ENGINEERING DESIGN REPORT
ARCO HARBOR ISLAND TERMINAL 21T
SEATTLE, WASHINGTON

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1. Introduction

This report presents the final design for remediation of contaminated groundwater and soils at the ARCO Products Company (ARCO) Harbor Island Terminal 21T located in Seattle, Washington. It has been prepared to satisfy the requirements of the Model Toxics Control Act (MTCA) Consent Decree No. 00-2-05714-8SEA cooperatively entered into between ARCO and the Washington State Department of Ecology (Ecology) and entered into court on March 24, 2000 by the Washington State Attorney General.

This report includes additional data that has been collected in selected areas since the completion of the Remedial Investigation (RI) (Geraghty & Miller [G&M] 1994a) and which support the design of the final cleanup actions.

1.1. Site Description and Location

The ARCO Harbor Island Terminal 21T consists of Plant 1, which is located adjacent to the West Waterway of the Duwamish River, and Plant 2, which is located inland of the waterfront in the north-central part of Harbor Island (Figure 1). Groundwater flows in a radial pattern outward from the center of Harbor Island and enters the marine surface water at the Island's edge. The site is zoned industrial and meets the industrial criteria established under Washington Administrative Code (WAC) 173-340-745. In addition, the site will likely remain an industrial facility in the foreseeable future because of the site zoning, and, perhaps more importantly, because of the substantial industrial improvements to Harbor Island (e.g., construction of cargo handling facilities and construction of major petroleum distribution pipelines for the Island). Ecology and EPA have determined that there is no current or planned future use of groundwater beneath Harbor Island for drinking water purposes. The remediation areas that will be addressed with the final cleanup actions selected for the site are shown on Figures 2 and 3.

1.2. Cleanup Objectives

The selected cleanup action is designed to accomplish the following requirements: protect human health and the environment; comply with cleanup standards established in WAC 173-340-700; comply with applicable state and federal laws under WAC 173-340-710; provide compliance monitoring as set forth in WAC 173-340-410; use permanent solutions to the maximum extent practicable as mandated in WAC 173-340-360 (2), (3), (4), (5), (7), and (8); provide a reasonable restoration timeframe in accordance with WAC 173-340-360(6); and consider public concerns as designated in WAC 173-340-600.

Groundwater and soil cleanup levels were developed based on the industrial zoning of the site and the determination by Ecology that there is no current or planned future use of the groundwater for drinking water purposes. Remedial objectives for the Plant 1 waterfront area and Plants 1 and 2 soils are summarized below.

1.2.1. Plant 1 Waterfront

The remedial objectives for groundwater at the site are based on the protection of the adjacent surface waters and its ecosystems and intended to prevent dissolved petroleum hydrocarbons (dissolved hydrocarbons) in the groundwater from migrating off site and impacting adjacent properties.

1.2.2. Plants 1 and 2 Inland Soils

The goal of inland soil cleanup levels for petroleum hydrocarbons is to protect the beneficial use of groundwater (surface water quality and associated ecosystem).

1.3. Cleanup Action Performance Requirements

Indicator hazardous substances (IHSs) were identified for the ARCO Terminal 21T site as part of the Focused Feasibility Study (FFS) (G&M 1997) using the criteria outlined in WAC 173-340-708(2). The final list of IHSs determined by Ecology for groundwater and soil are a subset of the contaminants detected at the site. The final soil IHSs are total petroleum hydrocarbons as gasoline-range hydrocarbons (TPH-G), total petroleum hydrocarbons as deisel-range hydrocarbons (TPH-D), total petroleum hydrocarbons as oil-range hydrocarbons (TPH-O), and free-phase product (product). The final groundwater IHSs are dissolved copper, TPH-G, TPH-D, TPH-O, carcinogenic polynuclear aromatic hydrocarbons (cPAHs), benzene, and product. Cleanup action performance requirements for the Plant 1 waterfront area and inland soils located in Plants 1 and 2 are summarized below.

1.3.1. Plant 1 Waterfront

Groundwater cleanup levels were determined by Ecology to be surface water standards that are protective of aquatic organisms in the Duwamish River. These surface water standards are the adopted ambient water quality criteria (WAC 173-201A and Section 304 of the federal Clean Water Act). The category of ambient water quality standards selected as relevant and appropriate for the site are the chronic criteria for protection of aquatic organisms (WAC 173-201A-040). Surface water standards are not established for TPH; therefore, the groundwater cleanup levels for TPH-G, TPH-D, and TPH-O were selected as protective cleanup goals at this time. The following are the cleanup levels for the site groundwater:

Product	No Sheen
Benzene	0.071 milligrams/liter (mg/L)
cPAHs	0.000031 mg/L

Copper	0.0029 mg/L
TPH-G	1.0 mg/L
TPH-D	10 mg/L
TPH-O	10 mg/L

Copper is attributable to off-site sources and is found throughout the groundwater beneath Harbor Island.

The achievement of cleanup levels in groundwater shall be measured at points of performance and compliance located within the product plume area and at the downgradient edge of the site.

1.3.2. Plants 1 and 2 Soils

The subsurface soil cleanup goal for TPH at the primary areas of concern (Plant 1) of the site is set to meet the remedial objective of protecting surface water at the property boundaries and shorelines, and is:

Total TPH 10,000 milligrams/kilogram (mg/kg)

This TPH cleanup goal is also protective for other chemical constituents in petroleum product (i.e., benzene, toluene, ethylbenzene, and total xylenes [BTEX]).

The subsurface soil cleanup level for TPH at the secondary areas of concern (Plant 2) of the site is set to meet the remedial objective of protecting surface water at the property boundaries by improving general groundwater conditions at the source, enhancing timely restoration of the impacted area through natural biodegradation, and is:

Total TPH 20,000 mg/kg

The determination of adequate soil treatment will be based on the ability for the remedy to comply with the groundwater cleanup standards for the site, to meet performance standards designed to minimize human health or environmental exposure to soils above cleanup levels, and to provide practical treatment of contaminated soils.

1.4. Report Organization

This report summarizes the site history, historical data, and engineering parameters and justification for the design of the cleanup actions. Detailed construction drawings and specifications will be presented in a separate document that will be prepared for subcontractors interested in bidding on the construction and excavation activities.

The report format was developed based on the outline requested by Ecology. The report is organized as follows:

- **Section 1** presents the site description and location, and the cleanup objectives and cleanup criteria established for the groundwater and soil in Plants 1 and 2.

- **Section 2** summarizes background information for the site, including the regulatory status and the Cleanup Action Plan (CAP) (Ecology 1999) prepared for the site. Additional site data collected since the RI and CAP were completed, which has been used to support the design, is also presented in this section (Section 2.7 and 2.8). The cleanup actions are also described in this section.

- **Section 3** presents the construction, excavation, and operation and maintenance (O&M) schedule for the cleanup actions at the site.

- **Section 4** summarizes the contents of the final construction plans and specifications that will be prepared for submission to contractors who are qualified and interested in bidding on the construction and excavation activities of the final cleanup actions.

- **Section 5** describes the cleanup action conceptual plans and design approach.

- **Section 6** provides the engineering justification for the cleanup action design based on the analytical data obtained from the site.

- **Section 7** describes the design features to control spills and accidental discharges from the cleanup action construction, excavation, and O&M activities.

- **Section 8** describes the safety features that have been designed into the cleanup action for worker protection and protection of the environment.

- **Section 9** details the waste management procedures for waste streams that will be generated during construction, excavation, and O&M.

- **Section 10** describes the testing and quality control procedures that will be implemented during construction activities to ensure proper operation of the cleanup action.

- **Section 11** summarizes the compliance monitoring activities that will be implemented. This Section includes revisions to performance and confirmational monitoring that were previously described in the Groundwater Compliance

Monitoring and Contingency Plan (included in the Consent Decree [Ecology 1999]).

- **Section 12** summarizes the procedures that will be followed during construction to ensure the health and safety of workers.

- **Section 13** summarizes the public participation plan for the engineering design for the final cleanup actions at the site.

- **Section 14** lists the references used in the completion of this report.

2. Background Information

The following Sections summarize the regulatory status and results of the site investigations that support the final remedy selection and design.

2.1. Current Site Regulatory Status

ARCO Terminal 21T, along with the adjacent Texaco and GATX terminals, form the Tank Farm Operable Unit (OU) of the Harbor Island Superfund site. Ecology is the regulatory lead for the Tank Farm OU. The United States Environmental Protection Agency (U.S. EPA) is the regulatory lead for the Lockheed OU, the Sediments OU, and the Harbor Island OU.

Site remedial investigation, feasibility study (RI/FS), and cleanup action plan (CAP) activities were completed for the site to satisfy the requirements of MTCA Agreed Order No. DE 92 TC-N-158, cooperatively entered into between ARCO and Ecology.

The final cleanup actions selected for the site will occur under the legal framework of a consent decree between ARCO and Ecology. The Washington State Attorney General signed Consent Decree No. 00-2-05714-8SEA on March 24, 2000, which includes the CAP and Groundwater Compliance Monitoring and Contingency Plan.

2.2. Summary of Remedial Investigation

The results of the site characterization activities conducted during the RI (G&M 1994a) indicate that contaminants present in groundwater and soil at the site are primarily highly-weathered total petroleum hydrocarbons as diesel with lesser amounts of weathered gasoline and heavier oil, cPAHs, and a few inorganic metals (copper and lead). The weathered TPH is most likely the result of historic spills at the site. The inorganic metals are present at low concentrations at a few locations in groundwater and shallow soils, and are most likely due to historic lead smelter and ship building activities.

2.2.1. Plant 1 Waterfront

The results of the RI show that the primary area of impact at the site is the product plume located beneath the warehouse adjacent to the Duwamish River in Plant 1. The product is trapped behind the subsurface warehouse foundation and Island bulkhead that form a partial barrier to groundwater flow to the river. These structures act as a “hanging wall” which allows groundwater and possibly some dissolved hydrocarbons to flow beneath the foundation while trapping the product. The water table elevations fluctuate seasonally due to rainfall, and in response to tidal influence from the Duwamish River; however, the water table elevation does not drop below the base of the subsurface barriers.

Although the warehouse foundation and Island bulkhead retard the transport of product to the Duwamish River, a sheen occasionally appears on the West Duwamish Waterway and may be due to minor areas of discontinuity in the hanging wall (e.g., small cracks in the warehouse foundation or Island bulkhead). The sheen is contained using sorbent booms. In addition, an interim groundwater/product recovery system (interim remediation system) has been in operation under the warehouse since 1992. This system has been effective in removing product and reducing the frequency and extent of hydrocarbon sheens in the Duwamish River, and in the removal of dissolved hydrocarbons from groundwater.

Due to the dampening effect of the warehouse foundation and Island bulkhead on the shallow groundwater, water table fluctuations in response to tidal influence are only 1 to 2 feet near the Duwamish River. Seasonal fluctuations in water table elevations due to rainfall are similarly only 1 to 2 feet. The resulting "smear" zone of product in soil at the water table is less than 4 feet thick. The extent of the smear zone was confirmed during the RI soil sampling activities. Elevated TPH concentrations in soil were detected below the water table but it is limited to the area within the zone of tidal fluctuation and does not extend below the seasonal low-lower tide water table elevation.

Concentrations of TPH-G and TPH-D have been detected in groundwater above cleanup levels within or in close proximity to areas where historical spills have occurred. Groundwater monitoring results indicate no exceedances of the cleanup level for TPH-O. Benzene and cPAHs have also been detected within the groundwater plumes above cleanup levels. Concentrations of benzene exceeded the cleanup level in approximately 15 percent of the groundwater samples collected for five quarters of monitoring during the RI (the second, third, and fourth quarters of 1993 and the first and fourth quarters of 1996); concentrations of cPAHs exceeded the cleanup level in approximately 1 to 10 percent of the samples collected, depending on the cPAH analyzed.

The results of five quarters of monitoring data collected during the RI and the twelve quarters of voluntary monitoring since the RI indicate that the dissolved hydrocarbon plumes located in the tank farms of Plant 1 and Plant 2 are stabilizing overall in extent and concentration due to on-going intrinsic biodegradation/natural attenuation.

Dissolved copper was the only metal detected in groundwater in Plant 1 and Plant 2 above cleanup levels during the five quarters of monitoring for the RI. Concentrations of dissolved copper exceeded the cleanup level in approximately 7 percent of the samples collected. Dissolved copper was also detected across much of the northern portion of Harbor Island during the U.S. EPA RI, indicating elevated background concentrations. Copper was not detected in soils above the cleanup level. This inorganic metal is associated with marine paints used at shipbuilding and repair facilities adjacent to Plant 1 (Tetra Tech 1988). Due to the infrequency of dissolved copper detected in the groundwater at the site and the elevated background concentrations of dissolved copper, Ecology has agreed that groundwater sampling for dissolved copper may be discontinued at the site.

2.2.2. Plants 1 and 2 Soils

The results of the RI indicate that localized areas of soil with elevated concentrations of TPH are present within the tank farms of Plants 1 and 2 inland of the waterfront and warehouse area. These soils have been undergoing intrinsic biodegradation/natural attenuation and appear to be in equilibrium with groundwater at the site (i.e., the soils are not causing an increase in hydrocarbon concentrations in groundwater). One area in Plant 1 and three areas in Plant 2 remain above the cleanup level for total TPH and will be excavated to improve general groundwater conditions at the source, enhance restoration time for the impacted areas, and enhance intrinsic biodegradation/natural attenuation for the residual TPH contaminated soil left in place.

2.3. Summary of Feasibility Study and Cleanup Action Plan

Site-specific cleanup action alternatives were developed and analyzed for groundwater and soil in the FFS (Volume II: Evaluation of Remedial Alternatives, Geraghty & Miller 1997), to ensure the protection of human health and the environment at the site. Based on this initial screening and evaluation of supplemental data collected during the FFS, four alternatives were selected for further evaluation. Of these four alternatives, three remedial alternatives (GW-4, S-1, and S-2) were selected to be included in the final cleanup action for the site.

Remedial Alternative GW-4 includes pumping and treatment for product and dissolved hydrocarbon recovery, air sparging and vapor extraction for accelerated mass removal of residual hydrocarbons in soil beneath the warehouse, maintaining the foundation cap for the warehouse, groundwater compliance monitoring, deed restrictions, institutional controls, and natural attenuation.

Remedial Alternative S-1 is designed to address the warehouse and inland accessible TPH soil hot spots. Institutional controls and degradation of organic contaminants by intrinsic biodegradation/natural attenuation have been selected for inaccessible soils beneath the warehouse area and inland of the warehouse area for Plant 1 and Plant 2 to ensure protection of human health and the environment. These remedial actions are expected to be accelerated following implementation of the Plant 1 waterfront remedial action, described in the previous paragraph, and the removal of the accessible TPH hot spot soils in Plants 1 and 2, as described below. A deed restriction will also be implemented to prevent inappropriate future use of the site.

Remedial Alternative S-2 is designed to address the accessible TPH soil hot spots located in the inland portions of Plant 1 and Plant 2. This remedial action includes excavation of accessible TPH contaminated soil hot spots and treatment at an off-site facility.

These three remedial alternatives have been grouped to form the two major elements of the cleanup action: 1) the Plant 1 waterfront, and 2) Plants 1 and 2 soils. The CAP issued by Ecology under MTCA for the site (Ecology 1999) identifies and describes the selected remedial action alternatives for the site. Additional details regarding these alternatives are further summarized in the following sections.

2.4. Description of Cleanup Actions

The primary components of the final cleanup actions are summarized below.

2.4.1. Plant 1 Waterfront

The remedial action for the Plant 1 waterfront area includes the following elements:

- Pumping and treatment for product plume and dissolved hydrocarbon recovery,
- Air sparging and vapor extraction for accelerated mass removal of residual hydrocarbons in soil beneath the warehouse,
- Maintenance of the foundation cap for the warehouse area,
- Groundwater compliance monitoring,
- Deed restrictions,
- Institutional controls, and
- Natural attenuation.

2.4.2. Plants 1 and 2 Soils

The remedial action for Plants 1 and 2 soils includes the following elements:

- Excavation of accessible TPH contaminated soil hot spots in the inland portions of Plant 1 and Plant 2,

- Institutional controls and degradation of organic contaminants by intrinsic biodegradation/natural attenuation for inaccessible soils beneath the warehouse area and inland of the warehouse area for Plant 1 and Plant 2, and

- Deed restrictions.

2.5. Summary of the Interim Remediation System

An interim remediation system has been in operation since 1992 to mitigate the product plume along the waterfront beneath the warehouse area. The interim system has undergone several changes since the initial installation in 1992. The current interim system consists of a product and groundwater recovery system and a soil vapor extraction (SVE) system, as described below. The interim remediation system has been effective in recovering product and dissolved hydrocarbons from beneath the warehouse area and reducing sheens on the West Duwamish Waterway. The cleanup actions selected in the FFS and CAP build on the success of the interim remediation system.

The current product and groundwater recovery system consists of two recovery wells (GM-11S and RW-1) in the warehouse area that depress the water table to enhance product recovery. From June 1998 until July 1999, one recovery well (RW-4) in the loading rack area was also in operation. RW-4 was installed for a groundwater pumping test in 1998 and operated following the conclusion of the pumping test activities until July 1999 when it was taken off-line due to effluent pipe corrosion. Another recovery well in the warehouse (RW-3) operated for a short period of time, but product was not recovered from RW-3 and it was subsequently taken off-line.

Product recovered by the system is pumped directly into Tank 20, located in the Plant 1 tank farm, for recycling. Groundwater collected by the system is treated by air stripping and discharged to the King County Department of Natural Resources (KCDNR) sanitary sewer system. The groundwater contains naturally occurring metals (e.g. iron and manganese), which precipitate during the air stripping process. Sodium metaphosphate is added to the effluent stream as an anti-precipitation agent.

The interim SVE system consists of five soil vapor extraction wells along the waterfront to recover the volatile fraction of petroleum hydrocarbons remaining in the vadose zone (i.e., unsaturated soils above the water table). Effluent concentrations are below the Puget Sound Air Pollution Control Agency (PSAPCA) levels that require treatment.

2.6. Summary of Pilot Tests

Pilot testing of the SVE, groundwater, and air sparging components of the remedy were conducted to collect design parameters for the final remedy. The results of these pilot tests are summarized below. The information, data, and design parameters resulting from the pilot tests were combined with data collected from operation of the interim remediation system were used to support the design of the groundwater/ product recovery system for the final cleanup action.

2.6.1. SVE Pilot Test

A SVE pilot test was conducted along the waterfront in the warehouse area of the site in 1994 to determine the effectiveness of this technology in removing volatile hydrocarbons and enhancing in-situ biodegradation of heavier hydrocarbons in the vadose zone. The following design parameters for a full-scale SVE system were collected:

- SVE well radius of influence,
- Vapor extraction flow rate,
- Blower size, and
- Effluent treatment method, if necessary.

The pilot test was conducted using the existing SVE wells SVE-1, SVE-2, SVE-4, and another well SVE-3, which was later replaced with SVE-3R. The results of the pilot test indicate that the average radius of influence for the SVE wells is 50 feet with an applied vacuum of 25 inches of water (in. H_2O) and a total extraction flow rate of approximately 300 standard cubic feet per minute (scfm) from four extraction wells.

The results of the SVE pilot test concluded that SVE is an effective technology for removing volatile hydrocarbons and reducing the residual hydrocarbon concentrations located within the smear zone beneath the warehouse and near the loading rack area.

The activities and results of the SVE pilot test are detailed in the Soil Vapor Extraction Field Design Test Results report (G&M 1994b). The information, data, and design parameters collected from the pilot test and from operation of the interim SVE system were used in the design of the SVE system for the final cleanup action.

2.6.2. Groundwater Pumping Test

A groundwater pumping test was performed in 1998 to determine the following parameters for the design of the final product and groundwater remediation system for the warehouse area:

- Optimum extraction rates and/or draw down levels for the new recovery well to minimize saline water production from the Duwamish Waterway,
- Optimum well spacing,
- Quality and treatment requirements for the groundwater withdrawn from the area between the warehouse and truck loading rack, and
- Pump type and, if necessary based on pump selection, oil/water separation equipment requirements.

The data and results of the pumping test are detailed in the Air Sparging Pilot Test and Groundwater Pumping Test Report (TechSolv 1999) and are summarized below.

The pumping test was conducted by installing a new recovery well, RW-4, near the truck loading rack. The results of the groundwater pumping test in RW-4 were compared to data collected as part of the operation of RW-1 and previous pumping analysis for the warehouse area.

The results of the pumping tests indicated that the shallow soils near the loading rack may yield slightly higher flow rates than the shallow soils underlying the warehouse. The recovery wells installed in both the warehouse and loading rack areas will be installed in the shallow hydraulic fill materials, and are anticipated to be completed between 15 to 20 feet below ground surface (bgs).

It is recommended that recovery wells installed in the warehouse area be installed on 50-foot centers and pumped at 2 to 3 gallons per minute (gpm) to provide overlapping capture zones between wells. An additional three wells are required within the warehouse building and one outside the southern end of the warehouse (Figure 4). This well spacing will provide capture along the entire warehouse area.

The pumping test results indicated that recovery wells in the truck loading rack area be installed on 20-foot centers and pumped at a rate of 2 to 3 gpm each. Two to three wells in the truck loading rack area will provide sufficient hydraulic capture between the loading rack area and the warehouse (Figure 4). The closer well spacing in this area was selected to maximize the extent of the combined capture zones beneath the inaccessible areas of the loading rack and warehouse office space.

2.6.3. Air Sparging Pilot Test

An air sparging test was conducted in 1998 to determine the following parameters for the design of the air-sparging portion of the final remedial system for the warehouse area:

- Zone of air sparging influence per injection well,
- Removal rate of volatile hydrocarbons from the saturated zone,
- Air injection pressure, and
- Injection airflow rate.

The results of the air sparging pilot test indicated that the air sparging wells' effective zone of influence is approximately 20 feet per well (TechSolv 1999). This zone of influence provides the basis for the full-scale system design. The results indicated that air sparging wells placed 30 feet apart will provide some overlap of capture zones between wells. This spacing will result in complete coverage along the waterfront except beneath a small portion of the warehouse that is inaccessible due to the office space. This area will be adequately covered by the recovery wells and SVE system.

The pilot test also provided additional design parameters for air sparging well depth and construction parameters, and airflow rate. In the full-scale system, air sparging wells will be completed to a depth of approximately 15 feet bgs within the saturated fill material and have two feet of screen length. The wells will be constructed of 2-inch diameter schedule 40 PVC with 0.01-inch slotted screen. The airflow rate will be 10 scfm, and the air injection pressure will be determined in the field during system start-up.

2.7. Summary of Investigation Near Well GM-11S, Plant 1

Additional site data has been collected near the northeast area of the warehouse since the completion of the RI and CAP which has been used to support the design of the final remedy. The investigation and results are included in a report in Appendix A. The results and recent remedial actions taken to mitigate the impacts of contamination in this area are summarized below.

During quarterly groundwater monitoring in September 1999, a product thickness of approximately 0.29 feet was measured in Monitoring Well GM-11S. Although product was observed in soil samples collected from this area during the RI, product had not been observed on the water table in GM-11S prior to September 1999. The product was removed from the well and the well was gauged the following month. In October 1999, product had reappeared in GM-11S at a thickness of 0.59 feet. A sample of the product was collected and submitted to the laboratory for hydrocarbon identification. The laboratory results of the hydrocarbon identification analysis indicate that the product in GM-11S is a mixture of gasoline and diesel fuel.

A soils investigation in the vicinity of GM-11S was subsequently conducted in January 2000 to further define the extent of product in this area. Soil boring locations were laid out in a grid pattern to the north, east, and south of GM-11S. The investigation did not extend to the west of GM-11S due to the location of the warehouse, and was limited to the north by the loading rack. Soil samples were collected from each of the locations in 2-foot intervals from depths of 4 to 10 feet bgs, which was below the top of the shallow water table (mostly encountered at depths of 6 to 7 feet bgs). In addition, groundwater samples were collected from each of the borings and examined for the presence of product.

Selected soil and groundwater samples were submitted for laboratory analysis of BTEX, TPH-G, TPH-D, and TPH-O. Soil samples submitted for analysis were from the borings in closest proximity to GM-11S and from the northern-most, eastern-most, and southern-most borings. Sample intervals with the highest and lowest organic vapor readings as recorded in the field on a hand-held organic vapor meter (OVM) were selected from each of those borings. Groundwater samples that did not have a sheen present were submitted for laboratory analysis of BTEX, TPH-G, TPH-D, and TPH-O.

The results of the sampling indicated that the extent of the product is confined to the area immediately around GM-11S. The only evidence of product detected during the investigation was observations of a sheen on the groundwater samples in that area. The extent of the hydrocarbon concentrations in groundwater above cleanup levels is delineated to the south at a distance of approximately 85 feet south of GM-11S and to the east at a distance of approximately 50 feet east of GM-11S. A groundwater sample collected adjacent to the storm water lift station indicates that groundwater to the north of GM-11S has hydrocarbon concentrations above cleanup levels.

Soil sample results indicate that the southern extent of the hydrocarbons in soil above cleanup levels is defined at a distance of approximately 115 feet south of GM-11S. Hydrocarbon concentrations east of GM-11S extend to the tank farm wall, but hand augered soil samples collected east of the tank farm wall have concentrations below soil cleanup levels. The northern extent of hydrocarbon-impacted soil extended to the loading rack, approximately 100 feet north of GM-11S.

As an expansion of the existing interim remedial system, a pneumatic submersible total fluids pump was installed in GM-11S and began pumping in April 2000 to recover product and groundwater. Vapor extraction was also initiated in GM-11S in April to extract volatile hydrocarbons from the soils in the vicinity of GM-11S. These measures were initiated to protect the waterfront and to mitigate the impacts of detected product in this area.

The results of this investigation have been included in the design for the final cleanup action. The groundwater capture zone model completed for the final groundwater/ product recovery system includes GM-11S as a recovery well. GM-11S will be used as a recovery well in the final cleanup action. Although this area was included in the targeted areas for cleanup as part of the CAP, the final remedial system has been expanded in this area based on the additional data collected. The cleanup action selected in the CAP is still appropriate for the area around GM-11S because the product detected in GM-11S is similar to the contamination detected in this area during the RI (gasoline and diesel).

2.8. Summary Investigation Near MW-03, Plant 2

Additional soil sampling has been conducted since completion of the RI in the area of Well MW-03, located outside the eastern firewall of Plant 2, which will affect the design of the soil remedy for Plant 2. This well was planned for continued performance monitoring as part of the Consent Decree. Recent monitoring showed that the product sheen detected in this well since 1995 (ARCADIS Geraghty & Miller 1996) increased to approximately 0.5 feet in the late summer of 1999. Limited drilling and soil sampling away from this well was subsequently conducted in the fall, which indicated soils with TPH above cleanup level are present in this area.

The results of these activities were conveyed to Ecology during a meeting in February 2000. Additional drilling and soil sampling is planned to be conducted in this area during the 2000 summer season (Section 3.2). Per Ecology's approval, the results of the investigations in this area (including the fall 1999 sampling activities) will be presented as a supplement to this design report. This report will include an evaluation of the extent and sources of contamination, and the impacts on the soil remedy and monitoring for Plant 2. The appropriate remedial options will be evaluated with Ecology based on the results of the investigation. Remedial action in this area may be conducted separately from the planned remedial action presented in this report and may require amending the schedule presented in Section 3.

2.9. Owner and Operator Information

ARCO will own, operate, and maintain the cleanup action during and following remedial action (construction activities). The ARCO project coordinator is:

Ralph Moran, Senior Environmental Engineer
ARCO Products Company
4 Centerpointe Drive
La Palma, California 90623-1066
(714) 670-5126

Additional documents, including the Health and Safety Plan (HASP), Final Construction Plans and Specifications, and the O&M Manual, interrelate with this Engineering Design Report. The HASP will provide site-specific and general safety procedures to be followed during construction and implementation of the remedial actions. The Final Construction Plans and Specifications document will be prepared and submitted to interested bidders for construction of the final cleanup actions. The construction plans are summarized in Section 4 of this report and draft construction plans are included as Appendix B. The O&M Manual will describe procedures for operation of the groundwater depression/product recovery system, SVE system, air sparging system, and the associated monitoring program. The HASP and O&M Manual will be prepared under separate covers and submitted to Ecology for review. The O&M Manual will be prepared following startup of the installed final remediation system.

3. Schedules

The cleanup actions selected for the site will be implemented upon approval of the final design from Ecology. The cleanup action design, construction, and startup activities will be performed according to the schedules described below and will begin in the summer of 2000. A detailed schedule and time frame is included as Figure 5.

3.1. Plant 1 Waterfront Tasks

- Continue groundwater monitoring in accordance with the Groundwater Compliance Monitoring and Contingency Plan;
- Obtain revised KCDNR and PSAPCA permits;
- Complete final remediation system design plans and specifications;
- Prepare bid documents and solicit bids from qualified contractors;
- Select contractors;
- Construct and install the final remediation system components;
- Groundwater/product recovery system startup;
- SVE system startup;
- Air sparging system startup.

3.2. Plants 1 and 2 Inland Soils Tasks

- Continue groundwater monitoring in accordance with the Groundwater Compliance Monitoring and Contingency Plan;
- Complete excavation design plans and specifications;
- Prepare bid documents and solicit bids from qualified contractors;
- Select contractors;

- Excavate TPH hot spot soils;

- Backfill, regrade excavations.

As discussed in Section 2.8, additional drilling and soil sampling will also be conducted in the area of Well MW-03 at Plant 2 to further delineate the extent of TPH in this area and its impacts on the soil remedy. The schedule for these activities is also included in Figure 5. The schedule for implementing cleanup actions and monitoring in this area will be developed as part of the additional investigation and engineering design activities summarized in Section 2.8.

4. Construction Plans and Specifications

Draft construction plans for the remedial treatment system along the waterfront area are included as Appendix B of this document. Draft excavation plans for the inland soils at Plants 1 and 2 are included as Appendix C of this document. Final construction plans and specifications will be prepared under separate cover to detail the cleanup actions to be performed. The Final Construction Plans and Specification document will be prepared in conformance with currently accepted engineering practice and WAC 173-340-400 (4)(b). Plans and specifications will be stamped/signed by a Washington State Registered Professional Engineer (P.E.) The document will be provided to qualified potential bidders and will contain the following:

- A general description of the project which details the cleanup actions (including work to be done), a summary of design criteria, an existing facility map, adequate site surveying, and a copy of permits/approvals.

- Detailed plans and specifications necessary for construction, including surface contours, construction materials storage, construction waste storage/management, utility locations within cleanup areas, surface drainage, pumps, piping and valves, treatment units, materials, backfill/rip-rap, and change in grades.

- A description of construction impact controls (including dust, traffic, and noise).

- Construction documentation including specific quality control tests, frequency of tests, and acceptable results.

- The HASP for health and safety requirements for workers during construction and excavations.

5. Cleanup Action Conceptual Plans

This section describes the conceptual plans for the overall cleanup action, which consists of two major elements: 1) the Plant 1 waterfront area, and 2) the Plants 1 and 2 soils excavation. Each of these elements is described separately in the following sections.

5.1.1. Plant 1 Waterfront Area Design Approach

This section describes the design approach for the Plant 1 waterfront area cleanup action, which includes a groundwater/product recovery system, soil vapor extraction system, and air sparging system. Each of these systems is described separately in the following sections.

5.1.1.1. Groundwater/Product Recovery System

The objectives of the groundwater/product recovery system are to remove contaminated groundwater and product from the waterfront area and to transfer these fluids to the treatment facility. The system components include recovery wells; recovery pumps; total fluids (groundwater and product) piping; treatment system; effluent streams (groundwater, product, vapor); instrumentation and control logic; a treatment building; and heating, ventilation, and electrical systems. The design of individual treatment system components is discussed in the sections below and is further detailed in Appendix B and in the Final Construction Plans and Specifications document, to be provided separately.

5.1.1.1.1. Recovery Wells

The groundwater/product recovery system includes ten recovery wells. The well locations (Figure 4) have been selected to capture the groundwater and product along the waterfront. The recovery wells include four existing wells (RW-1, RW-2, RW-4, and GM-11S) and six new wells (RW-5 through RW-10).

New recovery wells RW-5 and RW-6 will be located north of the warehouse and RW-10 will be installed south of the warehouse. These wells will be constructed of 4-inch diameter Schedule 40 polyvinyl chloride pipe (PVC) to a total approximate depth of 19.5 feet bgs with 0.02-inch slotted screen extending from 4 to 19 feet bgs. RW-7, RW-8, and RW-9 will be located inside the warehouse building. These wells will be constructed of 4-inch diameter PVC to a total approximate depth of 22.5 feet bgs with 0.02-inch slotted screen extending from 7 to 22 feet bgs.

The depths for the wells to be installed inside of the warehouse have been selected to account for the raised warehouse foundation (approximately 4 feet above the surrounding ground surface). The selected depths will result in all of the recovery wells completed with well screens at similar elevations. The six new recovery wells will be installed using the hollow stem auger drilling method. During well installation, a geologist, in contact with the design team, will supervise the drilling activities to observe and document the lithology at each location and to determine the exact depths for placement of the screens. Construction details for the recovery wells are provided in Appendix B and will be further detailed in the Final Construction Plans and Specifications document, to be provided separately. All recovery well designs are consistent with the requirements of WAC 173-160.

Recovery wells will accommodate the recovery pumps and all necessary down-hole piping, as described in the following sections.

5.1.1.1.2. Recovery Pumps

A pneumatic submersible pump will be installed in each recovery well to pump groundwater and product to the treatment system. The groundwater and product will be pumped together as total fluids to the treatment system. All wetted parts of the pumps will be specified to be compatible with petroleum hydrocarbons and the expected groundwater chemistry. The submersible pump specifications will be included in the Final Construction Plans and Specifications document, provided separately. The pump specification requires that each pump be capable of producing the required maximum flow rate (5.5 gpm) at a head of approximately 40 feet of water. This is the head required to transmit the groundwater from each well, through the pipe, fittings, and manifolds, to the influent of the treatment system at the oil/water separator.

The discharge flow rate from each recovery well will be controlled individually by valves and measured by cycle counters located at the wellhead or at the influent manifold. Internal pump sensors will control the operation of the pumps to preclude pumping the well dry. In addition, the pump control logic will shut down pumping if a predetermined high level switch setting is reached in the treatment system oil/water separator, thereby precluding overflow of the oil/water separator.

5.1.1.1.3. Total Fluids System Piping

The locations of the total fluids system piping run between the recovery wells and the treatment system are shown in Appendix B, and further details will be provided in the Final Construction Plans and Specifications document. Valves and cycle counters for the wells will be located at the wellheads in underground vaults. All transmission piping between the recovery wells and the treatment system building will be black steel pipe. This pipe material was selected based on its compatibility with petroleum hydrocarbons, ARCO terminal requirements, and ease of installation. Underground piping will be placed a minimum of one foot bgs to prevent freezing during the winter. Above ground piping will be protected from freezing by electrically-operated heat tracing.

5.1.1.1.4. Treatment System Components

The objectives of the groundwater/product recovery system are to separate product from groundwater and to reduce dissolved hydrocarbon concentrations to levels acceptable for discharge. Treatment system processes include particulate bag filtration, oil/water separation, and air stripping. The design of individual treatment system components is discussed in the sections below. Draft construction plans are included in Appendix B. Engineering design calculations are included in Appendix D.

Particulate Bag Filter

Filtration of particulates will be provided by a bank of bag filters located in the treatment equipment compound at the south end of the warehouse. The bag filter system incorporates three parallel lines that each contains two bag filters in series. The first filter will house a coarse-mesh bag; the second will house a fine-mesh bag. Under standard operating conditions, each of the three lines will be used to filter particulates. When a filter is changed, the corresponding line will be closed off and the flow will be directed to the two remaining lines. Filter mesh sizes will be selected based on particulates encountered during system startup. Spent particulate bag filters will be managed as described in Section 8.5.

In the event that suspended particulate concentrations require excessive filter bag changes (i.e., more than once per day) during initial operation of the system, the treatment system may be modified to upgrade the particulate filter system to a mixed-media (e.g., sand-type) filter.

Oil/water Separator

The objective of the oil/water separator is to separate recovered product from the extracted groundwater. A 1,100-gallon oil/water separator will be installed inside the treatment building in a manner that will allow the oil/water separator effluent to gravity feed into the air stripper. Extracted groundwater and product will be pumped directly to the oil/water separator. Accumulated product will be pumped from the separator to a product storage tank (Tank 20) located inside the Plant 1 tank farm, as described in Section 8.1.

Air Stripper

The purpose of the air stripper is to decrease the concentration of dissolved hydrocarbons in the groundwater prior to discharge. The volatile portion of the dissolved hydrocarbons will be stripped from the groundwater by the atmospheric air streams that are injected into the groundwater by a blower. The treated effluent water will be pumped to the sanitary sewer at concentrations at or below the permitted discharge limits. The air, which has stripped the volatile hydrocarbons from the groundwater, will be discharged to the atmosphere through an existing effluent stack at the south end of the warehouse in accordance with the PSAPCA permit for the treatment system (Appendix H).

5.1.1.1.5. Effluent Streams

Effluent streams from the groundwater treatment system will consist of treated groundwater exiting the air stripper, vapor exiting the air stripper, and recovered product exiting the oil/water separator. Each of these effluent streams is described below.

Treated Groundwater

Treated groundwater will be pumped from the air stripper to either the KCDNR publicly owned treatment works (POTW) system via the City of Seattle sanitary sewer system or to the Duwamish River. Currently, the effluent from the interim system is discharged to the sanitary sewer, in accordance with a KCDNR discharge permit (Appendix H) and is monitored to meet applicable discharge limits prior to disposal. The effluent for the final system can also be discharged to the sanitary sewer under the existing permit, however,a NPDES permit may be applied for to discharge the effluent to the Duwamish River. If discharged to the Duwamish River, the effluent will be monitored to meet applicable discharge limits prior to disposal. The frequency of monitoring will be described in the O&M Manual.

Product to Tank 20

Recovered product will be pumped from the oil/water separator to a product storage tank (Tank 20) located inside the tank farm. The terminal recycles the product in Tank 20.

Air Stripper Effluent Vapor

The vapor stream exiting the air stripper has stripped the volatiles from the groundwater. The air stripper effluent vapor will be discharged to the atmosphere through an effluent stack installed above the warehouse roof in accordance with the PSAPCA permit for the treatment system (Appendix H). Based on data collected from the interim groundwater/product system in operation between 1992 and 2000, it is not anticipated that the air stripper effluent vapor will require off-gas treatment prior to atmospheric discharge. Management of possible vapor effluent streams is detailed in Section 9.4.

5.1.1.1.6. Treatment Building

The treatment system equipment will be installed on a reinforced concrete slab designed to withstand the equipment loadings. The system enclosure will be an insulated metal building. The building design complies with local and federal building standards. The Final Construction Plans and Specifications document, to be provided separately, will include the design details of the treatment building and building foundation. During building construction, the foundation for the building will be installed with a minimum 12-inch secondary containment berm to contain 110 percent of the volume of the largest vessel inside the building.

The air compressors will also be housed in a separate equipment building that will be properly ventilated. The air compressor building will not require a secondary containment berm.

5.1.1.1.7. Heating, Ventilation, and Electrical

The building heating, ventilation, and electrical designs comply with local, state, and federal standards. The draft building design is included in Appendix B. The Final Construction Plans and Specifications document, to be provided separately, will include the design details of the treatment building, including heating, ventilation, and electrical design.

5.1.1.2. Soil Vapor Extraction System

The objectives of the SVE system are to remove volatile hydrocarbons from the vadose zone beneath the warehouse adjacent to the waterfront and maintain elevated oxygen concentrations within the vadose zone to enhance on-going biodegradation of residual hydrocarbons.

The design of individual treatment system components is discussed in the sections below and is further detailed in Appendix B and in the Final Construction Plans and Specifications document, to be provided separately.

5.1.1.2.1. SVE Wells and Lines

The SVE system includes one existing vertical combination groundwater recovery/vapor extraction well (GM-11S) and four new horizontal vapor extraction lines. The SVE well and line locations (Figure 6) have been selected to capture the residual volatile petroleum hydrocarbons remaining in the vadose zone from the waterfront and warehouse areas.

The new horizontal SVE lines will be constructed of 4-inch diameter 0.02-inch slotted PVC installed in the vadose zone at a depth of approximately 3 feet bgs. The horizontal SVE lines that will be located underneath the warehouse building will be installed by the horizontal drilling method. The other new horizontal SVE lines will be installed in shallow trenches excavated by hand and with a backhoe. During horizontal SVE line installation, an engineer or geologist, in contact with the design team, will supervise the excavation activities to observe and supervise the installation of each line.

Each horizontal SVE line will be connected to the SVE blower at a junction in the SVE line contained in a SVE vault. Each SVE line will have two vaults associated with it; one vault will be a 12-inch diameter round, traffic-rated vault; the second vault will be a 24-inch by 24-inch traffic-rated vault. Construction details for the SVE lines and vaults are available in the draft construction plans provided in Appendix B and will be included in the Final Construction Plans and Specifications document, to be provided separately.

5.1.1.2.2. SVE Blower

One blower will be installed to provide the vacuum required for vapor recovery from the new horizontal SVE lines and GM-11S. All parts of the blower will be specified to be compatible with petroleum hydrocarbons. The blower specifications are included in the draft construction plans (Appendix B) and will be included in the Final Construction Plans and Specifications document, to be provided separately. The blower specification requires that the blower be capable of providing 30 in. H_2O vacuum and an airflow rate of 1,200 scfm. This vacuum and flow rate are required to extract the soil vapors from the horizontal lines and well and transmit the vapors to the treatment area, through the off-gas treatment equipment (if necessary), and out the existing effluent stack located at the south end of the warehouse. The effluent off-gas stream will be permitted in accordance with the PSAPCA permit (Appendix H) for the final remediation system.

5.1.1.2.3. Off-Gas Treatment

Based on experience at this site since SVE startup in 1996, hydrocarbon emissions from the SVE system are not expected to exceed the air emission standard of 50 parts per million (ppm) for volatile hydrocarbons established by PSAPCA. For this reason, no off-gas treatment has been included with the final remediation system.

In the unexpected event that the blower effluent does exceed the PSAPCA standard, contingent options are available for consideration at that time. Primarily, the injection/withdrawal rates can be adjusted to redistribute airflow within the subsurface. This adjustment would be designed to reduce injection into the most highly impacted zones, thus reducing the concentration of hydrocarbons in the effluent vapor stream until effluent concentrations have dropped. Based on SVE experience at the site, it is anticipated that the vapor concentrations may initially be high in some sections of the SVE extraction pipes, but that the concentrations will decrease rapidly over a short period of time. The system flow rates for individual sections will be monitored and adjusted to maintain a balance between maximum removal rates and compliance with PSAPCA discharge limits. Emission controls such as catalytic oxidation or vapor-phase carbon can also be employed in the unlikely event that emissions cannot be controlled through manipulation of the subsurface injection/extraction systems.

5.1.1.3. Air Sparging System

Air sparging will be combined with SVE to enhance the removal of residual hydrocarbons from above and below the water table along the waterfront. This will be accomplished by: 1) accelerating the mobilization and recovery of residual hydrocarbons, 2) enhancing in-situ biodegradation by the injection of air into the saturated zone along the waterfront beneath the warehouse area and, 3) stripping volatile hydrocarbons dissolved in the groundwater and from the smear zone. The smear zone is the result of the influence of tidal and seasonal fluctuation on the water table. The smear zone encompasses approximately two to four vertical feet of soils at the water table where residual hydrocarbons and product have been entrained in the soil matrix (i.e., "smeared").

The design of individual treatment system components is discussed in the sections below. The draft construction plans are included in Appendix B of this report and will be included in the Final Construction Plans and Specifications document, to be provided separately. Engineering design calculations are included in Appendix D of this report.

5.1.1.3.1. Air Sparging Wells

The air sparging system will consist of 12 new air sparging wells installed along the waterfront (AS-3 through AS-14) located as shown on Figure 7. The two existing air sparging wells (AS-1 and AS-2) located south of the warehouse will be abandoned due to their depth of construction, which is not consistent with the final system design.

Based on a conservative radial influence of 20 feet determined during the pilot test (TechSolv 1999), the distance between air sparging wells will be 30 feet to provide overlapping coverage between wells along the waterfront. The wells will be placed near the warehouse foundation and/or Island bulkhead to provide the greatest amount of coverage along these existing barriers to groundwater flow.

The air sparging wells will be constructed of 2-inch diameter schedule 40 PVC with two feet of 0.01-inch slotted screen. The wells will be completed to an approximate depth of 15 feet bgs north the warehouse, 13 feet bgs south of the warehouse, and 19 feet bgs inside the warehouse.

The depths of the wells to be installed inside of the warehouse have been selected to account for the raised warehouse foundation (approximately 4 feet above the surrounding land surface). The selected depths will result in all of the air sparging wells completed with well screens at similar elevations. The air sparging well locations have been selected to provide complete coverage along the waterfront, to optimize the mobilization and recovery of residual hydrocarbons, and to strip volatile hydrocarbons dissolved in the groundwater and from the smear zone. The design parameters for the air sparging system were determined based on the data collected from the pilot test completed in January 1999 (TechSolv 1999).

The air sparging wells will be installed using the hollow stem auger drilling method. A geologist, in contact with the design team, will supervise the drilling activities to observe and document the lithology at each location and to determine the exact depths for placement of the screens. Construction details for the air sparging wells are provided in Appendix B and will be further detailed in the Final Construction Plans and Specifications document, to be provided separately. Engineering design calculations are included in Appendix D of this report.

5.1.1.3.2. Air Compressor

An air compressor will be installed for the air sparging system to provide the airflow required for injection into the 12 air sparging wells at a flow rate of 10 scfm into each well. The airflow rate was determined during the pilot test conducted in 1998 (TechSolv 1999). The air injection pressure of each air sparging well will be determined in the field during the start-up of the system because the injection pressure is dependent on the permeability of the soil and the groundwater elevation for each installed air sparging well.

The air compressor equipment specifications are available in the draft construction plans in Appendix B and will be further detailed in the Final Construction Plans and Specifications document, to be provided separately. Engineering design calculations are included in Appendix D of this report.

5.1.1.4. Instrumentation and Control Logic

The instrumentation and control logic of the groundwater treatment, SVE, and air sparging systems have been designed to operate as automatic systems. While the systems will require operator inspections and site visits on a regular basis to maintain maximum efficiency, the logic controller will govern everyday operating parameters of the systems. A detailed description of the instrumentation and control logic is provided in Appendix B and will be further detailed in the Final Construction Plans and Specifications document, to be provided separately.

5.1.2. Plants 1 and 2 Inland Soils Conceptual Plan

Accessible soil TPH hot spots that meet or exceed the TPH cleanup levels have been identified in Plants 1 and 2, as shown in Appendix C. The accessible TPH hot spots will be excavated at Plant 1 and Plant 2 without undermining the integrity of the above ground storage tanks, piping or other structures adjacent to the hot spot. The excavated TPH soil hot spots in Plants 1 and 2 will be treated on- or off-site using thermal desorption and disposed of on- or off-site.

The objectives of the excavations are to remove the bulk of accessible hydrocarbon contaminated soil, improve general groundwater conditions at the source, enhance restoration time for the impacted areas. In addition, the groundwater monitoring program has been implemented to monitor the on-going biodegradation of the residual TPH in soils as part of the final cleanup action. A deed restriction will also be implemented to prevent inappropriate future use of the site. An overview of the sequencing and events associated with remedial excavation activities is presented below.

- Locate and mark all underground utilities, piping, and obstacles to the greatest degree practical.

- Construct temporary erosion and sediment control measures.

- Prepare temporary soil stockpile areas, if necessary.

- Prepare equipment staging area, decontamination station, residuals storage area, and site ingress and egress.

- Delineate health and safety-regulated areas (exclusion zone, contaminant reduction zone, and support zone).

- Remove and segregate surface cap material (asphalt or gravel).

- Excavate contaminated soil using an excavator (and backfill before proceeding with next excavation).

- Maintain a minimum five-foot distance away from any above ground storage tank.

- Slope the sidewalls of excavations adjacent to tanks with a 3:1 slope.

- Field screen soil during excavation and segregate potentially non-contaminated overburden from soil to be removed from the site.

- Sample stockpiled contaminated soil to determine appropriate off-site disposal or treatment, if necessary.

- Temporarily stockpile non-contaminated soil that may be reused as backfill and stockpile soil that will be hauled off site, if necessary.

- If free product is encountered, implement product removal using a vacuum truck or sorbents, as needed.

- Obtain soil samples from sidewalls and bottom of excavations, documenting sample locations and depths. Soil samples will be analyzed for benzene, TPH-G, TPH-D, and TPH-O. Soil samples will be collected at approximately one sample per 20 feet along the sidewall with two soil samples collected from the bottom of each excavation.

- Obtain confirmation soil samples from non-contaminated overburden stockpiles, if necessary. The sampling frequency will be in accordance with the following Ecology guidance:

BULK CUBIC YARDS OF SOIL	MIN. NUMBER OF SAMPLES
0-100	3
101-500	5
501-1,000	7
1,001-2,000	10
>2,000	10 + 1 for each additional 500 cy

All work will be conducted in accordance with applicable federal, state, and local regulations including Occupational Safety and Health Administration (OSHA), Washington Industrial Safety and Health Act (WISHA), and Washington State Department of Labor and Industries, for excavation safety and for operations at hazardous waste sites. Ecology sampling guidance documents will be followed for all sampling activities.

5.1.2.1. Soil Disposal

Waste characterization will be performed to determine the appropriate disposal or treatment of the contaminated soil. Waste characterization soil samples from the excavation areas will be collected in-situ prior to the commencement of excavation activities.

If the soil is classified as “non-hazardous” based on the waste characterization and acceptance criteria of the receiving facility, the soil will be transferred immediately to the receiving facility. Facilities that will accept non-hazardous soil are TPS Technologies, Inc. in Tacoma, Washington, Rabanco Landfill in Roosevelt, Washington, Waste Management's Arlington Landfill in Arlington, Oregon, or Waste Management's Columbia Ridge Landfill in Oregon.

If the soil is classified as “hazardous” based on the in-situ soil samples, the soils will be temporarily stockpiled on site. The stockpiled soils will be sampled for waste characterization as described in the previous section. If the results of the stockpile soil samples indicate the soils are “hazardous”, the soils will be transferred to Waste Management's Arlington Landfill, in Arlington, Oregon, which is permitted to accept hazardous waste. If the stockpile sample results classify the waste as “non-hazardous”, the soil will be handled as described in the previous paragraph.

5.1.2.2. Backfilling, Regrading, and Capping

Backfilling and regrading will be performed upon completion of excavation activities. The sequence of steps for this phase of the cleanup action is described below:

- Excavations will be backfilled with clean overburden on an excavation-by-excavation basis (i.e., the excavation will be backfilled prior to commencing with the next excavation).

- The excavation will be backfilled and filled up to the finished surface grade.

- The areas will be regraded as needed to the finished grade.

- The area will be recapped with gravel in a condition that is consistent with the surrounding gravel.

6. Engineering Justification

The following sections present the engineering justification for the design of the final remedial system and the inland soils excavations. The design approach and objectives are detailed and includes design criteria, assumptions, and calculations. Capture zones, zones of influence, and general equipment specifications are described for the waterfront area. Expected treatment efficiencies, documentation of effectiveness, and demonstration of compliance with cleanup goals is described in the following sections for the waterfront area and for Plants 1 and 2 inland soils.

6.1. Plant 1 Waterfront Design Approach

The final cleanup action proposed for ARCO Terminal 21T consists of several components that have been selected and combined to address the hydrocarbon impacts identified during the RI and subsequent investigation activities. The final cleanup action has been designed to build on the success of the interim remediation system for the waterfront area. The specific processes included with the proposed final remediation system have been designed to be consistent with the final remedy included in the Consent Decree and CAP issued by Ecology.

As an overview, Figure 2 provides an illustration of the hydrocarbon impacts to Plant 1 targeted by the planned remedial program at the site.

The following sections discuss the elements of the proposed final remediation system.

6.1.1. Groundwater/Product Recovery System

The following sections discuss the objectives, design criteria, calculations, and justification for the groundwater/product recovery system of the final cleanup action.

6.1.1.1. Groundwater/Product Recovery System Objective

The groundwater/product recovery system has been designed as a hydraulic barrier between the groundwater beneath and north of the terminal warehouse and the adjacent surface water. Specifically, the system is intended to intercept product and, to a lesser degree, dissolved hydrocarbons having the potential to migrate west toward the West Duwamish Waterway, adjacent to Plant 1.

To achieve the objective of this subsystem, a roughly linear array of wells will be installed along the west edge of the terminal (Figure 4). Once operational, the wells will create a localized depression in the water table beneath the warehouse area approximately

10 to 20 feet east of the waterfront. Product will accumulate in the depression where it will be subsequently recovered by the wells. In creating a localized depression in the water table, the well array will also produce a hydraulic gradient that is directed inward toward the recovery well array. Thus, in addition to the product, dissolved hydrocarbons found in the shallow groundwater will be recovered by the wells.

6.1.1.2. Design Criteria, Assumptions, and Calculations

The following section presents an overview of the steps that were involved in determining the groundwater/product recovery system parameters. The design calculations presented in Appendix D provide additional information on the design parameters.

6.1.1.2.1. Extent of Petroleum Hydrocarbons in Groundwater

The lateral extent of the product and dissolved hydrocarbons extends from the Plant 1 loading rack north of the warehouse to the remedial equipment area south of the warehouse (Figure 2). The product in this area is “patchy” and discontinuous; however, the recovery system has been conservatively designed to capture product and groundwater under the entire warehouse area. Currently, the maximum apparent thickness of the product measured in wells installed beneath the warehouse is approximately 2 to 4 inches. The thickness of product measured in the wells (“apparent thickness”) is an exaggeration of the actual product thickness in the formation. Based on recent investigation activities conducted subsequent to the completion of the RI, and as discussed previously, product and dissolved hydrocarbons have been recently detected in well GM-11S northeast of the warehouse. In that location, the apparent product thickness (measured in the well) reached a maximum of approximately 6 inches in October 1999.

The vertical extent of dissolved hydrocarbons at Plant 1extends from the water table (1 to 4 feet above mean sea level [msl]) to a maximum depth of approximately 30 feet bgs. The vertical distribution of hydrocarbons is supported by samples collected from discretely screened wells GM-10D and GM-13D. Below 30 feet, dissolved hydrocarbons are below cleanup levels established for the site.

6.1.1.2.2. Capture Zone Analysis/Well Configuration

The well array selected for the groundwater/product recovery system was based on hydraulic parameters determined for the site through aquifer testing and analysis. The array includes GM-11S that has recently been converted to a recovery well. Specifically, a pumping test was performed in Recovery Well RW-4 in 1998, as detailed in the report documenting results of pilot testing (TechSolv 1999), and summarized in Section 2.6.2 of this report.

The aquifer parameters determined from the pumping test were then incorporated into a three-dimensional (3D) numerical flow model to evaluate the aquifer's response to various pumping well layout and operating parameters. The model was then used to verify that the selected well configuration would achieve hydraulic control over the targeted product and dissolved hydrocarbon impacts adjacent to the West Duwamish Waterway.

As determined by the model, the waterfront recovery well array will extend approximately 460 feet south of the loading rack to south of the warehouse (Figure 4) to provide recovery of product and dissolved hydrocarbons. Appendix E provides documentation of the model setup, assumptions, and output. As detailed in Appendix E, the modeling runs were first completed to determine the minimum flow rates necessary to achieve hydraulic capture of the targeted area of the aquifer. The model was then re-run using sustainable well yields determined during long-term operation of the existing extraction system.

The wells have been spaced such that each well's capture zone overlaps with the capture zone of the adjacent wells. This ensures complete recovery within the array. The well capture is predicted to extend to at least the bottom of the shallow fill material.

Figure 8 provides a plan view of the extent of hydraulic capture predicted based on the model simulations. As shown on Figure 8, the predicted capture zone encompasses the area of hydrocarbon impact targeted by the system.

As detailed in Appendix E, the capture zone is a function of the well pumping rate and the aquifer properties of soil transmissivity, storativity, and hydraulic gradient.

The results of the capture zone analysis show that the entire targeted waterfront area will be captured at a flow rate of approximately 1 gpm per well. However, a conservative safety factor has been built into the system design to accommodate variability in the model parameters. The system has been designed to pump at 2 to 3 gpm per well to ensure overlapping capture zones for each well. Based on experience with the existing interim system, sustainable yields can vary from well to well, but 2 to 3 gpm is the maximum sustainable yield observed for an individual well installed in the warehouse area. Actual pumping rates will be based on field conditions. As discussed in the following section, the pumps selected for each well will have additional pumping capacity, if needed.

6.1.1.2.3. Recovery Pumps/Air Supply

As described in Section 6.1.1.2.2 of this report, the well locations and operating flow rates were based on hydraulic capture achieved with sustainable well yields determined through operation of the existing interim remediation system and the results of the pumping test. As with the existing interim remediation system, pneumatic (air driven) pumps will be used for recovery of both groundwater and product from the area adjacent to the West Duwamish Waterway.

Although well yields of 2 to 3 gpm are predicted, the recovery pumps have a pumping capacity of up to a maximum of 5.5 gpm for each well. To maximize flexibility of the system, the air compressor has been sized to provide sufficient airflow to operate the pumps at their maximum capacity, if needed. By this design, additional wells can be added in the future and greater groundwater flow rates can be achieved, if needed, without the need for a significant system modification.

6.1.1.2.4. Groundwater/Product Recovery System Components

As described previously, a ten recovery well network is proposed to achieve hydraulic control and capture product along the waterway. Treatment components downstream of the recovery wells were sized based on the ten-well network operating at a maximum of 5.5 gpm/well. A 30% contingency was included for a maximum fluid processing capacity of 72 gpm.

The groundwater/product recovery system consists of two primary treatment components: an oil/water separator and a low-profile tray air stripper. The separator provides a means of separating product from the pumped groundwater. Product accumulates within the separator and is removed once a sufficient product volume has been recovered. The groundwater effluent from the separator flows by gravity into a transfer tank. This tank contains level switches connected to the control system that operates the effluent transfer pump. From the transfer tank, the product is pumped to Tank 20 in the Plant 1 tank farm and recycled. The air stripper then removes dissolved hydrocarbons prior to discharge. Within the stripper, air is blown counter-current to the groundwater flow. The dissolved volatile hydrocarbons partition into the air stream and are removed in vapor phase. Groundwater effluent from the air stripper is pumped to the sanitary sewer system in compliance with the existing KCDNR discharge permit (Appendix H). Based on predicted system flow rates, dissolved hydrocarbon concentrations and air emission requirements, treatment of the vapor stream is not necessary or included in the process components.

A schematic of the groundwater treatment system components proposed for the system is provided on Sheet 5 of Appendix B.

6.1.1.3. Expected System Treatment, Destruction, Immobilization, and Containment Efficiencies

The groundwater treatment system will recover and treat product and dissolved hydrocarbons. Groundwater treatment system efficiency is detailed in the following two sections.

As described in Section 6.1.1.2.2, with supporting documentation provided in Appendix E, hydraulic capture along the waterfront is predicted to be achieved by a flow rate of approximately 1 gpm for each of the ten extraction wells (10 gpm total flow). To provide greater assurance of capture and accelerate the rate of contaminant removal, the design flow rate for each well is based on the maximum sustainable yield from each well, as determined by long-term operation of the existing interim remedial system. This design flow (2 to 3 gpm per well) represents approximately a 100% to 200% safety factor over the predicted minimum flow requirement. Actual flow rates will be determined based on optimizing the total system during the startup operations.

As described in Section 6.1.1.2.4, the groundwater treatment system combines product separation and dissolved-phase air stripping. These processes have proven to be efficient under conditions encountered at this site, based on operation of the existing interim remedial system.

6.1.1.4. Documentation of Effectiveness and Demonstration of Compliance with Cleanup Standards

The final cleanup action will effectively remediate the petroleum hydrocarbons present in the groundwater at the site. The final cleanup action builds on the success of the interim remediation system. The following sections document the effectiveness of the interim system, anticipated effectiveness of the final cleanup action, and demonstrate that the final cleanup action will comply with cleanup standards.

6.1.1.4.1. Interim Remediation System Effectiveness

The groundwater recovery system of the final cleanup action is expected to provide efficient containment of the petroleum hydrocarbons along the waterfront in Plant 1. Combined with the air sparging system, it is expected to achieve the cleanup objectives described in the CAP. In support of this, the interim remediation system, operational since 1992, has recovered an estimated 9,100 gallons of product. The concentration of dissolved hydrocarbons has also decreased. Finally, the interim remediation system has significantly reduced apparent product thickness in the subsurface in the vicinity of Recovery Well RW-1 and similarly reduced incidents of sheen on the West Duwamish Waterway.

6.1.1.4.2. Groundwater/Product Recovery System Effectiveness

Both quantitative and qualitative parameters will be measured for the groundwater/product recovery system to document system effectiveness. Product thickness measurements will be collected periodically from those wells historically containing measurable accumulations of product (specific wells and monitoring frequency are included in the Groundwater Compliance Monitoring and Contingency Plan). Additionally, the total product volume recovered will be recorded for the system. Each recovery well will be fitted with a cycle counter that indirectly records the volume of groundwater and product (as total fluids) removed from the subsurface.

A log will be maintained at Plant 1 to document the occurrence and severity of any sheen occurring on the West Duwamish Waterway. At present, sorbent booms are placed in the waterway to contain and remove hydrocarbon sheen. The sorbent booms and the waterway are inspected on a minimum monthly basis. Because the groundwater/ product recovery system is designed to intercept petroleum hydrocarbons that are migrating toward the waterway, sheens on the waterway are anticipated to become non-existent soon after startup and operation of the system. While the booms will be removed when sheens are no longer available for migration into the waterway (as determined through measurements of product thickness in adjacent wells), visual inspections of the waterway will continue on a minimum monthly basis as long as the system remains operational. The booms may be redeployed if a persistent sheen associated with the terminal operations is detected.

Groundwater samples will be collected from Plant 1 monitoring wells and submitted for laboratory analysis in accordance with the Groundwater Compliance Monitoring and Contingency Plan (included in the Consent Decree) to monitor the effectiveness of the recovery system developed in cooperation with Ecology for the site. Adjustments to the system may be made based on the monitoring results to ensure the efficiency of the system.

The oil/water separator and air stripper that are part of the interim remediation system at Plant 1 have been effective in removing product and dissolved hydrocarbons to the extent that the system has met discharge requirements since becoming operational. To verify that standards are met with the final remediation system, samples will be collected from the liquid effluent stream of the air stripper in accordance with the existing permit. The KCDNR effluent standards are listed in the permit included in Appendix H.

Based on air samples collected from the air emissions of the existing air stripper, the air emissions of the planned air stripper are not expected to exceed the air emission standard of 50 ppm for volatile hydrocarbons in accordance with the PSAPCA permit currently in effect for the interim remediation system (Appendix H). To verify that the PSAPCA air emission standard is being met, samples will be collected from the air stripper air emissions in accordance with the existing PSAPCA permit. The PSAPCA effluent standards for the air stripper are listed in the permit included in Appendix H.

6.1.1.4.3. Literary Documentation

The engineering and design of the groundwater/product recovery system at Plant 1 is based on the experience with the interim remediation system, pilot study results, and experience with similar sites and conditions and is supported by remedial system design literature and vendor documentation. The following documents were used to support the groundwater/product recovery system design:

- TechSolv Consulting Group, Inc., Air Sparging Pilot Test and Groundwater Pumping Test Report, ARCO Harbor Island 21T, Seattle, Washington, 1999.

- Suthersan, Suthan, Remediation Engineering Design Concepts, CRC Press, Boca Raton, Florida, 1997.

- Nyer, Evan, In Situ Treatment Technology, Lewis Publishers, Boston, Massachusetts, 1996.

6.1.2. Soil Vapor Extraction System

The following sections discuss the objectives, design criteria, calculations, and justification for the SVE system of the final cleanup action.

6.1.2.1. SVE System Objective

The horizontal SVE wells are designed to induce airflow in the unsaturated zone of the subsurface soil beneath the warehouse area. A blower will be used to create a vacuum in the SVE wells and induce the airflow. The induced airflow results in the volatilization and capture of volatile hydrocarbons found in the unsaturated soil matrix. The induced airflow also results in enhanced aerobic biodegradation of hydrocarbons found in the soil matrix. Enhanced biodegradation is especially desirable with the semi-volatile hydrocarbons (e.g., diesel-range hydrocarbons), which volatilize less readily than lighter volatile hydrocarbons (e.g., gasoline-range hydrocarbons).

The horizontal SVE system lines situated beneath the warehouse at Plant 1 are also designed to intercept off-gas from the air sparging wells, which will also be located beneath the warehouse area. The air sparging well off-gas will contain volatile and some semi-volatile hydrocarbons, and may present a risk to the health of the warehouse occupants if not intercepted.

6.1.2.2. Design Criteria, Assumptions, and Calculations

The following section presents an overview of the steps that were involved in determining the SVE system design parameters. The design calculations presented in Appendix D provide additional information on the design parameters.

6.1.2.2.1. Extent of Petroleum Hydrocarbons in Soil and Cleanup Goals

The Consent Decree and CAP (Ecology 1999) stipulate that accessible soil in Plant 1 containing total TPH concentrations in excess of 10,000 mg/kg will be excavated and treated for disposal. Accessible soils in Plant 1 are the inland soils located inside the tank farm. The Plant 1 inland soils excavation design is addressed in Section 6.2. Along the waterfront, soils with total TPH concentrations exceeding 10,000 mg/kg are not accessible for excavation. These soils will be addressed by in-situ soil vapor extraction and enhanced biodegradation/natural attenuation.

6.1.2.2.2. Soil Vapor Extraction System Zone of Influence

The horizontal SVE well layout was designed such that all soils with a total TPH concentration exceeding 10,000 mg/kg are located within the zone of influence of the SVE wells. The horizontal SVE wells will be operated at a vacuum range of 20 to 25 in. H_2O and a flow rate of approximately 1.0 to 1.5 scfm per linear foot of screen, based on the operating parameters of the existing interim system.

Results from the pilot test (G&M 1994b) conducted for the interim system indicate a zone of influence under those operating conditions and in the shallow fill material soil ranging from 50 to 100 feet. The more conservative value of 50 feet was used in determining the layout for the horizontal SVE wells to ensure sufficient capture.

Figure 6 provides a plan view of the proposed SVE well layout for this area of Plant 1. This figure also shows the zone of total TPH concentrations exceeding 10,000 mg/kg and the predicted zone of influence for the SVE system.

The total length of horizontal SVE well screen will be approximately 760 feet. With a flow rate per linear foot of well screen of 1.0 to 1.5 scfm per linear foot, the total system flow rate will range from 760 scfm to 1,040 scfm. To ensure that this flow rate can be achieved, the SVE blower has been designed to provide 1,200 scfm at an operating vacuum of 30 in. H_2O.

6.1.2.3. Expected System Treatment, Destruction, Immobilization, and Containment Efficiencies

The design of the final SVE system builds on the success of the interim remediation system. The following sections describe the expected efficiency of the final SVE system based on the interim remediation system and design calculations (Appendix D).

6.1.2.3.1. Hydrocarbon Mass Reduction

The reduction in hydrocarbon mass from the subsurface at Plant 1 will result from a combination of processes. The first mechanism responsible for mass reduction is direct volatilization. The removal of soil vapors results in an upset in the equilibrium between product, residual-phase (soil), and vapor-phase constituents. Specifically, the removal of mass of vapor-phase hydrocarbons promotes additional volatilization of the product and residual-phase hydrocarbons.

Secondly, the withdrawal of soil vapors results in the elevation of oxygen levels within the subsurface as atmospheric air is pulled into the area of impact. Elevated oxygen levels have been documented to promote enhanced aerobic biological degradation of hydrocarbons. For lower volatility hydrocarbons, aerobic biodegradation is often the dominant mechanism responsible for mass reduction from the subsurface.

The combined processes of direct volatilization and enhanced aerobic biodegradation are expected to achieve the cleanup goals. In support of this expectation, a SVE system has been operational at this facility since January 1996. Through January 2000, the system has recovered an estimated 4,500 pounds (640 gallons) of hydrocarbons through volatilization and an additional 14,000 pounds (2,000 gallons) via aerobic biodegradation.

6.1.2.3.2. Capture of Injected Air

As further described in Section 6.1.3, an air sparging system is included in the final cleanup action along the West Duwamish Waterway. This system will provide for air injection into 12 wells screened beneath the water table. With the injection of air within an area of known hydrocarbon impact, dissolved volatile hydrocarbons will be stripped from the groundwater generating vapors that contain elevated concentrations of volatile hydrocarbons. These vapors will be withdrawn from the subsurface to prevent their accumulation beneath or within the warehouse.

To adequately recover the off-gas from the air sparging system, the airflow rate for each horizontal SVE well cluster must exceed the airflow rate for the air sparging well cluster with which it is paired (Appendix B, Sheet 2). The following table lists the horizontal SVE and air sparging well pairs and the respective flow rates of each that will ensure full capture of the injected air.

SVE Well Cluster	Airflow Rate (scfm)	Sparging Well Cluster	Airflow Rate (scfm)
SVEH-1	160	AS-3, AS-4, AS-5	30
SVEH-2*	255		
SVEH-3	141	AS-6, AS-7, AS-8	30
SVEH-4	163	AS-9, AS-10, AS-11	30
SVEH-5	48	AS-13, AS-14	20

* No air sparging wells are associated with SVEH-2

6.1.2.4. Documentation of Effectiveness and Demonstration of Compliance with Cleanup Standards

As described in Section 6.1.2.1, the objective of the SVE system is to promote subsurface air flow within the area of impact exceeding 10,000 mg/kg, reduce hydrocarbon concentrations through volatilization and enhanced aerobic degradation and capture vapors created by the air sparging system. The following monitoring program will be employed to document the ability of the system to achieve the cleanup goals for this area.

Documentation of the SVE system's ability to remove hydrocarbons from the subsurface will be provided by field measurement of hydrocarbon concentrations in the blower effluent stream. Field measurements of hydrocarbon recovery rates will be supplemented by periodic laboratory analyses of vapor samples. The frequency of vapor sampling will be determined based on requirements of the PSAPCA permit (Appendix H) and will be detailed in the O&M Manual, to be provided separately.

Enhancement of aerobic biodegradation rates in the subsurface will be documented based on field measurements of fixed gas concentrations. Specifically, oxygen and carbon dioxide concentrations will be recorded for vapor streams collected by the SVE blower. The concentration of these gases will be compared to atmospheric concentrations. Depleted oxygen levels or elevated carbon dioxide levels are an indication of on-going bioactivity.

Groundwater samples collected from the waterfront area, in accordance with the Groundwater Compliance Monitoring and Contingency Plan (included in the Consent

Decree), will also confirm that the final remediation system is effective in meeting the cleanup goals for the waterfront.

6.1.2.4.1. Literary Documentation

The engineering and design of the SVE system at Plant 1 is based on the experience with the existing interim SVE system, pilot study results, remedial system design literature, and vendor documentation. The following documents were used to support the design of the SVE system.

- TechSolv Consulting Group, Inc., Air Sparging Pilot Test and Groundwater Pumping Test Report, ARCO Harbor Island Terminal 21T, Seattle Washington, 1999.
- Geraghty & Miller, Inc., Soil Vapor Extraction Field Design Test Results, ARCO Harbor Island Terminal 21T, Seattle, Washington, 1994.
- Suthersan, Suthan, Remediation Engineering Design Concepts, CRC Press, Boca Raton, Florida, 1997.
- Nyer, Evan, In Situ Treatment Technology, Lewis Publishers, Boston Massachusetts, 1996.

6.1.3. Air Sparging System

The following sections discuss the objectives, design criteria, calculations, and justification for the air sparging system of the final cleanup action.

6.1.3.1. System Objective

The air sparging system of the final cleanup action selected for this area of the terminal is designed to augment the groundwater/product recovery system described in Section 6.1.1. Specifically, the system relies on the injection of air within the zone of hydrocarbon-impacted area immediately adjacent to the West Duwamish Waterway. The injected air is expected to promote the following occurrences:

- Volatilize residual and dissolved hydrocarbons within the saturated soil matrix,
- Enhance product recovery through disturbance of the aquifer, and

- Enhance aerobic degradation of the hydrocarbons located within the zone of aeration.

6.1.3.2. Design Criteria, Assumptions, and Calculations

The following section presents an overview of the steps that were involved in determining the air sparging system parameters. The design calculations presented in Appendix D provide additional information on the design parameters.

6.1.3.2.1. Extent of Hydrocarbons in Groundwater

The air sparging system is targeting the area along the West Duwamish Waterway that has historically contained product, residual, and dissolved hydrocarbons. As described previously, the lateral extent of the product and dissolved hydrocarbons extends from the Plant 1 loading rack north of the warehouse to the area south of the warehouse (Figure 2). Dissolved hydrocarbons with concentrations exceeding the groundwater cleanup levels stipulated in the CAP extend from the water table to a maximum of 30 feet bgs.

6.1.3.2.2. Air Sparging Well Zone of Influence

A pilot test was conducted at the site in 1998 to determine the zone of influence achieved by an air sparging well. Based on the pilot test results, an individual injection well, screened approximately 10 feet below the top of the water table with an injection rate of 10 scfm, was found to influence groundwater to a radial distance of 20 to 40 feet. The zone of influence was determined by measuring changes in dissolved oxygen (DO) concentrations, reduction-oxidation potentials, and water table elevations during the injection of air into the pilot air sparging wells. For the system design, the more conservative estimate of a zone of influence of 20 feet was used to determine well spacing to ensure overlapping coverage.

Figure 7 illustrates the area targeted for remediation by the air sparging system. Also shown on this figure is the proposed well layout and expected zone of influence for the multi-well network. The air sparging wells will be associated with the groundwater/product recovery system and will be installed in a generally linear array along the Plant 1 waterfront. Within the array, the air sparging wells have been spaced such that the zones of influence of adjacent wells overlap.

The screen depth of the air sparging well of 10 feet below msl is based on the extent of hydrocarbon-impacted groundwater. As described previously, groundwater with hydrocarbon concentrations exceeding groundwater cleanup levels at Plant 1 extends from the water table to a maximum depth of 30 feet bgs.

The minimum airflow for the system based on the pilot testing results will be 120 scfm for the 12-well system at an injection pressure of approximately 20 to 25 pounds per square inch (psi). A safety factor has been included in this design to allow expansion of the system, if warranted based on performance of the system after startup. To meet this safety factor, a system capable of providing 146 scfm of oil-free air at 30 psi was selected for the air supply.

6.1.3.3. Depletion Rates for Volatile Petroleum Hydrocarbons in Site Groundwater

The air sparging system has been designed to assist the groundwater/product recovery system and the SVE system in achieving the cleanup goals described in the Consent Decree and CAP (Ecology 1999). The Plant 1 air sparging involves the injection of compressed air into the saturated zone of the subsurface soil at 12 separate sparging points. As the injected air travels upward, transfer of dissolved hydrocarbons occurs from the groundwater to the airflow. The removal of dissolved hydrocarbons from the groundwater results in an upset in the equilibrium between the mobile groundwater and the immobile volatile hydrocarbons that are sorbed to the saturated zone soil and trapped in the saturated zone pore spaces. The upset in equilibrium results in a transfer of hydrocarbons from the sorbed and saturated zone phases to the dissolved phase in the groundwater where it eventually volatilizes in the airflow. The airflow through the soils will also provide the additional physical force of drive to enhance mobilizing the maximum amount of product for recovery.

6.1.3.4. Documentation of Effectiveness and Demonstration of Compliance with Cleanup Standards

The air sparging system shares many of the parameters used to document the effectiveness of the groundwater/product recovery system (Section 6.1.1). Product thickness measurements will be collected periodically from those wells historically containing measurable accumulations of product. Additionally, total product volume recovered will be recorded for the system. Groundwater samples will be collected from Plant 1 monitoring wells and submitted for laboratory analysis in accordance with the Groundwater Compliance Monitoring and Contingency Plan (included in the Consent Decree) prepared for the facility.

In addition to groundwater monitoring, field measurements of DO will be obtained during operation of the air sparging system. As with the pilot test, DO measurements provide a direct measurement of the system's aeration of the groundwater.

6.1.3.4.1. Literary Documentation

The engineering and design of the air sparging system at Plant 1 is based on the experience with the existing interim groundwater/product recovery system, pilot test results, remedial system design literature, and vendor documentation. The following documents were used to support the SVE system design.

- TechSolv Consulting Group, Inc., Air Sparging Pilot Test and Groundwater Pumping Test Report, ARCO Harbor Island 21T, Seattle, Washington, 1999.

- Suthersan, Suthan, Remediation Engineering Design Concepts, CRC Press, Boca Raton, FL, 1997.

- Nyer, Evan, In Situ Treatment Technology, Lewis Publishers, Boston, Massachusetts, 1996.

6.2. Plants 1 and 2 Soils

Accessible soils having total TPH concentrations above 10,000 mg/kg in Plant 1 and above 20,000 mg/kg in Plant 2 will be excavated to remove the bulk of the contamination in those areas (Figure 2, Figure 3, and Appendix C).

The cleanup actions selected for the inland soils at Plants 1 and 2 are as follows:

- Implement institutional controls and degradation of organic contaminants by intrinsic biodegradation/natural attenuation for inaccessible soils beneath the warehouse area and inland of the warehouse area for Plant 1 and Plant 2,

- Excavate accessible TPH hot spots in the inland portions of Plant 1 and Plant 2, and

- Deed restrictions.

6.2.1. Design Criteria

The extent of the TPH hot spot excavations in Plants 1 and 2 are based on soil sampling that was completed during the RI. Soils that are above the total TPH cleanup levels in each plant will be excavated and transported off-site for disposal. During excavation activities, if free product is encountered, excavation of the soils that contain free product will occur. Accessible soils will be excavated without undermining the integrity of the above ground storage tanks or any underground utilities or structures adjacent to the hot spots. In addition, in accordance with the geotechnical study previously completed at the site (Appendix G), all excavations near above ground storage tanks will remain a minimum of five feet from the edge the tank and will have a 3:1 slope on the sidewall adjacent to the tank.

6.2.1.1. Plant 1

The soil cleanup level for total TPH in Plant 1 is 10,000 mg/kg as determined by Ecology and stated in the Consent Decree and CAP for the site. Soil borings that had total TPH equal to or greater than 10,000 mg/kg define the extents of the excavation. For the TPH hot spot in Plant 1, the excavation will be in the vicinity of soil borings B-17, B-20, B-21,

B-23, TS-25, TS-26, TS-27, TS-36, TS-37, TS-39, TS-40, TS-41, and TS-42 between above ground storage tanks 1, 8, 9, and 13, as shown in Appendix C. The total volume of this TPH hot spot is approximately 1,100 cubic yards (cy). The volume calculations are based on the area as determined by mathematical computation in AutoCAD drafting software and the depths as described in Appendix C. The excavation depths are based on the vertical extent of TPH concentrations above the cleanup level. Soil excavation volumes are listed in Table 1, and soil volume calculations are presented in Appendix F.

6.2.1.2. Plant 2

The soil cleanup level for total TPH in Plant 2 is 20,000 mg/kg as determined by Ecology and stated in the Consent Decree and CAP for the site. Soil borings that had total TPH equal to or greater than 20,000 mg/kg define the extents of the excavation. Figures showing the excavation areas are included in Appendix C.

The first TPH hot spot is located at soil boring TS-1. The total volume of this TPH hot spot is approximately 5 cy. The second TPH hot spot is located at soil boring B-059. The total volume of this TPH hot spot is approximately 2 cy. The third TPH hot spot is located between above ground storage tanks 59001 and 20001, and is in the vicinity of soil borings B-36, B-37, TS-12, TS-14, TS-15, TS-17, TS-19, TS-31, TS-32, TS-34, and TS-35. The total volume of this TPH hot spot is approximately 600 cy. The volume calculations are based on the area as determined by mathematical computation in AutoCAD drafting software and the depths as described in Appendix C. The excavation depths are based on the vertical extent of TPH concentrations above the cleanup level. Soil excavation volumes are listed in Table 1, and soil volume calculations are presented in Appendix F.

6.2.2. Soil Disposal Destruction Efficiencies

All excavated soils will be taken off-site for disposal at a landfill or will be treated by off-site thermal desorption. Thermal desorption is the preferred method of treatment for the hydrocarbon impacted soils being excavated at the site.

Landfilling the excavated soils will not destroy the hydrocarbons in the soils. Thermal desorption will destroy the hydrocarbons within the soil and is a permanent treatment technique and meets the MTCA objective for a permanent solution to the extent practicable.

6.2.3. Documentation of Effectiveness

The effectiveness of soil excavations to remove hydrocarbon-impacted soil will be documented by the sidewall and bottom samples collected from the excavations as described in Section 5.1.2.

Soil excavation has been successfully used to treat hundreds of hydrocarbon-impacted sites in the Puget Sound area. Ecology has documentation on file regarding many petroleum hydrocarbon-impacted sites that groundwater quality also improves following hydrocarbon-impacted soil excavations.

6.2.4. Compliance with Cleanup Levels

Accessible soils will be excavated to below the soil cleanup levels. Intrinsic biodegradation/natural attenuation of the residual TPH contaminated soil left in place will be monitored through groundwater monitoring activities in accordance with the Groundwater Compliance Monitoring and Contingency Plan (included in the Consent Decree).

7. Design Features for Spill Control

The final cleanup actions have features designed into the treatment components and excavation procedures to control accidental spills. The design features are described in the following sections.

7.1. Groundwater/Product Recovery System

The groundwater/product recovery system is the only component of the waterfront area treatment system that requires spill control features, as described below. The SVE and air sparging components do not require spill control features because they transport and treat only vapor-phase streams.

7.1.1. Pipes

All pipes used for the conveyance of recovered groundwater and product will be Schedule 80 welded black carbon steel. Black carbon steel piping is currently used in the existing interim groundwater/product recovery system and has proven effective in preventing leaks. The pipe is generally resistant to corrosion and has sufficient strength to prevent damage due to normal wear and tear.

All of the steel pipe will be cathodically protected by the existing terminal system with an impressed current to further retard corrosion. This type of cathodic protection involves impressing a "protective current" between several subsurface anodes and the pipe. The protective current differs from the naturally occurring corrosive cell current in that the cation flow is toward, rather than away from, the system piping. As a consequence, corrosion occurs on the subsurface anodes rather than on the piping.

All of the steel pipe used for conveyance of recovered groundwater will be hydrostatically pressure tested after installation. If any section fails the test it will be repaired and retested until it passes the pressure test to ensure that the groundwater/product recovery system piping continues to be leak tight.

7.1.1.1. Treatment Building Secondary Containment

A concrete dike will be constructed around the perimeter of the base of the treatment building to contain potential spills from the oil/water separator, air stripper, and sanitary sewer transfer pump. The containment dike will encompass an approximate area of 150 square feet, will be 14 inches tall, and will contain a total volume of approximately 1,320 gallons. It is designed to contain a total release from either the oil/water separator or the air stripper. The liquid capacities of the oil/water separator and the air stripper are 1,110 and 350 gallons, respectively. A high level switch installed in a sump within the containment dike will activate when the water level with the dike exceeds 3 inches. The high level switch, when activated, will de-energize the pneumatic recovery pump air compressor and a three-way emergency shutoff solenoid operated valve. When de-energized, the solenoid valve will release all compressed air remaining in the pneumatic pump feed lines thereby stopping the pumps.

7.2. Plants 1 and 2 Soil Excavations

The site will be secured at the end of every workday during excavation activities in both Plants 1 and 2. The site currently has controlled access to the facilities, which will be maintained during excavations. Securing the site will prevent accidental falls into the open excavations, as well as provide containment of any soil temporarily stockpiled on site.

Erosion control material will be used around the base of any temporary soil stockpiles to prevent the accidental run off of soil from the site.

All trucks will be covered during transportation of the excavated soil from the site to the treatment facility, to prevent contaminated soil from blowing out of the truck.

8. Design Safety Features

The final cleanup actions have safety features designed into the treatment components and installation and excavation procedures. The safety features are summarized in the following sections, and are detailed in the instrumentation diagram, Sheet 10 of Appendix B. The Final Construction Plans and Specifications document, which will be prepared under separate cover, will further detail the safety features incorporated in the design of the final cleanup actions. In addition, the HASP will contain details on safety features designed to protect workers during construction, excavation, and O&M.

8.1. Groundwater Recovery System

The groundwater/product recovery system has several safety features designed into the treatment equipment components. These safety features will prevent the accidental release of hydrocarbon-contaminated water and prevent electrical accidents.

8.1.1. System Interlock

The groundwater recovery system is equipped with a control system that is designed to prevent the following events from occurring:

- The pneumatic pump air compressor pressure exceeds the safe operational level.
- The water pressure in the oil/water separator influent exceeds the safe operational level.
- Recovered groundwater overflows in the oil/water separator.
- Recovered groundwater overflows in the diffused air stripper sump.
- The diffused air stripper airflow pressure exceeds the safe operational level.
- Spilled recovered groundwater overflows the treatment building secondary containment dike.

The following table lists the potential groundwater system alarm conditions and the subsequent control system response actions.

ALARM CONDITION EQUIPMENT - ACTION	NORMAL/ALARM LIGHT
AIR COMPRESSOR HIGH PRESSURE SWITCH 300 ACTIVATES	PSH ALARM LIGHT 300 ON

	GW AIR COMPRESSOR - DEENERGIZE	HS NORMAL LIGHT 300 OFF
	SOLENOID OPERATED VALVE 200 - OPEN TO ATMOSPHERE	SOV NORMAL LIGHT 200 OFF
	CHEMICAL FEED PUMP - DEENERGIZE	HS NORMAL LIGHT 600 OFF
AIR COMPRESSOR DEENERGIZES		HS ALARM LIGHT 300 ON
	CHEMICAL FEED PUMP - DEENERGIZE	HS NORMAL LIGHT 600 OFF

HEAT TRACE DEENERGIZES		HT ALARM LIGHT 500 ON
LEVEL SWITCH LOW 600 ACTIVATES		LSL ALARM LIGHT 600 ON
	CHEMICAL FEED PUMP - DEENERGIZE	HS NORMAL LIGHT 600 OFF
CHEMICAL FEED PUMP DEENERGIZES		HS ALARM LIGHT 600 ON
CHEMICAL FEED TANK HIGH PRESSURE SWITCH 700 ACTIVATES		PSH ALARM LIGHT 700 ON
	GW AIR COMPRESSOR - DEENERGIZE	HS NORMAL LIGHT 300 OFF
	SOLENOID OPERATED VALVE 200 - OPEN TO ATMOSPHERE	SOV NORMAL LIGHT 200 OFF
	CHEMICAL FEED PUMP - DEENERGIZE	HS NORMAL LIGHT 600 OFF
OIL/WATER SEPARATOR LEVEL SWITCH HIGH-HIGH 700 ACTIVATES		LSHH ALARM LIGHT 700 ON
	GW AIR COMPRESSOR - DEENERGIZE	HS NORMAL LIGHT 300 OFF
	SOLENOID OPERATED VALVE 200 - OPEN TO ATMOSPHERE	SOV NORMAL LIGHT 200 OFF
	CHEMICAL FEED PUMP - DEENERGIZE	HS NORMAL LIGHT 600 OFF
DIFFUSED AIR STRIPPER LEVEL SWITCH HIGH-HIGH 800 ACTIVATES		LSHH ALARM LIGHT 800 ON
	DIFFUSED AIR STRIPPER - DEENERGIZE	HS NORMAL LIGHT 800 OFF
	GW AIR COMPRESSOR - DEENERGIZE	HS NORMAL LIGHT 300 OFF
	GW AIR COMPRESSOR - DEENERGIZE	SOV NORMAL LIGHT 200 OFF
	SOLENOID OPERATED VALVE 200 - OPEN TO ATMOSPHERE	SOV NORMAL LIGHT 200 OFF
	CHEMICAL FEED PUMP - DEENERGIZE	HS NORMAL LIGHT 600 OFF
DIFFUSED AIR STRIPPER AIR FLOW HIGH PRESSURE SWITCH 800 ACTIVATES		PSH ALARM LIGHT ON
	DIFFUSED AIR STRIPPER - DEENERGIZE	HS NORMAL LIGHT 800 OFF
	GW AIR COMPRESSOR - DEENERGIZE	HS NORMAL LIGHT 300 OFF
	SOLENOID OPERATED VALVE 200 - OPEN TO ATMOSPHERE	SOV NORMAL LIGHT 200 OFF
	CHEMICAL FEED PUMP - DEENERGIZE	HS NORMAL LIGHT 600 OFF
DIFFUSED AIR STRIPPER AIR LOW FLOW SWITCH 800 ACTIVATES		FSL ALARM LIGHT 800 ON
	DIFFUSED AIR STRIPPER - DEENERGIZE	HS NORMAL LIGHT 800 OFF
	GW AIR COMPRESSOR - DEENERGIZE	HS NORMAL LIGHT 300 OFF
	SOLENOID OPERATED VALVE 200 - OPEN TO ATMOSPHERE	SOV NORMAL LIGHT 200 OFF
	CHEMICAL FEED PUMP - DEENERGIZE	HS NORMAL LIGHT 600 OFF
SANITARY SEWER TRANSFER PUMP 900 DEENERGIZES		HS ALARM LIGHT 900 ON
	DIFFUSED AIR STRIPPER - DEENERGIZE	HS NORMAL LIGHT 800 OFF
	GW AIR COMPRESSOR - DEENERGIZE	HS NORMAL LIGHT 300 OFF
	SOLENOID OPERATED VALVE 200 - OPEN TO ATMOSPHERE	SOV NORMAL LIGHT 200 OFF

	CHEMICAL FEED PUMP - DEENERGIZE	HS NORMAL LIGHT 600 OFF
CONTAINMENT DIKE FLOW SUMP LEVEL SWITCH HIGH 1000 ACTIVATES		LSH ALARM LIGHT 1000 ON
	GW AIR COMPRESSOR - DEENERGIZE	HS NORMAL LIGHT 300 OFF
	SOLENOID OPERATED VALVE 200 - OPEN TO ATMOSPHERE	SOV NORMAL LIGHT 200 OFF
	CHEMICAL FEED PUMP - DEENERGIZE	HS NORMAL LIGHT 600 OFF

8.2. Soil Vapor Extraction and Air Sparging Systems

To ensure that the off-gas from the air sparging system is captured by the SVE system, the air sparging system must de-energize if the SVE de-energizes. To ensure that this occurs, the air sparging system and SVE system are controlled by the same control system. The control system for the two systems is designed to prevent the following events from occurring:

- Liquid in the SVE blower inlet separator exceeds the safe operational level.
- The sparging air compressor pressure exceeds the safe operational level.
- The SVE blower deenergizes and the air sparging wells continue to operate.

The following table lists the potential SVE / air sparging system alarm conditions and the subsequent control system response actions.

ALARM CONDITION	EQUIPMENT - ACTION	NORMAL/ALARM LIGHT
SVE FLOW ELEMENT 200 INDICATES INADEQUATE FLOW		SVE FE 200 ALARM LIGHT ON
SEPARATOR LEVEL SWITCH HIGH-HIGH 200 ACTIVATES		SVE LSHH 300 ALARM LIGHT ON
	SVE BLOWER - DEENERGIZE	SVE HS 400 NORMAL LIGHT OFF
	SPARGING AIR COMPRESSOR - DEENERGIZE	SPARGING HS 300 NORMAL LIGHT OFF
SVE BLOWER DEENERGIZES		SVE HS 400 ALARM LIGHT ON
	SPARGING AIR COMPRESSOR - DEENERGIZE	SPARGING HS 300 NORMAL LIGHT OFF
SPARGING HIGH PRESSURE SWITCH 300 ACTIVATES		SPARGING PSH 300 ALARM LIGHT ON
	SPARGING AIR COMPRESSOR - DEENERGIZE	SPARGING HS 300 NORMAL LIGHT OFF
SPARGING AIR COMPRESSOR DEENERGIZES		SPARGING HS 300 ALARM LIGHT ON

8.3. Electrical

The groundwater recovery system, soil vapor extraction system, and air sparge system, are designed to comply with the following safety codes:

- National Fire Protection Association (NFPA) – The process has been engineered using all applicable safety codes, as published by NFPA. When constructed, the system will be in compliance with NFPA 497A, which pertains to electrical classification of chemical process areas.

- National Electric Code – All electrical equipment and appurtenances have been designed for deployment in compliance with the National Electric Code (NFPA 70), 1999 Edition.

- The groundwater recovery system, soil vapor extraction system, and air sparge system, are fitted with the following safety switches and alarms –

- Emergency Stop Switches – The system is equipped with two emergency stop switches, one located on the main control panel the other located in the equipment area. The emergency stop switches are maintained-contact, mushroom-top switches. When depressed, the switches will de-energize outputs to all motors and process control components.

- Automated Alarms – All monitored process parameters that can result in spills, or accidental environmental releases, are equipped with automated alarms. In the event of an alarm, system components will be automatically shut down in accordance with the tables in Sections 8.1.1 and 8.1.2.

- Automated Alarms Resets – All alarms in the system are equipped to "latch" upon occurrence, eliminating the possibility of "unattended restart". To clear an alarm, the operator must press the "reset" button. In the event of power loss following alarm occurrence, the controls are configured to "retain" the alarms, and not restart automatically.

- Autodialer – The system is equipped with an autodialer device. The autodialer will call a pre-designated phone number to notify personnel of an alarm condition and will enable remote call-in by system operators to check on system operation.

- Programmable Logic Controller (PLC) – The system is controlled with a PLC, which has a reliability of less than 1 failure in 10,000,000 cycles. This is equivalent to over 5 years of operation between failures.

8.4. Plants 1 and 2 Soil Excavations

Safety features that will be in-place during the soil excavation activities in Plants 1 and 2 are as follows:

- Ambient air monitoring for organic vapors using a hand-held OVM or photoionization detector (PID).
- Breathing space monitoring of workers for organic vapors using a hand-held OVM or PID.
- Ambient air monitoring for lower explosive limit of vapors using a hand-held explosimeter.
- Breathing space monitoring of workers for lower explosive limit of vapors using a hand-held explosimeter.
- Emergency cutoff switches on excavation equipment.

8.5. Long-Term Safety

All construction, excavation, and O&M activities will be performed in accordance with design criteria, federal and state OSHA regulations for construction safety, excavation safety, and work at hazardous waste sites, and local standard practice for construction and excavation.

The final cleanup actions at the site have been designed to eliminate potential exposure pathways (e.g., direct contact, ingestion, inhalation of dust, groundwater to surface water) and the site will not pose a threat to the safety of human health of future long-term workers or the environment. Addition specific long-term safety considerations are discussed below.

8.5.1. Flood Hazards

The ARCO Terminal 21T site and Harbor Island are not within an identified 100-Year Floodplain (King County 1990), and lesser floods in recent times have not significantly affected the ARCO 21T Terminal site (Bob Bunton, pers. Comm., 2000). Therefore, flooding is not expected to be a concern in relation to the remedial activities at the site. Specifically, flooding or heavy rainfall is not expected to affect the vapor extraction system (VES) since the screened intervals have been designed to be well above the water table. In addition, groundwater recharge in the areas of the VES is laterally from upgradient recharge areas (primarily the tank farms) because these areas are cover with pavement or building structures (e.g. the warehouse). The areas of the VES are therefore less subject to water table fluctuations due to local heavy rainfall.

8.5.2. Earthquake Hazards

Potential seismic activity is not anticipated to adversely impact the remedial actions at the ARCO terminal based on the seismic history of the site. The structures along the waterfront including the warehouse foundation, which is trapping floating product, have not been significantly impacted by past seismic events. Historically, the Puget Sound area has been subjected to frequent earthquakes of moderate intensity. The occurrence and severity of damage has been closely associated with areas of saturated, unstable soils that are subject to settling and liquefaction (in which sediments suddenly behave as a liquid). Areas of fill along the Duwamish River and its mouth were the locations of considerable building damage during recent earthquakes. During the most recent major earthquake (1965, magnitude 6.5), some structures on Harbor Island experienced significant damage (Steinbrugge and Cloud 1965); however, the ARCO warehouse foundation does not appear to have been significantly impacted. This foundation (including the driven interlocking sheet piling that the foundation rest on) continues to serve as an effective barrier to product migration as evidenced by the accumulation of product beneath the warehouse and paucity of sheens on the adjacent Waterway.

Due to the historical frequency of earthquakes in the Puget Sound region and the saturated fill materials underlying Harbor Island, it is likely that the ARCO Terminal 21T site will experience seismic activity at some time in the future. However, all structures and equipment have been (or will be) constructed and installed in accordance with the applicable professional codes to minimize risks to personnel and property. In addition, the product recovery system will provide hydraulic capture along the water front and the targeted timeframe for cleanup in five years. The groundwater pumping system and associated capture zones will also provide hydraulic protection to the Duwarmish Waterway during the cleanup phase of the project.

9. Waste Management

Wastes will be generated during construction, excavation, and O&M of the final cleanup actions. All wastes will be managed in accordance with all applicable local, state, and federal requirements.

The primary waste streams that will be generated during construction, excavation, and O&M are as follows:

- Treated groundwater discharged to the sanitary sewer,
- Recovered product transferred to Tank 20,
- Product recovery booms,
- Off-gas vapor effluent streams from the SVE system and the groundwater treatment system air stripper,
- TPH-impacted soils from the TPH hot spot excavations in Plants 1 and 2, and
- Product sorbents from collection of product during excavations, if necessary.

ARCO will be implementing cleanup that incorporates technologies [(i) reuse or recycling, (ii) destruction or detoxification] with a higher preference under MTCA [WAC 173-340-360(4)] as follows:

(i) reuse or recycling - Recycling of recovered petroleum product from the waterfront area,

(ii) destruction or detoxification - Destruction of petroleum-impacted soils via thermal desorption.

By using technologies with a higher preference under WAC 173-340-360 (4), this cleanup action meets the MTCA objective for a permanent solution to the extent practicable.

The management practices for each primary waste stream are described below.

9.1. Treated Groundwater

The waterfront area groundwater treatment system located will be generating treated groundwater that will be disposed through the sanitary sewer in accordance with the KCDNR discharge permit for the site. The volume of treated groundwater discharged on a monthly basis will be a maximum of 1,166,400 gallons, based on a 3 gpm per well pumping rate.

The groundwater effluent stream will be sampled monthly for the constituents required by the permit to ensure compliance with the discharge limits. In the event of a discharge permit exceedance, the groundwater/product recovery system will be taken off-line and KCDNR will be notified. The groundwater/product recovery system will be evaluated and the results of the evaluation will be discussed with KCDNR. The groundwater/product recovery system will be restarted after necessary corrective actions have been taken and following approval by KCDNR.

9.2. Recovered Product

Product recovered by the groundwater/product recovery system will be pumped from the oil/water separator and transferred via recovery system piping to a product storage tank (Tank 20) located inside the Plant 1 tank farm. The terminal recycles the product in Tank 20.

9.3. Product Recovery Booms

Two product recovery booms are maintained along the shoreline of the site in the West Duwamish Waterway to absorb any sheen that may appear on the waterway. These booms are replaced when necessary. Waste profiling has been completed for the booms and they are classified as “non-hazardous”. A licensed waste handler properly disposes the booms off-site.

9.4. Vapor Effluent Streams

The groundwater/product recovery system and the SVE system will have a combined effluent vapor stream, which will be discharged to the atmosphere in accordance with the PSAPCA permit in effect for the systems (Appendix H).

The air stripper and SVE system has been designed to discharge at a combined maximum flow rate of 1,200 scfm. The actual flow rates will be based on field conditions and balancing of the system operating parameters. The vapor effluent stream will be discharged to the atmosphere through an existing stack located at the southern end of the warehouse.

9.5. Plants 1 and 2 Excavated Soils

Waste characterization sampling will be completed in-situ as described in Section 5.1.2.1 to determine the appropriate disposal or treatment of the contaminated soil. The steps for sequencing of off-site disposal or treatment are described below:

- Verify approved waste profile by designated disposal or treatment facility. The selected facility will be determined by the nature of the waste (Washington State Dangerous Waste or Problem Waste) and acceptance criteria of the receiving facility. Potential off-site landfill disposal or thermal desorption treatment facilities include TPS Technologies, Inc. in Tacoma, Washington; Waste Management's Arlington Landfill in Arlington, Oregon; Waste Management's Columbia Ridge Landfill in Oregon; and the Rabanco Landfill in Roosevelt, Washington.

- Load excavated contaminated soil into trucks.

- Cover contaminated soil.

- Transport soil directly to the facility or to a local landfill transfer station.

- Document the number of trucks, the approximate volume of soil transported from the site, and the weight of the material received at the landfill or treatment facility.

Based on the results of previous waste profiling sampling of soil samples collected from the hot spot areas, it is anticipated that the soils will be treated as a non-hazardous waste.

9.6. Product Sorbents from Excavation Activities

If product is encountered during excavation activities, sorbents or a vacuum-truck will be used to recover the product. If sorbents are used, the sorbents will be sampled for waste classification. Pending classification, the sorbents will be stored in sealed 55-gallon drums on-site in a secure location. Following waste classification as a "hazardous" or "non-hazardous" waste, the sorbents will be properly transported by a licensed waste handler to a licensed treatment or disposal facility.

9.7. Residual Wastes

Residual wastes from construction, excavation, and O&M activities will be generated during this cleanup action.

Final remediation system construction and inland soils excavation activities will generate residual wastes that will be managed by the following procedures:

- All water generated during decontamination activities will be treated by the interim remediation system. Decontamination water will be transferred into the oil/water separator and treated by the air stripper prior to discharge to the sanitary sewer.

- Disposable personal protective equipment (PPE) will be placed in plastic bags and disposed of as solid waste.

Groundwater/product recovery system, SVE system, and air sparging system O&M activities will generate occasional residual wastes consisting of purge water, particulate bag filters, oil/water separator sludge, air stripper sludge, spent off-gas treatment residuals, and disposable PPE. These residual wastes will be managed as follows:

- Purge water collected during groundwater monitoring activities will be treated by the groundwater/product recovery system located at the Plant 1 waterfront area and disposed to the sanitary sewer with the treated groundwater.

- Wastes from O&M activities will be segregated and placed in separate 55-gallon drums.

- Each drum will be labeled with a description of the contents and date filled.

- Each drum will be sealed and secured. An on-site staging area for the accumulation of drums has been established at the ARCO terminal. The drums will be stored in this designated location temporarily until waste characterization has been completed and the drums are picked up for disposal at a licensed facility.

- If off-gas treatment is used for the SVE system, treatment residual wastes may consist of spent catalyst beds and/or carbon vessels. These residual wastes will be properly managed and disposed of according to manufacturer directions. A record of all off-gas treatment wastes will be maintained.

- Disposable PPE will be placed in plastic bags and disposed of as solid waste.

- A record of all residual wastes generated and disposed of will be maintained.

10. Construction Testing and Quality Control

The contractor will perform construction quality control consistent with the requirements and provisions of the Final Construction Plans and Specifications, which will be provided under separate cover. Construction quality control will include the necessary elements to ensure that contaminated materials are handled properly and that construction of the final cleanup actions are performed properly. In accordance with WAC 173-340-400(7)(b), all aspects of construction will be performed under the supervision of a P.E. registered in the state of Washington or a qualified technician under the direct supervision of the engineer. The engineer and qualified technicians under his supervision are the quality assurance/quality control (QA/QC) managers.

A QA/QC plan will be provided in the Final Construction Plans and Specifications document and provided to interested contractors. The QA/QC Plan will provide the following information:

- Project organization,
- Identification of QA/QC managers and responsibilities,
- Description of the construction testing,
- Documentation, and
- Change order procedures.

The QA/QC managers will also provide as-built drawings and a report following completion of construction. These documents will detail all aspects of the construction. The as-built report will also contain certification from the engineer that the work performed was conducted in substantial compliance with the plans and specifications.

10.1. Groundwater/Product Recovery System

The final groundwater/product recovery system will have several components quality-control tested to ensure proper operation of the component and entire system. The following sections describe the components to be tested and the tests that will be performed.

10.1.1. Pneumatic Pressure Testing

After its installation, all black carbon steel piping used for conveyance of recovered groundwater will be hydrostatically pressure tested. The test will involve the application of a pressure of 150 psi for a period of two hours. After two hours of being pressurized, all pipe sections that fail to remain within 0.5 psi of the original applied pressure fail the pressure test. Each section failing the test must be repaired and retested until it passes the pressure test.

10.1.2. Equipment Mechanical Check

Once the equipment has been installed, complete with all auxiliary and support systems, and is ready for operation, each piece of equipment will be mechanically checked to verify that it is installed per the manufacturer's instructions. The equipment shall be fine-tune adjusted, and completely checked out before the equipment and support systems are considered ready for process start-up.

10.1.3. Equipment Performance Check

The equipment will be performance tested after it has been demonstrated that the equipment can operate continuously without mechanical interruption under process flow conditions for a minimum of up to five days unattended.

The performance check for each piece of equipment will be in compliance with the design criteria stipulated in the manufacturer's specifications, the contract drawings, and project technical specifications. The performance test will be based on maintaining the design criteria for five consecutive days. In the event that the equipment does not conform to the design criteria, it will be modified as necessary and retested.

10.2. Plants 1 and 2 Inland Soils

Excavation quality control will be performed as described previously for construction quality control in Section 10 in accordance with WAC 173-340-400(7)(b). The QA/QC plan that will be provided in the Final Construction Plans and Specifications document and provided to bidding contractors will further detail the quality control measures during excavation of TPH contaminated soils in Plants 1 and 2.

The QA/QC managers will also provide as-built drawings and a report following completion of excavations. These documents will detail all aspects of the excavations. The as-built report will also contain certification from the P.E. that the work performed was conducted in substantial compliance with the plans and specifications.

11. Compliance Monitoring

The final cleanup actions incorporate monitoring to determine that cleanup goals are achieved and maintained after remedial actions have been completed. The Groundwater Compliance Monitoring and Contingency Plan (included in the Consent Decree) details the monitoring that will be performed at the site. Three types of compliance monitoring will be performed to meet the monitoring program objectives:

- **Performance monitoring** will be performed to confirm that the cleanup action has attained cleanup standards and other performance standards.

- **Confirmational monitoring** will be performed to confirm the long-term effectiveness of the cleanup action once cleanup levels and other performance standards have been attained.

- **Protection monitoring** will be performed to confirm that human health and the environment are protected adequately during all phases of the cleanup actions (WAC 173-340-410 (1)(a)). Protection monitoring will be addressed in the HASP and is summarized in Section 11.

Monitoring methods, monitoring locations, and types of analyses were selected to monitor the effectiveness of the cleanup actions in attaining the soil, product, and groundwater cleanup levels for the site. These monitoring activities are summarized below. Included in the following sections are modifications to the monitoring plan submitted with the CAP, which have been approved by Ecology.

11.1. Groundwater/Product Recovery, SVE, and Air Sparging Systems

Performance monitoring of the operation of the expanded recovery system at the Plant 1 waterfront area will be conducted to ensure the cleanup criteria are achieved within the established restoration timeframe. O&M and monitoring activities generally consist of the following and will be detailed in the O&M manual:

- Inspecting equipment and piping;

- Monitoring operational parameters of the groundwater depression/product recovery system (water flow rate, system pressure, power usage, etc.);

- Gauging product and water levels in all of the recovery wells;

- Adjusting water flow rates, completing site visit report forms and daily log forms;
- Monitoring SVE system operational parameters (flow rate, system vacuums, hydrocarbon concentrations, power usage, etc.);
- Measuring applied vacuums, air flow rates, and hydrocarbon concentrations at each SVE wellhead;
- Measuring induced vacuums and water level elevations at observation wells;
- Measuring air injection pressure and flow rate at air sparging wells; and
- Sampling the groundwater influent and effluent streams.

11.2. Plants 1 and 2 Inland Soils

The determination of adequate soil treatment will be based on the ability for the remedy to comply with the groundwater cleanup standards for the site, to meet performance standards designed to minimize human health or environmental exposure to soils above cleanup levels, and to provide practicable treatment of contaminated soils.

The groundwater monitoring program is designed to evaluate the effectiveness of the remedy in removing product and residual and dissolved hydrocarbons and to evaluate the long-term effectiveness of intrinsic biodegradation/natural attenuation of inaccessible soils. Selected wells will be monitored for product, hydrocarbons, and natural attenuation parameters.

11.3. Summary of the Compliance Monitoring Plan

Performance monitoring includes a combination of monitoring the groundwater/product recovery system and waterway surface water booms in Plant 1, and sampling of a selected well network in Plants 1 and 2 (Figures 9 and 10). Selected wells will be monitored for product, hydrocarbons, and natural attenuation parameters. Confirmational monitoring will consist of monitoring selected wells for product, hydrocarbons, and natural attenuation parameters.

Contingency plans are also included in the monitoring plan in the event the cleanup actions are ineffective in the restoration time frame for the site.

The monitoring plan, with the revisions approved by Ecology, is summarized below.

11.3.1. Plant 1

Performance monitoring wells in Plant 1 will consist of fourteen wells including nine existing wells (GM-11S, GM-12S, GM-13S, GM-14S, GM-15S, GM-16S, GM-17S, GM-24S, and AR-03) and five wells to be installed along the waterfront (AMW-01, AMW-02, AMW-03, AMW-04, and AMW-05). These wells will be monitored as follows:

- GM-11S, GM-12S, and GM-13S will be monitored monthly for the presence of free product or sheens to monitor the performance and effectiveness of the product recovery system in the warehouse area. GM-11S and GM-13S have historically had free product.

- GM-14S will be monitored monthly for the presence of free product or sheens to monitor the performance and effectiveness of intrinsic biodegradation/natural attenuation of the sheen historically detected in the well.

- GM-16S and GM-17S, located upgradient in Plant 1 along a westerly groundwater flow direction, will be monitored annually for the first year for biogeochemical parameters.

- GM-15S, GM-24S, and AR-03 will be monitored quarterly for the first year for benzene, TPH-G, TPH-D, and TPH-O. In addition, these wells will be monitored annually for the first year for biogeochemical parameters .

- AMW-01, AMW-02, AMW-03, AMW-04, and AMW-05 will be monitored quarterly for the first year for benzene, TPH-G, TPH-D, and TPH-O following installation.

Confirmational monitoring wells in Plant 1 will consist of AR-03, AMW-01, AMW-02, AMW-03, AMW-04, and AMW-05. These wells will be monitored for benzene, TPH-G, TPH-D, TPH-O and biogeochemical parameters. In addition, AMW-01 through AMW-05 will be monitored for cPAHs. Confirmational monitoring frequency will be discussed with Ecology at the first year site and data review.

11.3.1.1. Waterfront Well Construction

Five waterfront confirmational monitoring wells in Plant 1 will be AMW-01, AMW-02, AMW-03, AMW-04, and AMW-05. These wells will be installed along the waterway during the final remedial system construction activities. The wells will be constructed to allow representative sampling of the zone of groundwater discharge that is located beneath the warehouse foundation and Island bulkhead and above the brackish groundwater. The wells will be constructed as close to the shoreline and inland of subsurface barriers as practical to intercept the area of groundwater flow. The wells will be screened across this zone from near the base of the bulkhead to above the top of the brackish zone resulting in screen depths extending from approximately 25 feet to 35 feet bgs.

11.3.2. Plant 2

Performance monitoring wells in Plant 2 will consist of five existing wells (GM-19S, GM-19D, GM-21S, GM-22S, and MW-03) and any new wells that may be required as a result of the post CAP soil investigations and cleanup actions planned for the MW-03 area.

- MW-03 will be monitored monthly for the presence of free product or sheens to monitor the performance and effectiveness of the product and cleanup action in this area. MW-03 has historically had free product.

- GM-19S, GM-19D, GM-21S, and GM-22S will be monitored quarterly for the first year for benzene, TPH-G, TPH-D, and TPH-O. In addition, these wells will be monitored annually for the first year for biogeochemical parameters.

Confirmational monitoring wells in Plant 2 will consist of five wells (GM-19S, GM-19D, GM-21S, GM-22S, and MW-03). These wells will be monitored for benzene, TPH-G, TPH-D, TPH-O and biogeochemical parameters. MW-03 will be monitored following removal of free product and sheen. Confirmational monitoring frequency will be discussed with Ecology at the first year site and data review.

11.4. Summary of the Contingency Plan

A contingency plan is a cleanup technology that serves as a "backup" remediation technology in the event the preferred option fails or proves ineffective in a timely manner. A five-year restoration timeframe is anticipated for completion of site cleanup and monitoring activities.

<u>Plant 1 Waterfront Contingency</u>

Implementation of the contingency plan will be based on the results of the performance and confirmational monitoring program. A contingency plan may be implemented for the warehouse area as follows:

- A persistent sheen is observed on the waterway adjacent to the ARCO terminal;

- Product is observed in any monitoring well or recovery well. Confirmational groundwater monitoring results indicate increasing concentrations above cleanup levels of one or more IHS's which are attributable to historical on-site releases or which may indicate a new release.

Implementation of one or more of the following alternatives may be selected in response to any of the above occurrences:

- Review the efficiency of the existing remedial actions and restoration time frame to determine if the remedial actions are effective in providing sufficient protection but will take longer than anticipated to achieve the cleanup criteria;

- Identification and removal to the extent practicable of the source(s) causing the criteria to be triggered;

- Initiate passive or active product recovery in the well(s) in which product is observed;

- Startup or adjustment of specific elements of the product recovery system, SVE system, or air sparging system based on the location of product (i.e., in a monitoring or recovery well, or a persistent sheen on the waterway);

- Evaluate the effectiveness of the product recovery system, SVE system, or air sparging system based on the location of product to ensure system influence in that area, and expand the recovery system if necessary;

- Statistical evaluation of the groundwater monitoring data if groundwater monitoring results indicate an increasing trend above cleanup levels of one or more IHS's in a monitoring well;

<u>Plants 1 and 2 Inland Soils</u>

Implementation of the contingency plan will be based on the results of the performance and confirmational monitoring program. A contingency plan may be implemented for the inland soils at Plants 1 or 2 as follows:

- Product is observed in any monitoring well. Confirmational groundwater monitoring results indicate increasing concentrations above cleanup goals which are attributable to historical on-site releases or which may indicate a new release.

Implementation of one or more of the following alternatives may be selected in response to any of the above occurrences:

- Addition of nutrients to enhance intrinsic biodegradation/natural attenuation of the residual TPH in inaccessible soils. The results of the biotreatability study conducted as part of the RI concluded that natural attenuation is ongoing at the site, and that it may be enhanced by the addition of nutrients such as nitrates and/or phosphates.

- Evaluate groundwater migration control options, if necessary.

In the event that the contingency plan should be implemented at the waterfront or inland soils, ARCO will prepare a contingency work plan that contains engineering design criteria as needed to address the criteria triggering the contingency action.

12. Health and Safety Assurance

A site-specific health and safety plan (HASP) will be prepared for the cleanup actions by the contractor before beginning work at the site. The HASP will be prepared in accordance with the health and safety requirements of ARCO, Ecology (per WAC 173-340-810), OSHA, and the Washington Industrial Safety and Health Act (WISHA) (WAC 296-24, 296-62, and 296-155). All workers involved in cleanup activities will be required to read and sign the HASP. A health and safety meeting will be conducted with the contractor, subcontractors, construction testing personnel, and applicable ARCO employees prior to commencement of activities at the site.

13. Public Participation Plan

ARCO will cooperate with and support Ecology in the public participation activities during the engineering design and remedial action phases of the cleanup actions at the ARCO Harbor Island Terminal 21T in accordance with Section XXIV of Consent Decree 00-2-05714-8SEA.

These activities may include the following:

- Fact sheets,
- Public notices,
- Meetings with interested public and local governments,
- Public presentations on the progress of the cleanup actions.

14. References

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