EXHIBIT F

GROUNDWATER COMPLIANCE MONITORING AND CONTINGENCY PROGRAM

ARCO HARBOR ISLAND TERMINAL 21T

SEATTLE, WASHINGTON

ISSUED TO

WASHINGTON STATE DEPARTMENT OF ECOLOGY

SUBMITTED BY

ARCO TERMINAL 21T

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1.0 INTRODUCTION

1.1 Purpose

This Groundwater Compliance Monitoring and Contingency Program has been prepared to describe the protocol and procedures that will be used to confirm that cleanup requirements have been achieved at the ARCO Products Company (ARCO) Harbor Island Terminal 21T in Seattle, Washington (Figure 1). The monitoring plan has been prepared to satisfy the requirements of the Model Toxics Control Act (MTCA) regulations WAC 173-340-410, -720, and –820. This plan was also prepared in accordance with requirements of the Consent Decree, cooperatively entered into between ARCO and the Washington State Department of Ecology (Ecology).

The purpose of this Groundwater Compliance Monitoring and Contingency Program is to specify actions to be followed to confirm that human health and the environment are protected during remedial actions, to confirm that cleanup standards have been achieved, and to confirm the long-term effectiveness of the cleanup actions at Plants 1 and 2 at the ARCO Harbor Island Terminal 21 T.

This plan includes the following components:

1) Introduction: Discuss site location and overview of site and hydrogeology, cleanup action summary, monitoring objectives and rationale, types of monitoring, and monitoring locations and schedule to be used for compliance monitoring are provided in this section;

2) Protection Monitoring: Describe the criteria for protection monitoring under WAC 173-340-400;

3) Performance Monitoring: Describe the criteria and methodology for performance monitoring of free product recovery, natural attenuation, and other selected remedial technologies to document that the cleanup action is performing as anticipated;

4) Confirmation Monitoring: Describe the confirmation criteria which monitors the long-term effectiveness of the cleanup action once cleanup and performance standards have been attained;

5) Criteria for Meeting Performance and Compliance Standards: Discuss criteria to be used to determine if performance and compliance standards have been met; and

6) Data Evaluation and Reporting: Discuss free product monitoring, groundwater sampling and analytical procedures, data validation, evaluation procedures, reporting, and monitoring schedules;

7) Contingency Plans: Discuss the steps that will be implemented in the event the proposed cleanup actions are not effective.

1.2 SITE LOCATION

The ARCO Harbor Island Terminal 21T is located in Seattle, Washington (Figure 1). The ARCO site is comprised of two plants. Plant 1 is located along the West Waterway of the Duwamish River, and Plant 2 is located inland, in the north-central part of Harbor Island.

1.3. Summary of Site Hydrogeology

Harbor Island is a flat-lying island consisting of hydraulic and mechanical fills overlying native deltaic deposits. The hydraulic fill consists of approximately 15 to 20 feet of poorly graded fine to medium sand with silt. The native deltaic deposits also consist of poorly graded fine to medium sand with silt and are distinguished during drilling from the overlying fill deposits by the presence of silt and clay interbeds and abundant rootlets.

The ARCO terminal is mostly capped with concrete or asphalt, except within the tank farms, where much of the areas are capped with gravel or are covered by the above ground storage tanks. Less than approximately 30 percent of the ARCO facility is uncapped. Within the tank farm areas, most rainwater infiltrates through the unsaturated zone and recharges the groundwater. The water table occurs at depths ranging from one to eight feet below ground surface (bgs).

Unconfined groundwater occurs within the fill and native deltaic deposits. The groundwater occurs as a freshwater lens overlying saline water at depth. Saline water occurs at depths of approximately 40 feet bgs near the Island edge at Plant 1 and 80 feet bgs near the center of the Island at Plant 2. Groundwater beneath Harbor Island generally flows in a radial pattern outward from the center of Harbor Island to the Island's edge. Groundwater generally flows to the west at Plant 1. At Plant 2, shallow groundwater flow is generally to the northwest in the spring and summer, but flows in a radial pattern in the fall and winter due to ponding within the tank farm.

Groundwater levels near the Island edges respond in the short term to tidal changes in the surrounding surface water. The Duwamish Waterway adjacent to the site has a tidal fluctuation of up to approximately 14 feet. The tidal fluctuation affects the shallow groundwater near the Island edge and results in daily groundwater fluctuations of approximately one to two feet. The observed groundwater fluctuations are dampened by the warehouse foundation and Island bulkhead, which are located near the edge of Harbor Island. These barriers create a "damming" effect on groundwater entering the Duwamish River. Due to these barriers, groundwater is forced to flow out primarily in the narrow area beneath the foundation and bulkheads and above the saltwater interface.

The warehouse foundation and Island bulkhead also form a "hanging wall" that traps the migration of floating product into the Duwamish River. The water table elevations also fluctuate seasonally approximately only one to two feet due to rainfall. The combined fluctuation due to tidal influence and seasonal rainfall is approximately

three to four feet. The shallow water table elevation does not drop below the base of the subsurface barriers.

1.4 SELECTED CLEANUP ACTION SUMMARY

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 time restoration in accordance with WAC 173-340-360 (6) and consider public concerns as designated in WAC 173-340-600.

Cleanup actions at the site include source removal in the soil and groundwater, treatment, and recycling/off-site disposal, monitoring, natural attenuation, and institutional controls.

Soil. The goal of soil cleanup standards for petroleum hydrocarbons are to protect the beneficial use of groundwater (surface water quality and associated ecosystem). The preferred alternatives will result in substantive compliance with the soil cleanup standards by reducing concentrations of contaminants in soils to levels that will support and maintain compliance with ground water quality standards. The specific cleanup actions are:

- In-situ treatment of soil that includes Soil Vapor Extraction (SVE), Air Sparging, and Natural Attenuation/Intrinsic Biodegradation in Plant 1 shoreline area.

- Excavation of accessible total petroleum hydrocarbons (TPH) subsurface soil hot spots with concentrations above 10,000 milligrams per kilogram (mg/kg) in Plant 1 southeast area of the site (Figure 2).

- Excavation of accessible TPH subsurface hot spots with concentrations above 20,000 mg/kg in Plant 2 (Figure 3).

- Intrinsic biodegradation/natural attenuation of inaccessible TPH in subsurface soils in Plant 1 and Plant 2.

- Contingency plans, institutional controls/deed restriction.

Groundwater. 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. The wells at the downgradient edge of the site are considered points of compliance wells. These points of compliance and performance shall consist of a network of monitoring wells located in the product plume area and on the downgradient property boundary. Other wells (sentry well) situated off-site will also be used to document plume migration, performance standards, and to warn of any

unanticipated change in off-site groundwater conditions. Exact locations of these wells are identified in the later sections of this Groundwater Compliance Monitoring Program, Exhibit F, for the site. The specific cleanup actions are:

- Expansion of product skimming enhanced by depression of the water table in Plant 1 shoreline area.
- Groundwater treatment and proper disposal.
- Expansion of air sparging below the water table in Plant 1 shoreline area.
- Surface water boom maintenance and sheen monitoring in the Duwamish River.
- Free product monitoring in Plants 1 and 2. (Figure 2 and Figure 3)
- Groundwater monitoring in point of compliance (confirmation), performance and offsite (sentry) wells in Plants 1 and 2.
- Contingency Plans, Institutional control in the form of a deed restriction for the site

1.4.1 Indicator Hazardous Substances

The following hazardous substances serve as indicator hazardous substances (IHS's) established in the RI/FS for purposes of defining site cleanup requirements for ARCO Terminal 21T:

Groundwater IHS's-

- Dissolved copper
- Total petroleum hydrocarbons as gasoline (TPH-G)
- Total petroleum hydrocarbons as diesel (TPH-D)
- Total petroleum hydrocarbons as oil (TPH-O)
- Benzene
- Carcinogenic polynuclear aromatic hydrocarbons (cPAH's): benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)flouranthene, chrysene, dibenz(a,h) anthracene, indeno(1,2,3-cd)pyrene
- Free-phase product

Soil IHS's-

- TPH-G

- TPH-D
- TPH-O
- Free-phase product

1.5 MONITORING OBJECTIVES AND RATIONALE

The cleanup action incorporates monitoring to determine that cleanup standards are achieved and maintained after remedial actions have been completed. During the remedial actions, performance monitoring will be conducted to confirm that cleanup actions are performing as anticipated and have attained cleanup standards and treatment goals. After remedial actions are performed, compliance monitoring will be conducted to confirm and determine that cleanup actions have attained cleanup standards and performance standards. Protection monitoring will be used to adequately protect human health and the environment during construction and operation of the cleanup actions.

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 achievement of cleanup levels in groundwater shall be measured at points of performance and compliance located within the free product plume area and at the downgradient edge of the site. The overall objective of the compliance monitoring wells downgradient of the free product plumes and on the property boundaries is to provide additional safeguards by providing both Ecology and ARCO with early warning of potential contamination migration and basis for contingency plan reviews and implementation, if necessary. Sentry wells, situated off property limits and downgradient of dissolved petroleum hydrocarbon plumes, will also be used to monitor migration of dissolved petroleum constituents and contingency plan determination.

Monitoring methods, monitoring locations, and types of analyses were selected to monitor the effectiveness of the cleanup actions in attaining the soil, free product, and groundwater cleanup standards for the site. The specific details of these monitoring activities are described in subsequent sections of this document.

1.5.1 Soil

The sum of the TPH-G, TPH-D, and TPH-O at specific sampling locations were above levels requiring action at the site.

TPH in Plant 1. Accessible soil TPH concentrations were above the cleanup action levels (10,000 mg/kg) southeast of the site next to Tanks 1, 8, 9, and 13. These soil TPH concentrations are in the vicinity of soil borings B-17, B-20, B-21, B-23, TS-23, TS-25, TS-26, TS-27, TS-36, TS-27, TS-39, TS-40, TS-41 and TS-42.

TPH in Plant 2. Accessible soil TPH concentrations were above the cleanup action levels (20,000 mg/kg) southeast of the site next to Tanks 59001, 20001 and in the northeast corner of the site. These soil TPH concentrations are in the vicinity of soil borings B-36, B-37, TS-1, TS-12, TS-14, TS-15, TS-17, TS-19, TS-31, TS-32, TS-34 and TS-35.

1.5.2 Groundwater

Groundwater will be monitored for benzene, TPH-G, TPH-D, TPH-O, and free product in specific areas of the site prior, during and after implementation of the cleanup action discussed in Section 1.4. The selected analysis and monitoring locations addresses soils cleanup actions areas, areas of product recovery, and the water quality chemistry data for the site.

Wells Not Included in Compliance Monitoring Program. Monitoring wells not included in the confirmation, performance, or the sentry wells are excluded from this Compliance Groundwater Monitoring Program. After the one-year review of the site groundwater analytical data as discussed in Section 3.2.2, Ecology and ARCO will review potential wells for abandonment as appropriate.

Damaged Wells Due To Cleanup Action Implementation. Monitoring wells designated for confirmation, performance or sentry wells that become disabled as a result of the cleanup action implementation must be replaced. Ecology must approve the new proposed location before replacement of the damaged groundwater monitoring well.

Plant 1 Areas Above Cleanup Levels

Benzene and TPH Areas: Monitoring wells with periodic or consistent detection of benzene or TPH above the cleanup levels include, shallow monitoring well no. 11 (GM-11S), AR-03, GM-12S, GM-13S, GM-14S and GM-24S.

CPAH Areas: Monitoring well with periodic or consistent detection of total cPAHs above the cleanup levels is GM-12S.

These wells are located in or around Plant 1 and due to historic detection of petroleum-hydrocarbon-related IHSs above cleanup levels (Table 1), these monitoring wells (including the newly proposed wells along the shoreline AMW-01 through AMW-05) will be included in the compliance monitoring program. Monitoring in these wells will be focused on the IHSs for groundwater to provide water quality data for baseline data and trend analysis. Further these wells will be monitored for natural attenuation parameters (Table 2).

Plant 2.

Benzene and TPH Areas: Monitoring wells with periodic or consistent detection of benzene or TPH above the cleanup levels include, shallow/deep monitoring wells GM-19S, MW-03, GM-21S, GM-23S, and GM-19D.

These wells are located in or around Plant 2 and due to historic detection of petroleum-hydrocarbon-related IHSs and copper above cleanup levels (Table 1), these monitoring wells will be included in the compliance monitoring program. Monitoring in these wells will be focused on the IHSs for groundwater to provide water quality data for baseline data and trend analysis. Further these wells will be monitored for natural attenuation parameters (Table 2).

1.6 Compliance Monitoring Types and Schedule

The three forms of compliance monitoring will be performed in accordance with WAC 173-340-410. Groundwater compliance monitoring will consist of free product monitoring, groundwater elevation monitoring, and groundwater sampling.

- Free product monitoring will consist of measuring free product levels in areas of the site as part of the performance standard evaluation after implementation of the preferred remedial alternatives.

- Groundwater elevation monitoring will be performed during free product monitoring events and during groundwater sampling events.

- Groundwater samples will be collected from designated ARCO compliance monitoring, performance monitoring wells.

Three types of monitoring will be performed under the Groundwater Compliance Monitoring and Contingency Program to meet the monitoring program objectives:

- Protection Monitoring. 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 health and safety plan to be prepared in conjunction with the engineering design report, construction plans and specifications, and operation and maintenance plan (WAC 173-340-400).

- 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 actions and other performance standards have been attained.

Monitoring Locations. Figures 6 and 7 show the locations of all wells in which product will be monitored, groundwater levels will be measured, and groundwater samples will be collected as part of the site compliance monitoring program. Table 3 provides a list of compliance monitoring wells, identifying the well location, monitoring objective, and well use. A summary of the analytical parameters to be used in compliance monitoring is presented in Tables 1 and 2. Detail plans for Plants 1 and 2 performance and

confirmational monitoring component, including the media type, location, and schedule, is presented in Section 2.0.

Monitoring Schedule. Groundwater sampling will begin after the quarter the Consent Decree is approved (January 2000) and will continue for five years (January 2005). Sampling will occur quarterly for the first year. Ecology and ARCO will review the data after one year. This review will focus on evaluating the reasonableness/effectiveness of the remedies in the monitoring program. If trends are declining, the sampling frequency and number of parameters may be reduced. Ecology shall not unreasonably withhold approval of reductions in the monitoring program.

2.0 Groundwater Compliance Monitoring

A list of compliance monitoring wells identifying the general well location and monitoring objective is presented in Table 3. A summary of the analytical parameters to be used in compliance monitoring is presented in Tables 1 and 2. The location of all wells in which free product will be monitored, groundwater levels will be measured, and groundwater samples will be collected as part of the site compliance monitoring program are presented on Figures 6 and 7.

Compliance monitoring will begin after the quarter the Consent Decree is approved (January 2000) and will continue for five years (January 2005). Groundwater sampling will be performed quarterly for the first year. Ecology and ARCO will review the data after one year. If monitoring data shows that trends are declining, the sampling frequency and number of parameters may be reduced.

2.1 Protection Monitoring

The objective of protection monitoring is to confirm that human health and the environment are adequately protected during construction and operation and maintenance of the cleanup action [WAC 173-340-410(1)(a)]. Protection monitoring will be addressed in the health and safety plan prepared in conjunction with the engineering design report, construction plans and specifications, and operation and maintenance plan (WAC 173-340-400).

2.2 Performance Monitoring

The objective of performance monitoring is to confirm that the cleanup action has attained cleanup standards and other performance standards as appropriate [WAC 173-340-410(1)(b)]. Performance monitoring will consist of free product monitoring during product recovery activities and groundwater sampling to evaluate the effectiveness of soil and groundwater cleanup actions and natural attenuation.

2.2.1 Plant 1 Performance Monitoring

The Plant 1 performance monitoring program includes a combination of monitoring the expanded product recovery system and waterway surface water booms, and sampling of a selected well network. The monitoring program is designed to evaluate the effectiveness of the remedy in removing product and residual and dissolved hydrocarbons from beneath the warehouse and to evaluate the long-term effectiveness of intrinsic biodegradation/natural attenuation of inaccessible soils.

There are presently 16 monitoring wells being used to develop groundwater elevation contours for the site. When the 5 proposed monitoring wells along the shoreline are installed a total of 21 monitoring will be located in Plant 1.

Performance monitoring wells in Plant 1 will consist of fourteen wells (GM-11S, GM-l2S, GM-13S, GM-14S, GM-15S, GM-16S, GM-17S, GM-24S and AR-03) with five

wells to be installed along the waterfront (AMW-0l, AMW-02, AMW-03, AMW-04, and AMW-05) (Figure 6). These wells will be monitored for petroleum-hydrocarbon-related IHSs (Table 1), to provide water quality data for baseline data and trend analysis. Also, these wells will be monitored for natural attenuation parameters (Table 2).

- Wells AMW-01 AMW-02, AMW-03, AMW-04, and AMW-05 will be installed primarily for confirmational monitoring but will also be included in the performance monitoring to assist in evaluating the effectiveness of the recovery system. The wells will be installed as described in Section 2.2.5. The wells will be sampled quarterly for the first year for the parameters listed in Tables 1 and 2. Subsequent sampling frequency will be determine during the first annual review (Section 3.2.1).

- 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-13S has 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.

Tables 1 and 2 lists the field parameters and laboratory analytes that will be collected during sampling activities. Table 3 lists the performance wells, analytes, and sampling frequency. All of the performance wells will also be monitored for the presence of free product or sheens. If product is detected in the well, groundwater samples will not be collected for laboratory analysis. The product will be removed using a bailer, sorbents or other appropriate means.

Background Wells GM-16S and GM-17S, are located upgradient in Plant 1 along a westerly groundwater flow direction and will serve as the site background monitoring wells. These wells will be monitored for the IHSs for groundwater and natural attenuation parameters (Tables 1 and 2) to establish baseline and background groundwater quality data. Also, these monitoring wells will monitor the background rate of intrinsic biodegradation/natural attenuation upgradient of the TPH hot spot excavation area.

Sentry Well AR-03 will also be used as a "sentry" well to provide early warning for contaminant migration

Free Product: All monitoring wells where water level measurements are taken will be measured for free product. A measurable thickness of free product is defined as greater than or equal to 0.01 feet thick. Shallow wells located in or around a free product plume in Plant 1 with historic and current free product detection include, GM-11S, GM-13S and GM-14S.

Product performance monitoring will be performed in these wells prior, during and after implementation of the remedial action alternatives discussed in Section 1.4. The product performance standard is removal to the maximum extent practicable or a "measurable product thickness", and the product cleanup standard is "no visible sheen." After the performance standard has been met in these wells, they will be sampled for IHSs (Table 1) and natural attenuation parameters (Table 2). Product shall be removed from the water table throughout the site, when ever present.

Areas Below Cleanup Levels:

TPH and benzene were not detected above the groundwater cleanup levels (Table 1) more than once in shallow monitoring wells GM-10S, GM-10D, GM-13D, GM-16S, GM-17S, GM-17D, AR-04, and MW-04. Most of these wells are located east and some are north of Plant 1.

Total cPAHs were not detected above the groundwater cleanup levels (Table 1) more than once in shallow monitoring wells GM-13S, GM-14S, GM-16S and GM-24S.

2.2.1.1 Recovery System Monitoring

The operation of the expanded recovery system along the waterfront at Plant 1 will be monitored on a monthly basis to ensure the cleanup criteria are achieved within the established restoration time frame. A summary of monthly O&M and monitoring activities generally consists of the following activities and will be further 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.

Data collected during the O&M of the recovery system will be evaluated to monitor product and groundwater recovery rates, monitor capture of the dissolved plume, and evaluate the biodegradation rate for residual hydrocarbons.

2.2.1.2 Product Recovery System Monitoring

Product recovery system influent and effluent samples will be collected in accordance with the procedures detailed in the attached SAP (Appendix A). The influent and effluent samples will be analyzed monthly for benzene, toluene, ethylbenzene, total xylenes (BETX), TPH-G, TPH-D, and TPH-O. In addition, effluent samples will be analyzed semi-annually for total metals and annually for non-polar fats, oils, and greases (FOG) to comply with discharge permit requirements. Results of the influent and effluent sampling will be reviewed upon receipt of the analytical report from the laboratory to monitor for continued reductions in dissolved IHS's (Table 1) and to verify compliance with the King County Department of Natural Resources (KCDNR) Water and Land Resources Division, Industrial Waste Section permit which exists for the treated groundwater discharge. If a discharge permit limit is exceeded during operation of the recovery system, KCDNR Industrial Waste Section will be notified of the discharge exceedance and consulted as to the actions to be taken.

The recovery wells will be monitored for the presence of free product. This monitoring will be initially conducted on a monthly basis, and quarterly thereafter. The product recovery system will collect data regarding the amount of product recovered by the system and the recovery rate of the system. Operation of the product recovery system will be terminated upon removal of free product from the recovery wells to the extent technically practicable, and the recovery wells will continue to be monitored for the presence of free product to confirm the long-term effectiveness of the recovery system cleanup actions.

2.1.2.3 SVE System Monitoring

The SVE system vapor stream will be monitored at each wellhead and at the combined vapor stream manifold to monitor the removal of volatile hydrocarbons and the continued biodegradation of residual hydrocarbons remaining in the soils in the warehouse area. Concentrations of volatile organics will be monitored using field instruments such as an explosimeter to measure oxygen concentrations and percentage of lower explosive limit, and an organic vapor meter (OVM) to measure the concentrations of volatile organic compounds present in the vapor streams. The SVE system will be operated in a manner that will not exceed effluent concentrations greater than 50 parts per million (ppm) of TPH based on the Puget Sound Air Pollution Control Agency (PSAPCA) permit for the system. Given the preceding condition, the SVE system will not require off-gas treatment for the combined vapor stream. In order to ensure compliance with the permit limit for TPH discharge, the expanded SVE system will have a phased startup process, which will allow each section of the SVE system to be started individually and limit the effluent emissions of the system.

Geochemical fingerprinting has identified the product in the warehouse area as weathered diesel and minor amounts of detected weathered gasoline and heavy oil, which yield relatively low vapor concentrations in the unsaturated zone. Based on experience with the interim SVE system currently in operation, the vapor concentrations at startup will contain moderate TPH concentrations, which will decrease rapidly. Although vapor concentrations have never been observed in the warehouse or office, the operation or the SVE system will ensure that this potential exposure pathway is interrupted. Should SVE combined vapor stream concentrations exceed PSAPCA permit limits, off-gas treatment or other system modifications will be considered. All modifications to the existing treatment system will be discussed with PSAPCA and properly permitted prior to system startup and prior to any system changes.

2.1.2.4 Air Sparging System Monitoring

Air sparging will be used to enhance the removal of product from soils above and below the water table. Air sparging in conjunction with SVE, accomplishes this by 1) accelerating the mobilization and recovery of residual hydrocarbons, 2) enhancing natural intrinsic 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. Startup of the air sparging system will be initiated following removal of the majority of free product and will be determined based on product recovery system product recovery volumes and rates. Following startup, the air sparging system will be monitored on a monthly basis to ensure proper operating conditions and that all equipment is in proper working condition. Air injection pressure and airflow rate will be recorded for each of the air sparging wells. Adjustments will be made to the air injection pressure as necessary.

2.2.2 Plant 2 Performance Monitoring

The Plant 2 performance monitoring program includes sampling of a selected well network. The 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. There are presently nine monitoring wells being used to develop groundwater elevation contours for the site.

Performance monitoring wells in Plant 2 will consist of five wells (GM-19S, GM-l9D, GM-21S, GM-22S and MW-03 (Figure 7). These wells will be monitored for petroleum-hydrocarbon-related IHSs (Table 1), to provide water quality data for baseline data and trend analysis. Also, these wells will be monitored for natural attenuation parameters (Table 2).

- 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.

Tables 1 and 2 lists the field parameters and laboratory analytes, which will be collected during sampling activities. Table 3 lists the performance wells and sampling frequency. All of the performance wells will also be monitored for the presence of free product or sheens. If product is detected in the well, groundwater samples will not be collected for laboratory analysis. The product will be removed using a bailer or sorbents.

Free Product: All monitoring wells where water level measurements are taken will be measured for free product. A measurable thickness of free product is defined as greater than or equal to 0.01 feet thick. Shallow wells located in or around a free product plume in Plant 2 with historic and current free product detection includes, MW-03.

Product performance monitoring will be performed in this well prior, during and after implementation of the remedial action alternatives discussed in Section 1.4. The product performance standard is removal to the maximum extent practicable or a "measurable product thickness", and the product cleanup standard is "no visible sheen." After the performance standard has been met in this well, it will be sampled for IHSs (Table 1) and natural attenuation parameters (Table 2). Product shall be removed from the water table throughout the site, when ever present.

Areas Below Cleanup Levels:

TPH and benzene were not detected above the groundwater cleanup levels (Table 1) more than once in shallow monitoring wells GM-20s, GM-22S and GM-22D.

Total cPAH were not detected above the groundwater cleanup levels (Table 1) in shallow monitoring wells GM-19S, GM-19D, GM-21S and GM-23S.

2.2.3 Plant 1 Performance Criteria

Separate-Phase Hydrocarbons: To monitor the effectiveness of the preferred remedial alternative discussed in Section 1.4 for free product, the performance criterion will be removal to the maximum extent practicable or a lack of measurable product thickness in compliance monitoring wells, product recovery systems and until a persistent sheen is no longer observed on the waterway. A measurable thickness of free product is defined as greater than or equal to 0.01 feet thick.

Dissolved TPH Constituents: Groundwater cleanup levels (Table 1) are based on the protection of aquatic organisms and on human ingestion of such organisms. The Point of Compliance for the site groundwater is the property boundary and is represented by the confirmational monitoring wells (Section 2.2.5).

Natural Attenuation: To demonstrate that natural attenuation is occurring to reduce contaminant concentrations, the performance criteria will be periodic monitoring of constituent plume data (i.e., benzene and TPH) and a variety of other indicators of natural attenuation processes. These processes include physical, chemical, or biological processes in the form of biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization or destruction of contaminants. Following is the

rationale for the selection of the natural attenuation monitoring parameters (from USEPA, 1994c).

Constituent Plume Characteristics

In the absence of natural attenuation mechanisms, constituent concentrations would remain relatively constant within the plume and then decrease rapidly at the edge of the plume. If natural attenuation is occurring, constituent concentrations will decrease with distance from the source along the flow path of the plume as a result of dispersion. If other natural attenuation mechanisms are occurring, the rate at which concentrations of constituents are reduced will be accelerated.

Monitoring of constituent concentrations in the groundwater over time will give the best indication of whether natural attenuation is occurring. If natural attenuation is occurring, the contaminant plume will migrate more slowly than expected based on the average groundwater velocity. Receding plumes typically occur when the source has been eliminated. Natural attenuation may also be occurring in plumes that are expanding, but at a slower than expected rate. For example, in sandy soils [similar to Harbor Island] with relatively low organic carbon content (about 0.1 percent), BTEX constituents are expected to migrate at one-third to two-thirds of the average groundwater speed velocity (McAllister, 1994). Higher organic carbon content would further retard constituent migration. If constituents are migrating more slowly than expected based on groundwater flow rates and retardation factors, then other natural attenuation mechanisms (primarily biodegradation) are likely reducing constituent concentrations. For stable plumes, the rate at which contaminants are being added to the system at the source is equal to the rate of attenuation. A plume may be stable for a long period of time before it begins to recede, and in some cases, if the source is not eliminated, the plume may not recede.

Occurrence of biodegradation might also be deduced by comparison of the relative migration of individual constituents. The relative migration rates of BTEX constituents, based on the chemical properties, are expected to be in the following order:

benzene > toluene, o-xylene > ethylbenzene, m-xylene, p-xylene

If the actual migration rates do not follow this pattern, biodegradation may be responsible.

Dissolved Oxygen Indicators

The rate of biodegradation will depend, in part, on the supply of oxygen to the contaminated area. At levels of dissolved oxygen (D.O.) below 1 to 2 mg/L in the groundwater, aerobic biodegradation rates are very slow. If background D.O. levels (upgradient of the contaminant source) equal or exceed 1 to 2 mg/L, the flow of groundwater from the up-gradient source will supply D.O. to the contaminated area, and aerobic degradation is possible.

Where aerobic biodegradation is occurring, an inverse relationship between D.O. concentration and constituent concentrations can be expected (i.e., D.O. levels increase as constituent levels decrease). Thus, if D.O. is significantly below background within the plume, aerobic biodegradation is probably occurring at the perimeter of the plume.

Geochemical Indicators

Certain geochemical characteristics can also serve as indicators that natural attenuation, particularly biodegradation, is occurring. Aerobic biodegradation of petroleum products produces carbon dioxide and organic acids, both of which tend to cause a region of lower pH and increased alkalinity within the constituent plume.

Anaerobic biodegradation may result in different geochemical changes, such as increased pH. Under anaerobic conditions, biodegradation of aromatic hydrocarbons typically causes reduction of Fe^{3+} (insoluble) to Fe^{2+} (soluble), because iron is commonly used as an electron acceptor under anaerobic conditions. Thus, soluble iron concentrations in the groundwater tend to increase immediately downgradient of a petroleum source as the D.O. is depleted, and conditions change to be come anaerobic (i.e., reduced). The concentration of methane increases, another indication that anaerobic biodegradation is occurring.

Oxidation/Reduction Potential

The oxidation/reduction (redox) potential of groundwater is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons. Because redox reactions in groundwater are biologically mediated, the rates of biodegradation both influence and depend on redox potential. Many biological processes operate only within a prescribed range of redox conditions. Redox potential also can be used as an indicator of certain geochemical activities (e.g., reduction of sulfate, nitrate, or iron). The redox potential of groundwater generally ranges from 800 millivolts to about -400 millivolts... The lower the redox potential, the more reducing and anaerobic the environment.

Measurement of redox potential of groundwater also allows for approximate delineation of the extent of the contaminant plume. Redox potential values taken from within the contaminant plume will be lower than background (upgradient) redox values and values from outside the plume. This is due in part to the anaerobic conditions that typically exist within the core of the dissolved hydrocarbon plume.

Methane. Methanogenesis has been determined to be a predominant biodegradation mechanism for fuel spills. During the aerobic biodegradation of petroleum constituents, methane is produced. Methane concentrations above background levels may indicate the occurrence of aerobic biodegradation of petroleum constituents.

Nitrate. After dissolved oxygen has been depleted, nitrate may be used as an electron acceptor for anaerobic biodegradation. Nitrate concentrations below background levels may indicate the occurrence of anaerobic biodegradation of petroleum compounds.

Sulfate. After dissolved oxygen and nitrate have been depleted, sulfate may be used as an electron acceptor for anaerobic biodegradation. Sulfate concentrations below background levels may indicate the occurrence of anaerobic biodegradation of petroleum compounds.

On-going natural attenuation has been documented at the terminal (Geraghty & Miller 1997). A biotreatability study was conducted as part of the RI to evaluate the feasibility of in-situ biological treatment for TPH-impacted soils. Soil samples were collected from a variety of locations at the terminal and evaluated for biotreatability parameters including microbial plate counts. The results of the study concluded that

natural attenuation is ongoing at the site. These conclusions are further supported by the on going stabilization of the dissolved plumes at the site that are associated with the soil hot spots.

The effectiveness of continued natural attenuation at the site will be evaluated as part of the performance monitoring program. This evaluation will focus primarily on documenting loss of contaminant mass in groundwater and monitoring trends in biogeochemical parameters. The extensive database developed as part of the on-going groundwater monitoring program will support documenting trends in water quality. Biogeochemical trends will be established by analyzing groundwater samples for the parameters of Tables 1 and 2.

2.2.3.1 SVE System Performance Criteria

The purpose of operating the SVE system is to remove volatile hydrocarbons from the vadose zone, ensuring that the soil vapor to air pathway in the area of the product plume is interrupted. Also, SVE operation will maintain elevated oxygen concentrations within the vadose, zone and accelerate the in-situ biodegradation of residual hydrocarbons in the smear zone.

Operation of the SVE system will continue until volatile petroleum hydrocarbons are recovered and residual, hydrocarbons are, degraded to a level that ensures continued compliance of cleanup criteria in the warehouse area confirmational wells.

2.2.3.2 Air Sparging Performance Criteria

The purpose of operating the air sparging system is to enhance the removal of product from below and above the water table. The air sparging system will be operated until the effect on product recovery becomes negligible (measurable product thickness), and residual hydrocarbons are degraded to level that ensures continued compliance of cleanup criteria in the warehouse area confirmational wells. A measurable thickness of free product is defined as greater than or equal to 0.01 feet thick.

2.2.3.3 Surface Water Boom Monitoring

The two booms located in the Duwamish River adjacent to the warehouse and loading rack areas of Plant 1 will continue to be maintained to contain the sheens, which occasionally appear on the waterway. The sorbent booms are monitored by field observation for soiling and damage and are replaced when necessary. The spent sorbent booms are sampled for waste classification and are properly disposed.

The presence of sheens on the waterway will continue to be monitored by visual observation. The observations will be recorded on a log as to the presence or absence of sheens, area, and location. These observations will be compared to historical sheen observations, operational status of the recovery system, and the tide stage of the waterway. The results of the sheen monitoring will be used to determine the effectiveness of the remedial actions on reducing the sheen and to evaluate if adjustments to the

remedial actions are necessary along the waterfront. The booms will be maintained until there are no persistent sheens associated with the terminal detected.

2.2.4 Plant 2 Performance Criteria

To monitor the effectiveness of the preferred remedial alternative discussed in Section 1.4 for free product, the performance criterion will be removal of free product to the maximum extent practicable or a lack of measurable product thickness in compliance monitoring well(s) (Section 2.2.2). A measurable thickness of free product is defined as greater than or equal to 0.01 feet thick.

The effectiveness of continued natural attenuation at the site will be evaluated as part of the performance monitoring program. This evaluation will focus primarily on documenting loss of contaminant mass in groundwater and monitoring trends in biogeochemical parameters. The extensive database developed as part of the on-going groundwater monitoring program will support documenting trends in water quality. Biogeochemical trends will be established by analyzing groundwater samples for the parameters of Tables 1 and 2.

2.2.5 Plant 1 Confirmational Monitoring

The objective of confirmation monitoring is to confirm the long-term effectiveness of the cleanup action as discussed in Section 1.4, once performance and cleanup standards have been met [WAC 173-340-410(1)(c)].

Confirmational monitoring wells in Plant 1 will consist of six wells (AR-03 and the five wells to be installed along the waterfront AMW-0l, AMW-02, AMW-03, AMW-04, and AMW-05) (Figure 6). These wells will be monitored for petroleum-hydrocarbon-related IHSs (Table 1), to provide water quality data for baseline data and trend analysis. Further these wells will be monitored for natural attenuation parameters (Table 2).

The wells to be installed along the waterfront 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. After quarterly sampling of the parameters listed in Tables 1 and 2, for the first year of confirmational monitoring, ARCO and Ecology will review the data. Based on that review, sampling frequency and number of parameters may be reduced based on the results of that evaluation.

All of the confirmational wells will also be monitored for the presence of free product or sheens. If product is detected in the well, groundwater samples will not be collected for laboratory analysis. The product will be removed using appropriate means. After the performance standard has been met in this well, confirmational monitoring will include sampling for IHSs (Table 1) and natural attenuation parameters (Table 2)

quarterly for the first year. Subsequent sampling frequency and number of analytes to sample will be determined during the first year trend review and analysis (Section 3.2.2). Product shall be removed from the water table throughout the site, whenever present.

2.2.6 Plant 2 Confirmational Monitoring

Confirmational monitoring wells in Plant 2 will consist of five wells (GM-19S, GM-l9D, GM-22S, GM-21S and MW-03 (Figure 7). These wells will be monitored for petroleum-hydrocarbon-related IHSs (Table 1), to provide water quality data for baseline data and trend analysis. Further these wells will be monitored for natural attenuation parameters (Table 2).

- 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.

All of the confirmational wells will also be monitored for the presence of free product or sheens. If product is detected in the well, groundwater samples will not be collected for laboratory analysis. The product will be removed using a bailer or sorbents. After the performance standard has been met in this well, confirmational monitoring will include sampling for IHS (Table 1) and natural attenuation parameters (Table 2) quarterly for the first year. Subsequent sampling frequency and number of analytes to sample will be determined during the first year trend review and analysis (Section 3.2.2). Product shall be removed from the water table throughout the site, when ever present.

2.2.7 Plant 1 Compliance Criteria for Confirmational Monitoring

Separate-Phase Hydrocarbons: To demonstrate that free product removal has been accomplished, the confirmational criterion will be a lack of sheen in compliance monitoring wells for a period of 1 year.

Groundwater: Cleanup levels are based on the protection of aquatic organisms and humans ingesting such organisms. The point of compliance where these cleanup levels will be met is at the property boundary of the ARCO site and this is represented by the cofirmational groundwater monitoring wells (Section 2.2.5). The groundwater cleanup levels are presented in Table 1.

Groundwater samples will be collected from the confirmational monitoring wells for a maximum of five years following attainment of cleanup levels, or until the concentrations are determined as no longer being affected by on-site sources. Indications of that criterion are groundwater concentrations below cleanup levels for four quarters or the concentration of the analytes have stabilized and reached equilibrium. Groundwater quality will be evaluated based on trends and not based on a single event or cleanup exceedance in a single well. Equilibrium concentrations of each analyte may be determined using statistical methods or another method approved by Ecology. If groundwater quality data indicate that at least 95 percent of the wells are below cleanup

levels for four or more consecutive quarters, ARCO will petition Ecology for a site de-listing review for Plant 1. If Ecology concurs, the site shall be de-listed.

Sediment/biota Sampling Following completion of the product removal and compliance monitoring, one round of sediment/biota sampling will be conducted to ensure protection of the aquatic organisms in the Duwamish Waterway. The results of this sampling will be considered for the site de-listing.

2.2.8 Plant 2 Compliance Criteria for Confirmational Monitoring

Separate-Phase Hydrocarbons: To demonstrate that free product removal has been accomplished, the confirmational criterion will be a lack of sheen in compliance monitoring wells for a period of 1 year.

Groundwater: Cleanup levels are based on the protection of aquatic organisms and humans ingesting such organisms. The point of compliance where these cleanup levels will be met is at the property boundary of the ARCO site and this is represented by the confirmational groundwater monitoring wells (Section 2.2.6). The groundwater cleanup levels are presented in Table 1.

Groundwater samples will be collected from the confirmational monitoring wells for a maximum of five years following attainment of cleanup levels, or until the concentrations are determined as no longer being affected by on-site sources. Indications of that criterion are groundwater concentrations below cleanup levels for four quarters or the concentration of the analytes have stabilized and reached equilibrium. Groundwater quality will be evaluated based on trends and not based on a single event or cleanup exceedance in a single well. Equilibrium concentrations of each analyte may be determined using statistical methods or another method approved by Ecology. If groundwater quality data indicate that at least 95 percent of the wells are below cleanup levels for four or more consecutive quarters, ARCO will petition Ecology for a site de-listing review for Plant 2. If Ecology concurs, the site shall be de-listed.

2.2.9 Monitoring Schedule

Monitoring of the confirmation and performance groundwater monitoring wells will begin after the quarter the Consent Decree is approved (January 2000). Confirmation monitoring will continue for five years (January 2005) after completion of the cleanup action. Sampling will occur quarterly for the first year. Ecology and ARCO will review the data after one year. This review will focus on evaluating the reasonableness/effectiveness of the remedies in the monitoring program. If trends are declining, the sampling frequency and number of parameters may be reduced. Ecology shall not unreasonably withhold approval of reductions in the monitoring program.

3.0 DATA EVALUATION AND REVIEW

3.1 Data Evaluation

All data will be evaluated following collection of the data and/or validation of the laboratory analytical data after each monitoring event. All groundwater level and groundwater quality data will be entered into the comprehensive site database.

3.1.1 Data Validation

Laboratory analytical data from performance and confirmational monitoring will be validated according to the USEPA data validation guidelines (USEPA 1994b and 1994c). Data validation will include evaluation of holding times, method blank results, surrogate recovery results, field and laboratory duplicate results, completeness, detection limits, laboratory control sample results, and chain-of-custody forms. The data validation process also includes qualification of data if necessary. Data validation procedures are described in further detail in the SAP (Appendix A). All groundwater quality data will be entered into the site database with any applicable qualifiers following data validation.

3.1.2 Practical Quantitation Limits

Practical Quantitation Limits (PQL's) will be established for each analyzed groundwater quality constituent to determine whether any are above the corresponding cleanup level. Per WAC 173-340-707(2), if the PQL for any constituent is above the corresponding cleanup level, the cleanup level will be considered to be attained if the constituent is undetected at the PQL or detected below the PQL. The PQL will be determined by multiplying the lowest method detection limit obtained by the laboratory for groundwater samples collected from the site by a factor of ten (Ecology 1993). It is anticipated that PQL's will be used as cleanup levels for cPAH's only.

3.1.3 Product Monitoring and Recovery System Data

Product monitoring data and product recovery system influent and effluent data will be evaluated monthly following the monthly site O&M visit to determine if adjustments to the product recovery system are necessary and monitor the effectiveness of the system. The Waterway sheen monitoring information will be reviewed to evaluate the effectiveness of the product recovery system.

3.1.4 Performance Monitoring Data

The results of the performance monitoring will be evaluated to monitor trends in groundwater quality and confirm that cleanup levels have been attained or that concentrations are determined as no longer being affected by on-site sources. Indications of that criterion are concentrations below cleanup levels for four quarters or the concentrations of the analytes have stabilized and reached equilibrium. Equilibrium

concentrations of each analyte may be determined using statistical methods or another method approved by Ecology.

3.1.5 Confirmational Monitoring Data

The results of the confirmational monitoring will be evaluated to confirm the long-term effectiveness of the cleanup actions at the site. The data evaluation will include comparisons with trends established by the existing groundwater monitoring data. Statistical analysis may be used to support the data evaluations. The statistical methodologies that may be used are outlined in Ecology's statistical guidance document (Ecology 1992) and supplement (Ecology 1993).

3.2 Data Review

3.2.1 One Year Site Review

Following one year of performance monitoring at Plants 1 and 2, all groundwater performance data (recovery system data, groundwater level data, product level data, and groundwater quality and biogeochemical data) will be reviewed by ARCO and Ecology. The review will focus on evaluating the effectiveness of the cleanup actions and monitoring programs.

Appropriate adjustments to the cleanup actions or monitoring programs that effect attaining remedial action objectives and restoration time frames of the site may be made based on the results of the review. Additional reviews may be requested by ARCO and Ecology based on performance of the remedies.

Groundwater level data will be reviewed and groundwater contour maps for Plants 1 and 2 will be plotted to verify that groundwater flow directions have not significantly changed from historical groundwater flow patterns.

Biogeochemical data will be evaluated to determine the effectiveness and rate of natural attenuation, as discussed in the USEPA guidance document (USEPA 1994d).

Groundwater quality data from performance monitoring will be evaluated using time-trend analysis and also by comparing the data to cleanup levels. The one-year of quarterly performance data may be utilized along with the historic groundwater monitoring data when appropriate to evaluate long-term trends in the data. ARCO and Ecology will review sampling frequency based on the trends, and sampling frequency and/or number of parameters may be reduced.

3.2.2 Five Year Site Review

At a minimum, all groundwater data (groundwater level data, product level data, and groundwater quality and biogeochemical data) will be reviewed by ARCO and Ecology five years after performance monitoring begins at the site. This review will focus on evaluating the reasonableness/effectiveness of the remedies in the monitoring program. If trends are declining, the sampling frequency and number of parameters may

be reduced. Ecology shall not unreasonably withhold approval of reductions in the monitoring program.

Groundwater level data will be reviewed and groundwater contour maps for Plants 1 and 2 will be plotted to verify that groundwater flow directions have not significantly changed from historical groundwater flow patterns.

Biogeochemical data will be evaluated to determine the effectiveness and rate of natural attenuation, as discussed in the USEPA guidance document (USEPA 1 994d).

Groundwater quality data from monitoring activities will be evaluated using time trend analysis and also by comparing the data to cleanup levels. Statistical evaluation may be used to evaluate trends in individual wells if at least one result for a constituent is above the cleanup level. Any statistical evaluation will be completed per WAG 173-340-720(8) and Ecology guidance documents (Ecology 1992 and 1993).

The site has a five-year restoration time frame and it is anticipated that ARCO will petition Ecology for site delisting at the five-year site review, if prior site delisting was not requested and approved. Groundwater quality data must indicate that at least 95 percent of the wells are below cleanup levels for four or more consecutive quarters before requesting site delisting. Contingency plans will be enacted if ARCO does not meet the five-year restoration time frame for the site.

4.0 Reporting

Performance and confirmational monitoring data and information will be provided to Ecology throughout the restoration time frame for the site. The frequency and content of the reporting is as follows:

Monthly Reports. Product recovery system data and information will be provided to Ecology on a monthly basis for the first quarter after startup of the recovery system, and quarterly thereafter. The Monthly Status Report will include product recovery system operation and performance information, product monitoring data, groundwater influent and effluent data, SVE system field parameters, and any changes to the treatment system. Compliance with KGDNR Industrial Waste Section and PSAPCA permits will also be discussed.

Quarterly Reports. Laboratory analytical reports will be provided to Ecology following receipt of the laboratory report for quarterly sampling activities.

Annual Reports. Groundwater monitoring data will be provided to Ecology on an annual basis in the form of an Annual Groundwater Monitoring Report. The annual report will include a discussion of the activities completed, a discussion of the data, data validation information, data tables, concentration graphs, and laboratory analytical reports for the wells in the monitoring well network. A total of five annual reports will be completed and submitted to Ecology based on the five-year restoration time frame for cleanup and monitoring activities at the site. The annual report will also replace the quarterly monitoring report for the quarter it is submitted to Ecology.

Five Year Review Report. Following five years of cleanup actions and groundwater monitoring activities, one report summarizing the product recovery system data and groundwater monitoring data will be completed and submitted to Ecology for review. The report will include groundwater elevation data; analytical data from the product recovery system, SVE system, and groundwater monitoring; waterway sheen monitoring information; product monitoring data; product recovery system operational data and information; SVE and air sparging system operational information; groundwater data tables and concentration graphs; any statistical information used to support the data; a comparison of the data to cleanup levels; and a discussion of natural attenuation.

5.0 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 contingency plan is included as part of this Groundwater Compliance Monitoring and Contingency Program in the event that the remedial actions are not effective within the five-year restoration time-frame anticipated for site cleanup and monitoring activities to be completed.

Contingency Criteria

Implementation of the contingency plan will be based on the results of the performance and confirmational monitoring program. A contingency plan will be initiated and implemented within 30 days of meeting any of the following criteria:

- If, after implementing the selective remedial action, the results of the groundwater monitoring program indicate elevated contaminant concentration over the specified restoration time frame of 5 years;

- If contaminants are newly identified in point of compliance wells located beyond the original plume boundary, indicating renewed contaminant migration.

Detail contingency outline for the shoreline and the inland are summarized below.

Shoreline Contingency

- 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.

Shoreline Contingency plan components

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;

Inland Soils

The process for evaluating the results of monitoring and contingency actions for the inland soil's remedy are contained in the flow chart in Figure 8 and summarized below.

- Addition of nutrients to further 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 further enhanced by the addition of nutrients such as nitrates and/or phosphates.

- Evaluate and implement groundwater migration control options, if necessary.

In the event that the contingency plan should be implemented, ARCO will prepare a contingency work plan within 30 days of making contingency determination that contains engineering design criteria as needed to address the criteria triggering the contingency action.

6.0 References

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Table 1
Groundwater Cleanup Levels
ARCO Harbor Island Terminal
Seattle, Washington

Constituent	Cleanup Level (mg/L)
Benzene	0.071
CPAH	0.000031
Product	No Sheen
TPH-G	1
TPH-D	10
TPH-O	10

Table 2
Natural Attenuation Indicator Parameters
ARCO Harbor Island Terminal
Seattle, Washington

Field Parameters	Biogeochemical Analytes
pH	pH
Temperature	Carbon dioxide
Conductivity	Hardness
Turbidity	Methane
Water level	Redox
Product level	DO
	Conductivity
	Alkalinity
	Ferrous iron
	Sulfate and Sulfide
	Nitrate and Chloride

Table 3
Compliance Monitoring Wells
ARCO Harbor Island Terminal
Seattle, Washington

Monitoring Well	Well Location	Compliance Monitoring Objective
AR-03	Plant1	Performance/Confirmational / Sentry
AMW-01	Plant 1	Performance/Confirmational
AMW-02	Plant 1	Performance / Confirmational
AMW-03	Plant 1	Performance/Confirmational
AMW-04	Plant 1	Performance/Confirmational
AMW-05	Plant 1	Performance/Confirmational
GM-11S	Plant 1	Performance
GM-12S	Plant 1	Performance
GM-13S	Plant 1	Performance
GM-14S	Plant 1	Performance
GM-15S	Plant 1	Performance
GM-16S	Plant 1	Performance
GM-17S	Plant 1	Performance
GM-24S	Plant 1	Performance
GM-19S	Plant 2	Performance / Confirmational
GM-19D	Plant 2	Performance / Confirmational
GM-21S	Plant 2	Performance / Confirmational
GM-22S	Plant 2	Performance / Confirmational
GM-23S	Plant 2	Performance
MW-03	Plant 2	Performance / Confirmational/Sentry

Figures
Compliance Well Location Map
ARCO Harbor Island Terminal
Seattle, Washington