relative cost to implement a bank stabilization alternative is developed at a level of accuracy of approximately plus 50 percent and minus 30 percent. The costs are developed to provide a comparative ranking of potential alternatives, but are not particularly accurate as an estimate of the absolute cost of a stabilization alternative. Scoring on the basis of cost is straightforward, based on unit cost per square foot of shoreline. Alternatives were ranked from most expensive to least expensive. The no action alternative was always given a high score in terms of cost. However, the no action alternative does not always meet the threshold criterion of environmental protection.

4 GENERAL STABILIZATION TECHNOLOGIES

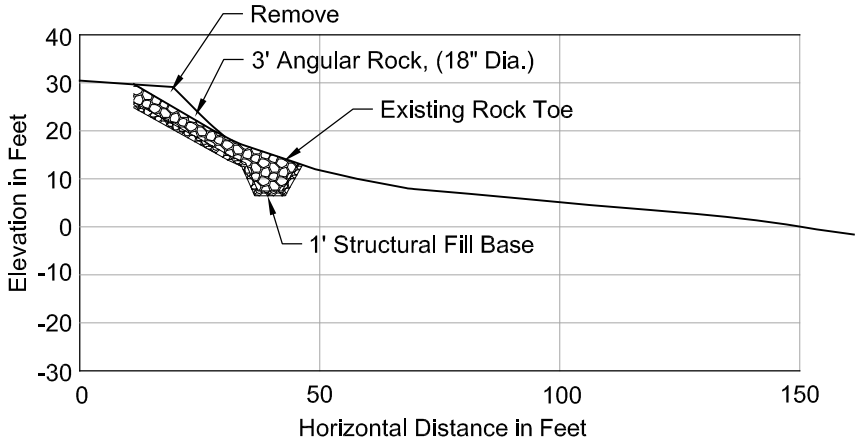
This report evaluates the suitability of five techniques for bank stabilization as well as a no action alternative. Each of these alternatives is evaluated for each of the five BMUs. These techniques address different bank stabilization functions. Cross sections of each method are shown in Figures 8 and 9. The appropriateness of a method should address both the mechanisms of erosion of a particular BMU, as well as the BMU's physical, chemical, and land use characteristics (i.e., site morphology, level of contamination, site operations, etc.) (Washington State 2003). These techniques also require different levels of disturbance and effort to install, and their appropriateness may be dependent on the ability to integrate the proposed bank stabilization technology with other cleanup or redevelopment activities. In some cases, variations of these methods can be used by combining one or more stabilization technologies at different elevations on the bank within a single BMU.

4.1 No Action

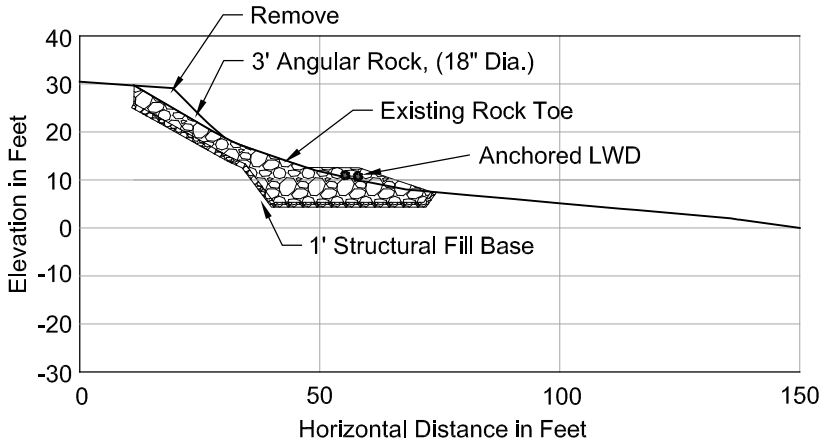
Areas of the bank that have stable slopes (intact riprap armor or established vegetation), show no signs of recent erosion, and/or contain low to moderate chemical concentrations that do not warrant an interim action are candidates for no action. This alternative avoids any short-term construction related risks and is generally consistent with existing or proposed future Site uses. This alternative will not conflict with any actions that may be implemented as part of a final upland or in-water remedy. Under the no action alternative, however, it is important that the existing banks be able to withstand rapid water level changes (alternate saturation and draining), and that the toe of the slope is adequately armored and buttressed.



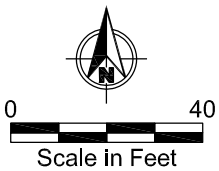
No Action Assumed Typical Cross-section



Riprap Typical Cross-section



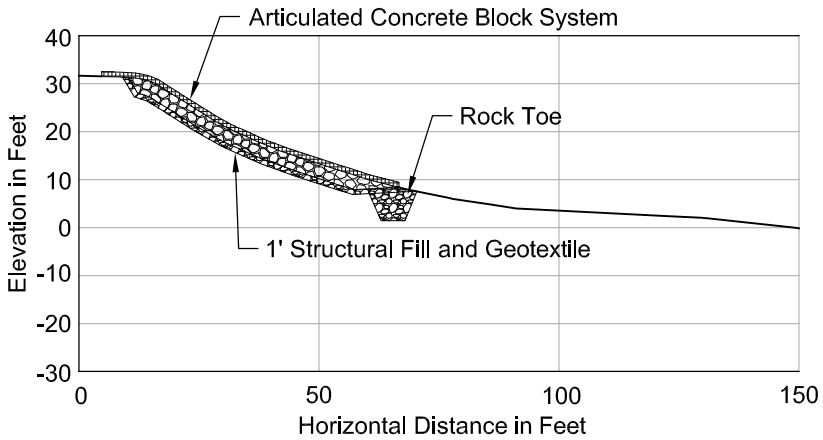
Barbed Riprap Typical Cross-section



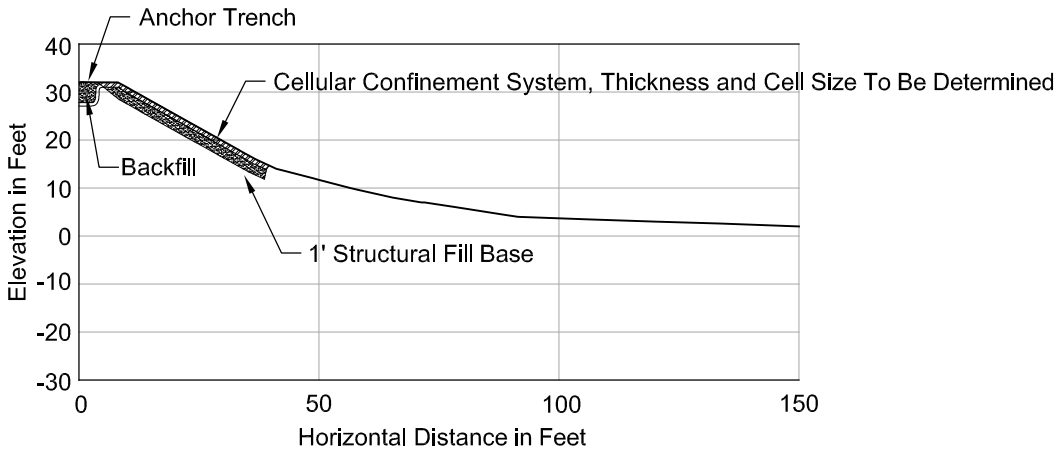
Oct 10, 2007 10:57am tgriga K:\Jobs\000029-GASCO\00002902\00002902-08.dwg FIG 8

ANCHOR ENVIRONMENTAL, L.L.C.

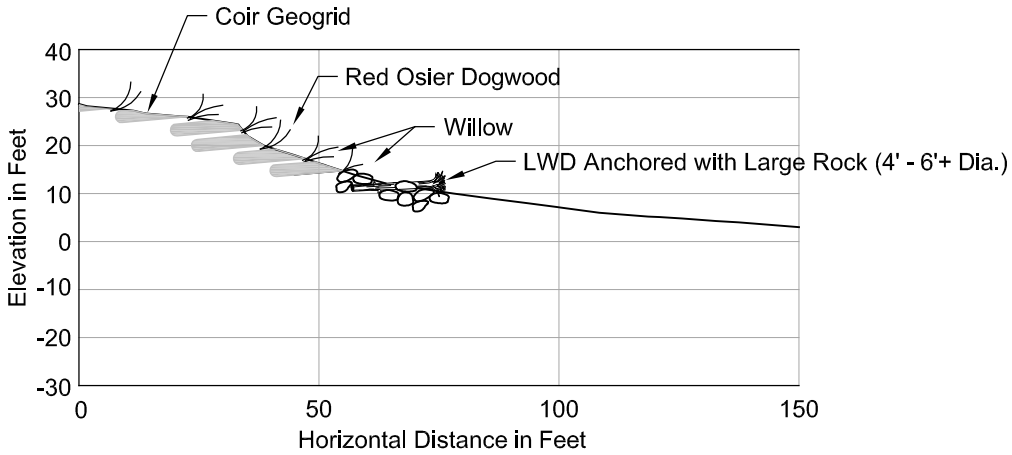
Figure 8
General Stabilization Technologies
Typical Cross-Sections
Northwest Natural Gasco Site



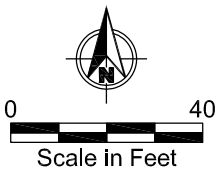
ACB Assumed Typical Cross-section



CCS Typical Cross-section



Bioenginnering Typical Cross-section



Oct 10, 2007 10:56am tgriga K:\Jobs\000029-GASCO\00002902\00002902-188.dwg FIG 9

ANCHOR ENVIRONMENTAL, L.L.C.

Figure 9
General Stabilization Technologies
Typical Cross-Sections
Northwest Natural Gasco Site

4.2 Riprap

Traditional riprap armor to resist expected river velocities are appropriate where bank excavation should be minimized, or where active waterfront uses preclude the use of softer methods. This method affords high resistance to propeller wash and vessel wakes associated with a working waterfront. For this evaluation, riprap is assumed to be 8 inches to 24 inches in diameter and 3 feet thick including a layer of gravelly sand to sandy gravel (i.e., structural fill) beneath it. The size of rock and thickness of armor can be adjusted to provide adequate integrity and design life for a given location and any specific energy regime (e.g., outfalls, propeller wash). Where existing riprap banks are being reconstructed, it is assumed that a key of larger rock would be installed at the toe to buttress the riprap above. This key would be approximately 10 feet wide at the surface and 2 to 4 feet thick (see Figure 8).

4.3 Barbed Riprap

This method is a modification of traditional riprap. Barbed riprap includes a series of rock 'barbs' that project waterward from the bank to create small embayments or eddy pools (see Figure 8). Barbs are intended to redirect flow away from the vulnerable toe of slope. (Undercutting of the toe is a common cause of slope failure on armored banks.) Barbs are typically built using larger rock than would be used as riprap, because they are exposed to greater wave energy and higher flow velocities. Barbs in this application would typically extend about 20 feet horizontally from the toe of the bank and rise vertically from below the mudline to a height between OLWL and OHWL.

There are potential disadvantages with barbs that also need to be considered. Barbs may cause localized amplification of wave energy reflected against the bank. Where amplification is focused, the high energy can have a deleterious effect on aquatic flora and fauna. Barbs will not be considered as a separate stabilization technology in the alternatives analysis, since the protectiveness is similar to a riprap alternative, but significantly more expensive.

4.4 Articulated Concrete Block Systems

Articulated Concrete Block (ACB) systems offer resistance to high flow velocities. These systems have relatively low depths into the bank, or are draped on top of the existing bank surface, which would reduce the risk of disturbing impacted soils during installation.

ACB systems typically consist of a grid of individual precast concrete blocks that are attached to one another with a web of stainless steel cables (see Figure 9). The grids are placed flat across the entire portion of the bank that is subject to erosion. These blocks can be manufactured with open cells that can then be planted. Some systems allow for the removal of individual blocks to accommodate additional, larger vegetation. Cost and implementability scores for ACB are made with the assumption that a riprap key will need to be constructed at the toe of slope and that existing conditions will be satisfactory for installation. This key will help with minimizing erosion under the toe of the ACB.

4.5 Cellular Confinement Systems

Like open-cell ACB systems, geosynthetic Cellular Confinement Systems (CCS) provide an opportunity to combine an engineered slope stabilization technology with native vegetation that enhances habitat and long-term slope stability. CCSs are typically three-dimensional structures made of polyethylene that form open-ended cylinders 3 to 12 inches deep (see Figure 9). Each cell acts as a small dam that allows water to pass over the top while holding in place the soil contained inside the cell. The cell walls inhibit the formation of rills. When used at and above the extent of woody vegetation, the individual cells can be planted with willows and other native species. The plants will then act to anchor the CCS and further reduce the potential for erosion. On the lower bank, the cells can be filled with gravel. Cost and implementability scores of CCS are based on deploying the method above OHWL and utilizing existing riprap below. The top of the CCS will be supported with an anchor trench for stability.

4.6 Bioengineered Slope

Bioengineered slope stabilization techniques have many variations. In this analysis, they are assumed to consist of brush layering and biodegradable geotextiles (e.g., coir; made from the fibers of coconut husks) to provide initial erosion control and woody hydrophytic (native willows) vegetation to provide long-term erosion control (see Figure 9). This

technique is generally limited to the upper bank (at or above OHWL) where such vegetation can survive. Below OHWL, large boulders mixed with LWD are used to protect the slope and buttress the toe. It is important that extra care is taken to prevent undercutting of a bioengineered slope, as vegetation will not be able to protect the lower bank.

Beginning at the lower extent of woody vegetation, live willow cuttings are placed horizontally along the contour of the slope in a layer of topsoil about 6 inches thick. Then a piece of biodegradable coir fabric is laid over the top. On top of the fabric, about 24 inches of structural fill is placed and the fabric is then wrapped over the top to form a geo-grid. Set back 3 to 5 feet, a second layer of willows is laid down following the new angle of the slope and the pattern is repeated to the top of bank. On the upper bank, other species such as red-osier dogwood, big-leaf maple, and black cottonwood can be added to the willows.

There are several variations of this technique, each having its particular advantages and disadvantages. Bioengineered bank stabilization often includes the use of LWD or rock barbs to direct flow toward the center of the channel. Generally, bioengineered slopes are costly to install and the vegetation may require irrigation and maintenance until it is well established. These systems have been shown to provide effective erosion control in the long term (as long as the vegetation remains healthy and intact) and do not introduce unnatural materials to the riverbank (Johnson 1993). For the purposes of this analysis, a buttressed toe constructed of LWD and very large rock is assumed.

4.7 Relative Cost of Stabilization Technologies

Unit costs (costs per square foot) were developed for the various stabilization technologies. Some of the assumptions underlying the unit costs include the following:

- All slopes will be laid back to 1.75H:1V or less
- CCS and bioengineered slopes are restricted to elevations above OHWL
- Fill is balanced with cut in each BMU; therefore, sufficient material will be removed to accommodate the installation of an engineered slope without causing a rise in the floodplain elevation
- Riprap slopes include 3 feet of overexcavation to place back the rock; CCS slopes require 1 foot of overexcavation to lay subgrade; ACB slopes require 0.5 foot of

overexcavation to lay subgrade; and bioengineered slopes require 6 feet of overexcavation to place overlapping layers of fabric, topsoil, and structural fill

- All excavated material will be disposed of offsite at an appropriate landfill facility.

The range and average values of unit costs to construct stabilized banks under typical site scenarios are summarized below.

Table 1
Unit Costs for Bank Stabilization ($/square foot of shoreline)

	Low Estimate	High Estimate	Average	Overall Cost Rank
No Action	$0	$0	$0	1
Riprap	$50	$53	$51	4
CCS	$22	$25	$24	3
ACB	$22	$24	$22	2
Bioengineered	$62	$69	$65	5

The range of unit costs reflects segment-specific bank characteristics, such as the degree of excavation needed to reduce the slope to a minimum of 1.75H:1V, the elevation range that requires stabilization, the amount of toe work involved, etc. The on-site reuse of any excavated material or reducing the amount of excavation before constructing the slope treatment could lessen the unit costs indicated above. All costs assume work would be done from the upland side of the shoreline, which appears to be the most viable option at this time. Due to fluctuations in river water levels and potential interference from shoreline structures, construction from the water side appears less likely and is not included in these costs.

The overall cost rank is also shown in the table. In general, these rankings indicate that the cost of No Action < ACB < CCS < Riprap < Bioengineered Slopes.

5 ALTERNATIVES EVALUATION

Each alternative was considered at each BMU, and the results are summarized in tables 2 through 4. Alternatives were required to provide an adequate level of environmental protection to be considered for the preferred alternative (threshold criterion). The sum scores (Low = 1, Mod = 2, High = 3) were then used to rank the alternatives, and select the preferred alternative. The alternatives were then ranked (column labeled "Overall Rank") from 1 to 5 with 1 being the alternative with the highest summed scores. Where two alternatives rank number 1, a comparative analysis of the two alternatives was conducted to determine the best alternative. These points of comparison are discussed for each criterion in the text.

5.1 BMU-1

BMU-1 does not have a current waterfront-dependent use associated with it, nor are any planned in the immediate future; however, an existing dock lift structure is present in this BMU and therefore does have the potential to be repaired for future use. During the 2003 Site visit, visible signs of erosion in this unit included a bowl shaped escarpment about 2 feet high near the pedestrian pier. The entire bank is armored with riprap and debris (concrete and asphalt) that is relatively intact, but is oversteepened in areas to 1H:1V or more. All of the actions being considered to stabilize applicable portions of the bank in BMU-1 would require regrading the bank to 1.75H:1V or less.

Table 2
Alternatives Ranking Matrix – BMU-1

	Environmental Protection	Implementability	Cost	Score	Overall Rank
No Action	Low	High	High	7	3*
Riprap	High	High	Mod	8	1
CCS	Mod	Mod	High	7	3
ACB	Mod	High	High	8	1
Bioengineered	Mod	Mod	Low	5	5

*unacceptable level of environmental protection

5.1.1 Environmental Protection

Significant soil contamination is present in the Former Tar Effluent Settling Pond Area on the uplands adjacent to this bank unit, and bank stabilization activities should therefore be coordinated to the extent possible with any proposed upland cleanup

efforts. Riprap armor on the shore and along the upper bank has evidently provided a reasonably stable bank in the past. If the slope were further reduced to 1.75H:1V or less, appropriately sized riprap with a liner should provide a reasonable level of environmental protection. It was assumed for the purposes of this analysis that the use of CCS or ACB systems and bioengineered solutions would also require slopes of 1.75H:1V or less. It should be noted that the scores for CCS and ACB were downgraded in this BMU compared to riprap because of concerns that the toe may continue to erode without additional armor, potentially leading to undercutting and undermining of the grids. A bioengineered solution will provide a thick layer of capping material, including adsorptive organic material (i.e., topsoil); however, the significant overexcavation required increases the risk of exposing contaminants during installation (implementation risk).

5.1.2 Cost

See Section 4.7 for a summary of relative unit costs for the various stabilization technologies. Bioengineered approaches involve the most earthwork and overexcavation; costs are driven upward by off-site haul and disposal costs, and the cost of importing clean structural fill and topsoil. Riprap, CCS, and ACB systems require much less overexcavation, but require a prepared subgrade and possible use of a geotextile fabric.

5.1.3 Implementability

There appear to be little or no current or future operational constraints that would affect the installation of any stabilization technology. In terms of ease of construction, riprap and ACB are the simplest. However, plantable stabilization technologies, such as open-cell ACB, CCS, and bioengineered slopes, would likely be favored in terms of permitting.

The most significant issue regarding implementability is consistency with future remedial actions, particularly in-water actions. Riprap materials may be stockpiled during cleanup, then re-used when cleanup is complete for a long-term cost savings. CCS, ACB, and bioengineered approaches rely on material installations that make it

difficult or impossible to reuse the materials. Also, established woody vegetation may be destroyed during future in-water construction work.

It is worth noting that bioengineering approaches may be advantageous as part of the long-term, final remedy on this portion of the bank. Bioengineering methods can help to achieve habitat restoration goals as well as bank stabilization, and such methods are usually favored by resource agencies. Such methods can also contribute to the fulfillment of City greenway requirements. Because this part of the slope is currently unencumbered with waterfront structures or operations, there are few impediments to regrading and overexcavation. However, the high risk of damage or recontamination of a bioengineered slope during in-water remediation make this method infeasible as an interim control measure. Further, this document provides an alternatives analysis for bank stabilization prior to any leasing of this area. If a lease and development is enacted before bank stabilization construction takes place, additional or different design and/or permitting may be needed.

5.2 BMU-2

BMU-2 contains the highest levels of soil concentrations on the Gasco shoreline, locally containing tarry or oily product. Bank slopes in this unit range from about 1H:1V at the upstream end to 1.75H:1V at the downstream end. All of the stabilization alternatives would therefore require some removal of material to set slopes back to 1.75H:1V or less. Buttressing of the pencil coal tar pitch pipeline may also be necessary.

Table 3
Alternatives Ranking Matrix – BMU-2

	Environmental Protection	Implementability	Cost	Score	Overall Rank
No Action	Low	High	High	7	3*
Riprap	High	High	Mod	8	1
CCS	Mod	Mod	High	7	3
ACB	Mod	High	High	8	1
Bioengineered	Low	Low	Low	3	5

*unacceptable level of environmental protection

5.2.1 Environmental Protection

Environmental protection scores for BMU-2 are similar to BMU-1. See Section 5.1.1 for a discussion of these issues. Because of the high chemical concentrations and increased potential for encountering buried tar residues, the implementation risk for bioengineering in applicable areas within this BMU, which would require substantial overexcavation, is more significant in BMU-2.

5.2.2 Cost

See Section 4.7 for a summary of relative unit costs for the various stabilization technologies. Because of the high chemical concentrations in the bank soils, and potential to encounter tarry residues, excavated soils may require more costly handling and off-site disposal (i.e., disposal at a Subtitle C facility). Riprap, CCS, and ACB systems may also require preparation of specialized and/or thicker subgrades, possibly including the use of geotextile fabrics, to provide additional containment of the elevated chemical concentrations in this area.

5.2.3 Implementability

The most significant obstacle to the implementation of bank stabilization measures in BMU-2 is the presence of significant waterfront structures near the top of the bank, in particular, the footings for the pencil coal tar pitch pipeline and associated pier. The degree of overexcavation required for bioengineering is therefore infeasible, both as an interim measure and also as a long-term solution. The degree of erosion protection and slope stability afforded by riprap is the preferred stabilization method to protect these waterfront structures. The protection and stability of ACB and CCS are somewhat less preferable unless coupled with riprap key rock at the base of the slope. However, riprap may be discouraged by permitting agencies unless vegetated slopes are constructed on other parts of the Gasco shoreline. If this area is leased before bank stabilization construction, the design may need new or additional design and/or permitting to integrate it into the lease activities.

Implementation of bank stabilization measures in BMU-2 would also need to account for the reactive geotextile mat that was placed below the shoreline bank during the tar body removal action. Any removal of shoreline materials to facilitate bank stabilization

would have to be designed so as not to disturb the mat. If a toe is constructed at the toe of slope to buttress the upper shoreline, the toe would need to be constructed just shoreward of the shoreline edge of the mat (Figure 10).

ACB and CCS would likely be damaged or contaminated during an in-water cleanup action in this area, whereas riprap could be stockpiled and reused.

5.3 BMU-3

BMU-3, the area between the two pipeline piers, has relatively flat slopes and a lower top of bank than the rest of the Site. Practical considerations for stabilizing applicable areas of the bank include the need to protect the structural integrity of the containment wall for the FAMM tank farm just beyond the top of bank. This portion of the shoreline had a long escarpment 1 to 2 feet high near the top of bank along most of its length during the 2003 Site survey. It appeared that this may have been the result of soils saturating during high river stage, then failing when water levels recede. The base of the slope below OHWL appears to be stable at slopes of 3H:1V to 4H:1V; it is therefore assumed that little or no work would need to be done on the toe in preparation for stabilizing escarpments at the top of the bank.

Table 4
Alternatives Ranking Matrix – BMU-3

	Environmental Protection	Implementability	Cost	Score	Overall Rank
No Action	Low	High	High	7	2*
Riprap	High	Low	Mod	6	5
CCS	High	High	High	9	1
ACB	High	Low	High	7	2
Bioengineered	High	High	Low	7	2

*unacceptable level of environmental protection

5.3.1 Environmental Protection

The flatter existing slopes in this unit are inherently more stable and require less earthwork than other, steeper units. Therefore, the long-term environmental risks associated with erosional undercutting of an engineered slope, and the short-term environmental risks associated with overexcavating contaminated bank soils, should be significantly reduced for virtually all stabilization methods. Existing slopes in this unit

are about 4H:1V and would not be likely to fail if any of the above actions were taken. The toe of this unit is stable and stabilization below OHWL is not necessary.

5.3.2 Cost

See Section 4.7 for a summary of relative unit costs for the various stabilization technologies. Actual costs in BMU-3 may be substantially reduced, however, because only a very limited elevation range (i.e., the 1 to 2-foot escarpment at the top of the slope identified during the 2003 Site survey) may require stabilization.

5.3.3 Implementability

Bank stabilization activities at areas within BMU-3 would include grading back the top 1 to 3 vertical feet of the bank to flatten existing escarpments back to 2H:1V or less. Further regrading, however, could jeopardize the integrity of the tank containment wall. Access to this portion of the Site is fairly good, but the two pipelines and the containment wall pose potential structural constraints. However, it appears that riprap, CCS, and ACB could all be delivered and installed within the space available.

To maintain no net rise in the floodplain elevation, a likely condition, any material imported to this unit would need to be offset by removing equal amounts from this unit. CCS, ACB, and bioengineered systems that incorporate woody vegetation would provide better aquatic habitat and would generally be considered to have lower impacts. The establishment of dense woody vegetation may enhance the long-term stability of the unit but could possibly interfere with lines of sight at the loading dock. CCS or ACB combined with perennial grasses would provide enhanced protection from runoff erosion and high river flows and would not interfere with sight lines.

As in BMU-1 and BMU-2, vegetated slopes may be damaged or contaminated during future in-water construction activities (e.g., remedial actions focused on the tar body in the shallow sediments that remain beneath a portion of the pencil pitch coal tar pipeline). However, the stabilization measures are restricted to portions of the upper portion of the bank, which may be effectively isolated from in-water activities during low water conditions.

5.4 BMU-4

Based on the 2003 site survey and general observations of the Site since that time, the existing slope in BMU-4 shows relatively few signs of erosion and existing riprap appears intact from the toe of slope to the OHWL. Waterfront operations include FAMM fuel pipeline and an emergency boom-slide and associated stairway on the bank. View corridors between the two buildings near the top of bank are important for operations.

5.4.1 Environmental Protection

The soils along BMU-4 do not contain evidence of tar, oil, or pitch, and the bank shows few indications of instability. Although any of the actions listed would provide adequate environmental protection, the risks associated with this unit are not sufficient to warrant interim stabilization measures.

5.5 BMU-5

This downstream unit contains the least contaminated soils and shows the fewest indications of potential instability. Based on the 2003 Site survey and general observations of the Site since that time, the lower bank is well armored with riprap and the upper bank has riprap completely covered with Scot's broom and Himalayan blackberry. While not usually considered desirable species, these plants nevertheless provide erosion protection during high river flows.

5.5.1 Environmental Protection

This unit appears stable and presents a low risk of erosion. All of the alternatives, including no action, would provide adequate environmental protection. Although any of the actions listed would provide adequate environmental protection, the risks associated with this unit are not sufficient to warrant interim stabilization measures.

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6 RECOMMENDED ALTERNATIVES

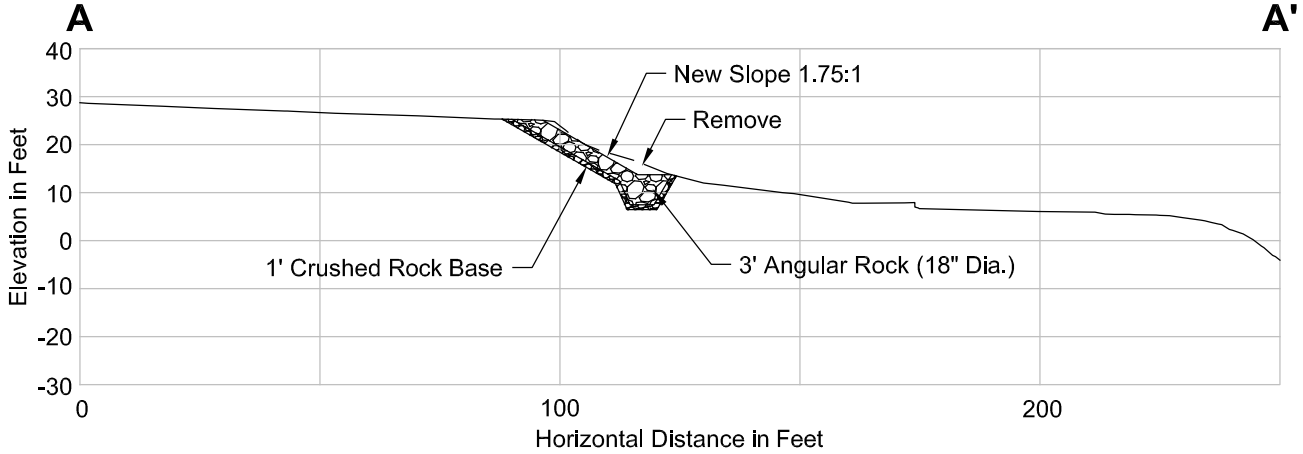
Recommended alternatives are summarized below. These recommendations are based on the analysis of alternative stabilization technologies using the criteria of environmental protection, cost, and implementability, as discussed in the previous section. Stabilization measures are warranted in portions of BMU-1, BMU-2, and BMU-3. These segments can locally contain residual deposits of tar, oil, or pitch in the some of the subsurface soils adjacent to the bank, and/or in the shallow sediments. The bulk of these deposits accumulated in and adjacent to a topographic swale that historically drained the Former Tar Effluent Settling Pond Area. To the extent practicable, the recommended stabilization measures should be integrated with the final upland and in-water remedies, proposed Site redevelopment activities, and possible future remedial action in the Former Tar Effluent Settling Pond area on the upland portion of the Site. Typical cross-sections for each BMU are shown in Figures 10 and 11.

6.1 BMU-1 – Riprap Repair

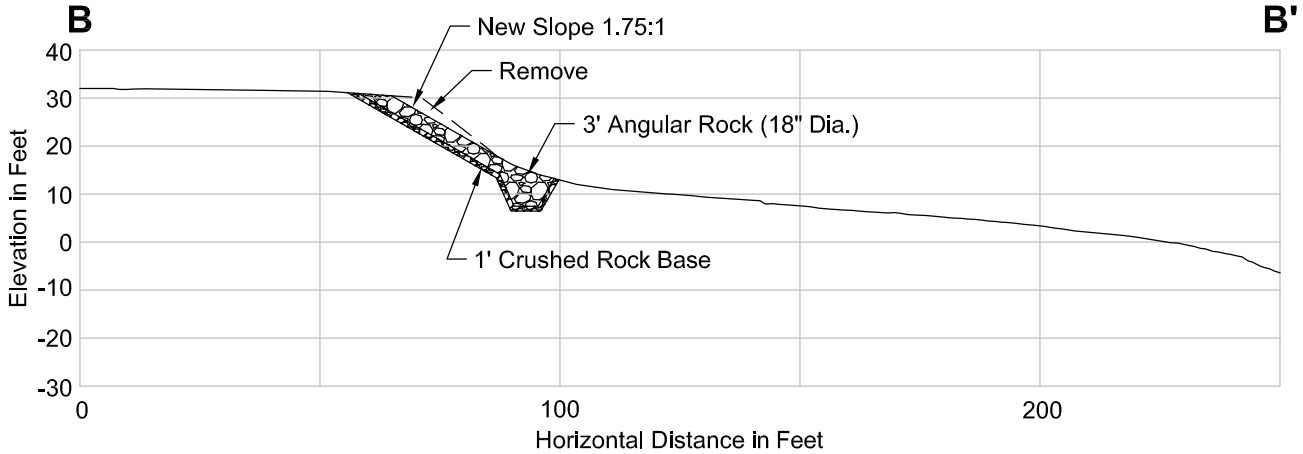
The preferred alternative for interim stabilization in BMU-1 consists of regrading areas of oversteepened slopes to 1.75H:1V and applying additional riprap and key rock to the slopes as needed (see Figure 10). Riprap provides good wave and current protection, is reasonable in cost, and straightforward to implement. CCS and ACB are similar in cost, but may be prone to erosional undercutting on these relatively steep and exposed slopes. Bioengineering is costly and may become damaged or contaminated as a result of subsequent in-water remedial actions. Bioengineering may provide some advantages as part of a final remedy, but this technology is not feasible to implement as an interim action.

6.2 BMU-2 – Riprap Repair

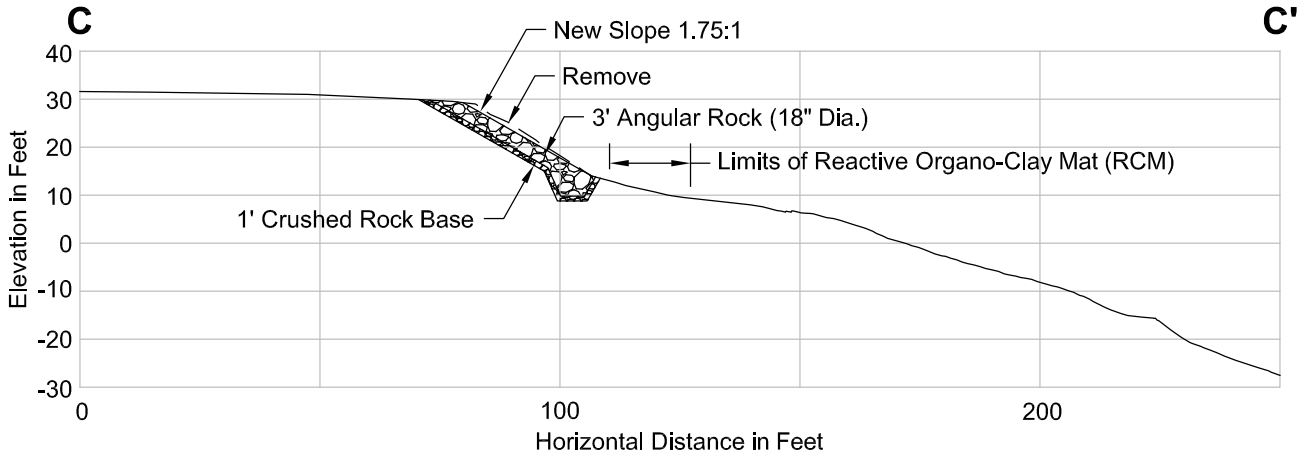
The preferred alternative for interim stabilization in BMU-2 consists of regrading applicable areas of oversteepened slopes to 1.75H:1V and applying additional riprap and key rock to the slopes as needed (see Figure 10). The advantages of using riprap as an interim stabilization measure are the same as those for BMU-1. In contrast to BMU-1, however, riprap or a variation of this technology might also be preferable as a final remedy to protect waterside structures and operations on this part of the shoreline. Riprap provides good structural support and erosion protection for the pencil coal tar pitch pipeline footings.



BMU-1 Riprap Repair (Typical)



BMU-2 Riprap Repair (Typical)



BMU-2 Riprap Repair (Typical)

0 40
Scale in Feet

Oct 10, 2007 10:54am tgriga K:\Jobs\000029-GASCO\00002902\00002902-189.dwg FIG 10

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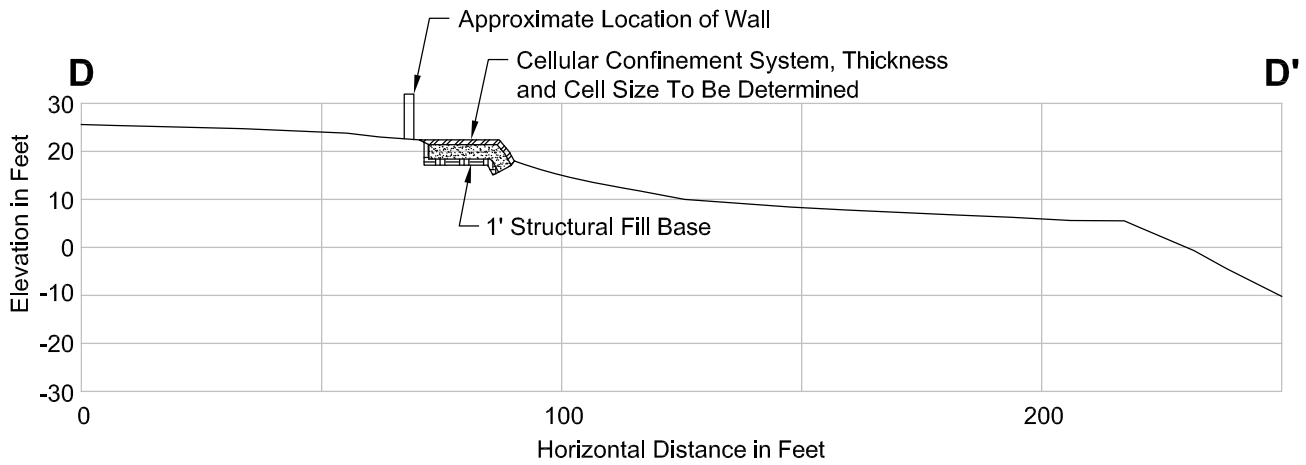
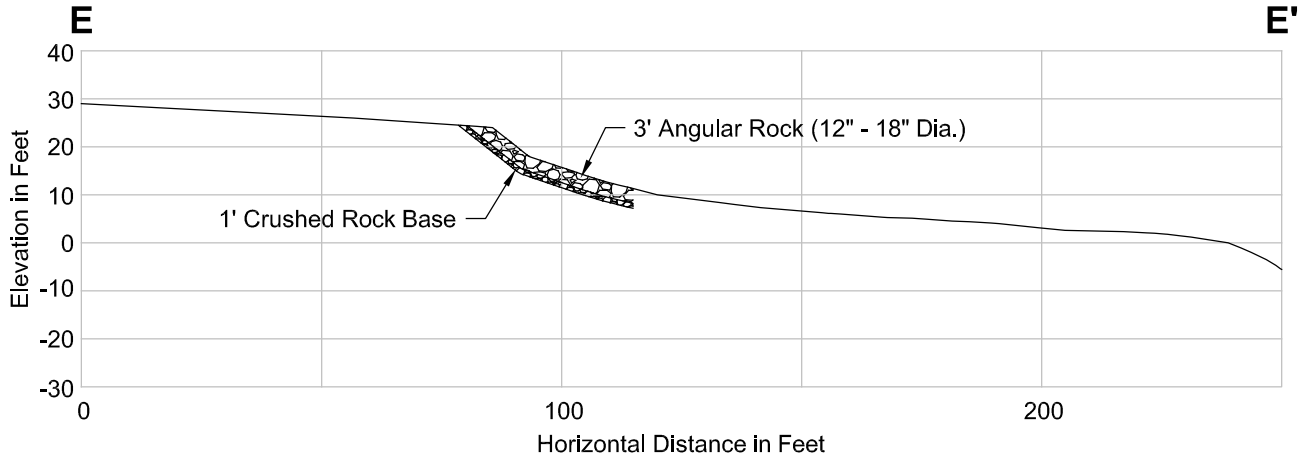
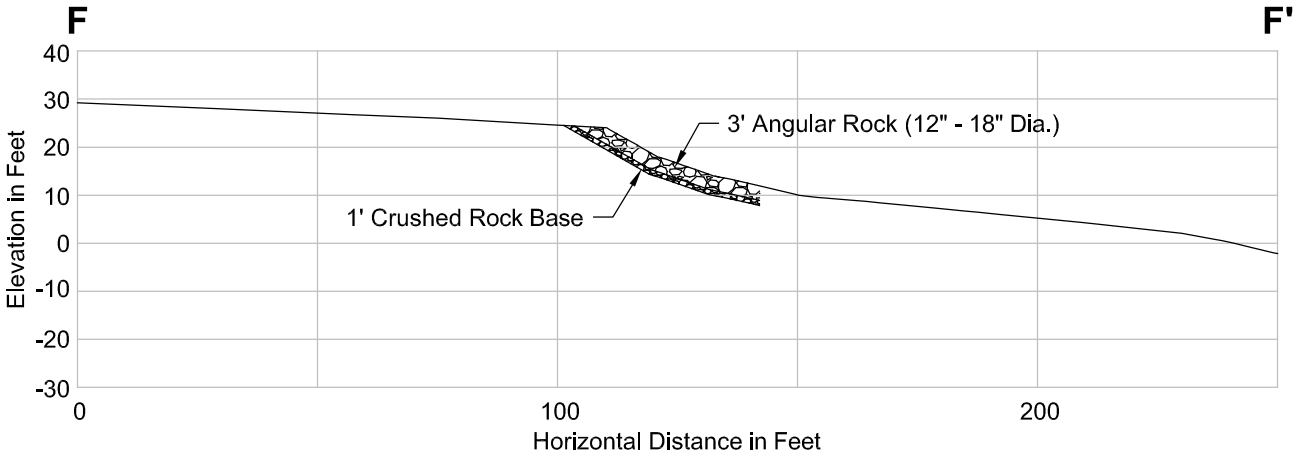
Figure 10
Preferred Alternative Cross-Sections
BMU-1 and BMU-2
Northwest Natural "Gasco" Site



BMU-3 Cellular Confinement System (Typical)



BMU-4 No Action (Typical)



BMU-5 No Action (Typical)

Oct 10, 2007 10:56am tgriga K:\Jobs\000029-GASCO\00002902\00002902-189.dwg FIG 11

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Figure 11
Preferred Alternatives Cross-Sections
BMU-3, BMU-4, and BMU-5
Northwest Natural "Gasco" Site

6.3 BMU-3 – Cellular Confinement System

The preferred alternative for interim stabilization in BMU-3 consists of regrading areas of short escarpment at the top of the bank to 2H:1V and applying a plantable CCS this narrow, 1- to 2-foot drop near elevation +20 feet (City of Portland datum; see Figure 11). The shallower slopes on this portion of the bank and the protection from wave energy afforded by the fueling dock are conditions well suited for this technology. Hardening these sand and gravel slopes with riprap or ACB would likely be discouraged by resource agencies. Although vegetated solutions, like CCS, may be impacted by subsequent in-water cleanup actions, they would be reasonably well isolated from these activities as a result of their position high up on the bank. Bioengineering incurs short-term environmental risks associated with having to substantially overexcavate the bank to prepare the subgrade, potentially exposing historical contamination.

6.4 BMU-4 – No Action

The banks of BMU-4 appear stable, vegetated, and well armored. No interim action is necessary (see Figure 11).

6.5 BMU-5 – No Action

The relatively low levels of contamination and good condition of the existing revetment do not warrant any action in this unit (see Figure 11).

7 PROPOSED IMPLEMENTATION SCHEDULE

As discussed in Section 2.2 and 2.3, it is currently anticipated that construction of the vertical barrier wall and groundwater extraction wells discussed in the GWFFS has the potential to restrict subsequent bank stabilization actions. This is particularly true where there is limited space at top of bank in BMU-2 and BMU-3. Therefore, the groundwater source control measures will be designed to facilitate future construction of bank stabilization measures. Because the time needed to obtain permits or other approvals for the bank stabilization will be much longer than those needed for the GWFFS recommended alternative, it is anticipated that the groundwater source controls will be in place prior to the start of any bank stabilization. Extraction wells, monitoring wells, and vertical barriers will be designed so that they will not interfere with construction of the recommended bank stabilization alternative discussed in Section 6.

Less urgent stabilization measures can be implemented with the final upland remedial action for the Gasco site. Such measures could include enhanced use of bioengineering technologies, especially if in-water remedial actions have largely been completed. The upland remedial action is contingent on DEQ approval of the Site RI and Risk Assessment, completion of the FS, and design of the upland remedy.

8 REFERENCES

Anchor Environmental, L.L.C., 2003. Baseline Level III Ecological and Human Health Risk Assessment Report Memorandum for NW Natural "Gasco" Site. Seattle, Washington.

Anchor Environmental, L.L.C., 2005. Removal Action Project Plan Final Design Submittal for NW Natural "Gasco" Site. Seattle, Washington.

Anchor Environmental, L.L.C., 2006a. Final Phase 1 Field Sampling Approach Gasco Siltronic Groundwater Source Evaluation for NW Natural "Gasco" Site. Seattle, Washington.

Anchor Environmental, L.L.C., 2006b. Gasco Source Control Data Gaps Evaluation for NW Natural "Gasco" Site. Seattle, Washington.

DEQ (Oregon Department of Environmental Quality). 1998. Final Guidance for Conducting Feasibility Studies. Waste Management and Cleanup Division. Portland, Oregon.

DEQ and EPA. 2005. Portland Harbor Joint Source Control Strategy – Interim Final. Prepared by State of Oregon Department of Environmental Quality and U.S. Environmental Protection Agency. September 2005.

Hahn & Associtess, Inc., 2007. Final Draft Remedial Investigation Report, NW Natural - Gasco Facility. Portland, Oregon.

Johnson, A.W. and J.M. Stypula. Eds. 1993. "Guidleines for Bank Stabilization Projects in the Riverine Environmentas of King County." King county Department of Public Works, Surface Water Management Division, Seattle WA.

Washington State Aquatic Habitat Guidelines Program. 2003. "Integrated Streambank Protection Guidelines."