DRAFT
SUPPLEMENTAL REMEDIAL INVESTIGATION REPORT

UNOCAL EDMONDS TERMINAL
EDMONDS, WA

Prepared for

Unocal Corporation

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ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, xylenes
cy	cubic yards
DRO	TPH as diesel range organics
EPH	extractable petroleum hydrocarbons
FS	feasibility study
GRO	TPH as gasoline range organics
HO	TPH as heavy oil range organics
IHS	indicator hazardous substance
mg/kg	milligram per kilogram
mg/L	milligram per liter
µg/L	microgram per liter
MLLW	mean lower low water
MTCA	Model Toxics Control Act
MW	monitoring well
PAHs	polycyclic aromatic hydrocarbons
RI	remedial investigation
SAP	sampling and analysis plan
SEPA	State Environmental Policy Act
SRI	supplemental remedial investigation
TDS	total dissolved solids
TP	test pit
TPH	Total Petroleum Hydrocarbons
TPH-G	TPH as gasoline
TPH-D	TPH as diesel
TPH-O	TPH as other
TSS	total suspended solids
VPH	volatile petroleum hydrocarbons
WAC	Washington Administrative Code

EXECUTIVE SUMMARY

The Unocal Edmonds Terminal comprises approximately 47 acres of land on and adjacent to the northern slope of a hillside and lies within approximately 1,000 feet of the Puget Sound shoreline. At its nearest point (southwest corner of site), the Terminal boundary is approximately 160 feet from the Puget Sound shoreline.

The Terminal, which operated from 1923 to 1991, was used for the bulk storage and distribution of petroleum fuels. The 22-acre lower yard consists of office buildings, former truck loading racks, aboveground piping, two underground (former vapor recovery) tanks, two underground vaults, two storm water detention basins, and an oil/water separator. Previous operations also included an air-blown asphalt plant, an asphalt packaging warehouse, and a railcar loading/unloading facility. The 25-acre upper yard consists of tank basins; all tanks and lines were cleaned and removed from the site.

A supplemental remedial investigation (SRI) was performed at the Unocal Edmonds Terminal between June 2001 and May 2002. Field work included investigations of subsurface soil, groundwater, and surface water, and was performed following a work scope prepared in June 2001. Soil borings were advanced, groundwater and surface water monitoring events were performed, and additional groundwater monitoring wells were installed. Data were validated and added to the project database. These activities were performed to augment site data collected during the remedial investigation (RI) performed at the site between October 1994 and August 1996.

Between August and November 2001, an interim remedial action was performed in the Terminal's lower yard. Following the removal of petroleum-saturated soil from four areas of the lower yard, soil samples were collected from the excavation sidewalls. During this time, 17 test pits were excavated along the southwest property boundary of the lower yard. The test pits were observed for the presence of groundwater and product sheens; soil and groundwater samples were also collected from the test pits. These data augmented the SRI findings.

Petroleum hydrocarbon distributions in groundwater do not appear to have changed appreciably between the time of the RI and the SRI. Gasoline-range hydrocarbons were not found in concentrations greater than 1 mg/L beyond the property boundary in 1996 or in 2001. The distribution of diesel and heavy oil-range hydrocarbons along the property boundary also appears to have remained consistent, with the exception of the eastern site perimeter, where petroleum was detected in concentrations greater than 1 mg/L in 1996

but not in 2001. Petroleum hydrocarbons were not detected in SRI groundwater samples collected from the site-wide aquifer beneath the upper yard.

An estimated 9,500 gallons of floating (free) petroleum product were recovered from beneath the lower yard between 1988 and 2001. During the 2001 interim remedial action performed in the lower yard, an additional estimated 2,500 gallons of petroleum product were removed. Thus, petroleum hydrocarbon concentrations in groundwater beneath the site have been reduced significantly over these years. Petroleum hydrocarbon concentrations in groundwater along the site perimeter remain consistently low, typically non-detectable or at concentrations less than 1 mg/L. Willow Creek, which runs along the Terminal's northeast, north and northwest boundary, was sampled in 1996 and 2001. Petroleum hydrocarbons were not detected in 1996 or in 2001.

Prior to the SRI, the Department of Ecology had requested that an additional monitoring well(s) be installed along the eastern boundary of the Terminal, based on petroleum hydrocarbons detected during the RI in monitoring well MW-136. This well is located near Willow Creek and lies at the eastern edge of a lobe of petroleum-contaminated fill. This impacted soil may be causing or contributing to the sporadic petroleum detections in groundwater along the eastern boundary. Based on the impacted fill and additional groundwater data collected since the RI, additional wells were not installed in this area. Continued groundwater monitoring in the existing wells is appropriate.

The potential for off-site migration of petroleum hydrocarbons from the Terminal onto the Port of Edmonds' South Marina property was evaluated during the scoping phase of the SRI. TPH would have had to migrate from the Terminal as free-phase product to cause the petroleum hydrocarbon concentrations found in soil at the South Marina (up to 20,000 mg/kg). The distribution of petroleum hydrocarbons in soil and groundwater in the Terminal lower yard provided no indication of the off-site migration of free-phase petroleum hydrocarbons to the Port’s South Marina property. Seven soil borings advanced along the east side of Admiral Way (located between the Terminal and the South Marina) showed petroleum hydrocarbon concentrations that were orders of magnitude below those found on the Port's property. Soil collected from test pits located on the Terminal approximately 150 feet upgradient of the Port's greatest petroleum concentrations (up to 20,000 mg/kg) contained less than 2,000 mg/kg. Groundwater data collected from the Admiral Way borings, the test pits, and from monitoring wells located between the Terminal and the south marina, do not suggest the off-site migration of free-phase petroleum to the Port property. The historical and SRI groundwater and soil data continue to indicate that the Port contamination derived from a separate source.

1 INTRODUCTION

Union Oil Company of California, dba Unocal, entered into Agreed Order No. DE 92TC-N328 with the Washington Department of Ecology (Ecology) to conduct environmental investigations at the UNOCAL Edmonds Terminal (Terminal) located at 11720 Unoco Road in Edmonds, Washington (Figure 1-1). The scope of the Agreed Order, issued pursuant to the Model Toxics Control Act (MTCA), included a remedial investigation (RI) of the existing Edmonds Terminal in accordance with the scope and contents specified in WAC 173-340-350.

The RI scope of work was described in the Final Remedial Investigation Work Plan and Work Plan Addendum (RI Work Plan), and included sampling and analysis procedures for soil, groundwater, surface water, product, and vapor monitoring (EMCON, 1995). Following completion of the investigation, a report was prepared summarizing the RI work and presenting the results of the data obtained between 1994 and 1996 (EMCON, 1996 and 1998a; Maul Foster & Alongi, Inc. (MFA), 2001a).

Ecology requested that supplemental remedial investigation activities be performed at the Terminal (Ecology, 2000). These activities included an update of the site database, installation of additional monitoring wells along the eastern boundary of the Terminal, an assessment of a storm drain line that exits the Terminal at the northwest site boundary, assessment of off-site investigations of contamination on former Unocal property with particular regard for what these investigations indicate regarding migration of contamination off-site, ongoing groundwater and surface water monitoring, consideration of residual saturation and whole effluent toxicity studies, and a terrestrial ecological assessment. An SRI work plan was prepared by Unocal and approved by Ecology in June 2001 (MFA, 2001b; Ecology, 2001). Whole effluent toxicity studies commenced in 2002; a work plan and preliminary test results were transmitted to Ecology under separate cover and are not included herein. Residual saturation and terrestrial ecological assessments have not been performed and are not discussed herein. Once performed, these assessments will be reported to Ecology under separate cover.

This report describes the results of the additional activities performed as a supplement to the RI and is organized as follows:

- Section 2 provides a brief site description;
- Section 3 summarizes the findings of the RI;
- Section 4 describes the supplemental remedial investigation procedures;
- Section 5 provides the results of the supplemental investigations; and
- Section 6 provides a discussion of the key findings and presents data summaries for use in the forthcoming feasibility study for the lower yard of the Terminal.

2 SITE DESCRIPTION

The Terminal comprises approximately 47 acres of land on and adjacent to the northern slope of a hillside and lies within approximately 1,000 feet of the Puget Sound shoreline. At its nearest point (southwest corner of site), the Terminal boundary is approximately 160 feet from the Puget Sound shoreline. The Terminal has two distinct areas, the upper yard (former tank farm) area and the lower yard area (Figure 2-1).

The lower yard is approximately 22 acres, lying east of the Burlington Northern Santa Fe Railroad (BNSFRR) right-of-way, south of Union Oil Marsh, west of the Deer Creek Salmon Hatchery, and north of the upper yard. The lower yard elevation ranges from approximately 10 to 25 feet above the mean lower low water datum (MLLW). The lower yard consists of office buildings, two former truck loading racks, aboveground piping, two underground (former vapor recovery) tanks, two underground vaults, Detention Basin No. 1, Detention Basin No. 2, and an oil/water separator. Previous operations also included an air-blown asphalt plant, an asphalt packaging warehouse, and a railcar loading/unloading facility.

The upper yard is approximately 25 acres located immediately south of the lower yard. Upper yard elevations range from approximately 25 to 150 feet MLLW. The upper yard consists of tank basins; all tanks and lines were cleaned and removed from the site.

Unocal operated the Terminal from 1923 to 1991. Fuel was brought to the Terminal on ships, pumped to the storage tanks in the upper yard, and loaded from the tanks into rail cars and trucks for delivery to customers. An asphalt plant operated on the site from 1953 to the late 1970s. Detailed descriptions of the Terminal facilities and historic activities are presented in the Background History Report (EMCON, 1994). The facility is currently used only for office purposes.

Fill, alluvium, and a sequence of glacial and pre-glacial deposits underlie the site. Groundwater is found in a site-wide aquifer at depths generally less than 8 feet below ground surface (bgs) in the lower yard of the Terminal and 20 to 140 feet bgs in the upper yard.

The Terminal is bounded on the northeast and northwest by a drainage ditch, which conveys Willow Creek, carrying surface water runoff from areas east and north of the site. The drainage ditch carries surface water into a tidal basin, where water is then conveyed beneath the BNSFRR right-of-way via a 48-inch-diameter culvert and on to

Puget Sound. North of the drainage ditch/Willow Creek lies the 23-acre freshwater and brackish water marsh known as the Union Oil Marsh. The marsh is tidally influenced and also fed by Shellabarger Creek from the northeast side of the marsh. The drainage ditch and the marsh are directly connected to Puget Sound and are tidally influenced. During periods of high tide, flow reversal occurs in the ditch and the marsh partially fills with water. During periods of low tide, the marsh completely drains.

3 REMEDIAL INVESTIGATION SUMMARY

3.1 Overview

The remedial investigation was performed between October 1994 and August 1996, and included investigations of air, soil, detention basin sediment/soil, groundwater, surface water, storm water, upland aquatic sediments, catch basin sediment, free product, and aquifer characteristics. Thirty-nine monitoring wells, 9 piezometers, and 120 shallow soil borings were drilled/installed; three test pits and four test trenches were excavated; 15 upland sediment samples were collected; over 375 subsurface soil samples, 31 surface soil samples, and 17 basin sediment/soil samples were collected for soil identification and chemical and physical analyses. Four quarters of groundwater samples were collected from monitoring wells. An aquifer characterization study was performed, consisting of a week-long tidal response study, nine slug tests, and twelve monthly rounds of water level measurements. Physical analyses, including grain size, porosity, and vertical hydraulic conductivity, were performed on 23 soil samples from the site.

3.2 RI Findings

An analysis of the RI data indicated the primary environmental impacts at the Terminal were free product on the groundwater table, related petroleum hydrocarbon chemicals in subsurface soil and groundwater, and paint/sand blast grit-related metals in the surface soil. Free product had been found in six lower yard plumes at the Terminal. These plumes were the result of releases during former Terminal operations.

Petroleum hydrocarbon constituents dissolved in groundwater were primarily found near free product plumes and in areas with free-phase product trapped in the unsaturated zone above the water table. These chemicals were not found in significant concentrations on the north side of Detention Basin No. 1, beneath and immediately downgradient of the upper yard, in deeper lower yard monitoring wells, or off site along the BNSFRR right-of-way.[1] Except for zinc, metals concentrations in groundwater were generally low, with the highest concentrations found in isolated locations around the Terminal. Zinc

[1] For purposes of this summary, insignificant concentrations means the chemical was not detected, detected at concentrations near the method detection limit, detected within the range of background values, and/or detected in the part per billion range.

was the most frequently detected metal in groundwater. Non-BTEX (benzene, toluene, ethylbenzene and xylenes) volatile organic compounds were not found in groundwater at the Terminal.

High concentrations of petroleum hydrocarbons in soil were primarily found near free product plumes and in areas with free-phase product trapped in the unsaturated zone above the water table. High concentrations of petroleum hydrocarbons were also found in the material within Detention Basin No. 1. These chemicals were not found in significant concentrations along the west and north sides of Detention Basin No. 1, in most of the randomly located (as opposed to focused) lower yard soil borings, in random upper yard soil borings, or off site along the BNSFRR right- of-way. Non-BTEX volatile organic compounds and non-polycyclic aromatic hydrocarbons (PAH) semivolatile organic compounds were not found in significant concentrations in Terminal soil. Elevated metals concentrations were found in surface soil in areas of sand blast grit and paint chips which occurred under pipe runs and manifolds, in isolated grit piles, and in certain tank basins. Leachable metals concentrations were low, indicating that the rate of leaching of metals from surface soil is probably low. Additionally, metals were not found in significant concentrations in subsurface soil.

Petroleum-related chemicals were detected in on-site storm water, primarily from the lower yard. Petroleum hydrocarbon (diesel range) concentrations ranged from 0.28 mg/L in runoff from the upper yard to 0.95 mg/L in runoff from the lower yard. Gas-range concentrations of approximately 0.6 mg/L were detected in lower yard storm water samples. BTEX constituents were detected in samples from the lower and upper yard, with maximum estimated concentrations of 2 µg/L for the lower yard and 0.5 µg/l for the upper yard. Petroleum hydrocarbons in the gasoline, diesel, and oil ranges were not detected in surface water samples collected in Willow Creek and the tidal basin adjacent to the site. Non-BTEX volatile organic compounds, and oil and grease were not found in storm water, in Willow Creek, or in the tidal basin samples. The highest metals concentrations, and elevated PAH concentrations, were found in surface water upgradient of the site.

Upland sediment from 8 of 15 locations in Willow Creek along the Terminal boundary, including the downstream tidal basin and sediment from the ditch adjacent to the marsh, passed all criteria for bioassay testing. At seven locations, including the upstream location, upland sediment failed one or more criteria for bioassay testing. No discernible pattern was identified that would point to a single sediment toxicity source.

Petroleum-hydrocarbon-related chemicals and paint/sand blast grit-related metals were identified as site indicator hazardous substances, and groundwater, storm water, and air were identified as migration pathways. Chemical concentrations in groundwater at the perimeter of the site and in surface water in Willow Creek were not found in concentrations that greatly exceed (i.e. by several orders of magnitude) anticipated regulatory cleanup levels. However, specific cleanup levels must be developed for

surface water and groundwater and the concentrations found compared to those levels. Upland sediment bioassay tests exhibited toxic effects at about half the locations tested. Soil is contaminated with petroleum hydrocarbons over much of the lower yard and surface contamination due to metals (e.g., arsenic, copper) from sand-blast grit occurs at several locations.

Site hydrogeology, the termination of site operations, chemical and product characteristics, product recovery operations, and the removal of product-saturated soil from four former plume areas, have combined to limit the rate at which chemicals have migrated within the Terminal boundaries and to the surrounded vicinity. The slow migration rate means the contaminants have remained in a relatively limited area and are hence more amenable to cleanup.

3.3 Additional Groundwater Monitoring

RI groundwater samples were collected over four quarters between November 1995 and August 1996; results were reported in the Draft and Final RI Report (EMCON, 1996 and 1998a; MFA, 2001a). Unocal continued to monitor groundwater at the site, collecting a fifth round of groundwater data in November 1996 (EMCON 1997a). In February 1997, the number of wells sampled and the analytical parameter list were reduced to focus on the wells at the perimeter of the site and on the indicator hazardous substances identified in the RI Report. Perimeter well sampling was performed biannually (February and August) in 1997 and 1998 and then annually (February) in 1999, 2000 and 2001 (EMCON, 1997b, 1998b, 1999; MFA, 2000, 2001b).

Samples were analyzed following procedures specified in the RI Work Plan and all data were validated in accordance with RI Work Plan procedures.

3.4 Project Database

The project database has been updated to include the post-RI groundwater monitoring data. All new data collected at the site are managed in this electronic database.

4 SUPPLEMENTAL INVESTIGATION

Field work for the SRI began in June 2001 and concluded in May 2002. The field work included investigations of subsurface soil, groundwater, and surface water. The SRI work scope was described in the Supplemental Remedial Investigation Work Plan (Work Plan) (MFA, 2001c). Seven shallow Geoprobe soil borings were advanced. Four groundwater monitoring events were performed. One surface water monitoring event was completed. Subsurface soil, groundwater, and surface water were sampled during the SRI field work.

Between August and November 2001, an interim remedial action (Interim Action) was performed in the Terminal's lower yard (MFA, 2001d and 2001e). Following the removal of petroleum-saturated soil from four areas of the lower yard, soil samples were collected from the excavation sidewalls and submitted for chemical analyses. During this time, Unocal elected to excavate 17 test pits along the southwest property boundary of the lower yard. The test pits were observed for the presence of groundwater and product sheens; soil and groundwater samples were also collected from the test pits. These data have been added to the project database.

Additionally, one intermediate-depth and 11 shallow wells were drilled/installed pursuant to additional scope items described by letter to Ecology (Unocal, 2001). The new monitoring wells were developed and surveyed. In November 2002, samples of the material in Detention Basin No. 1 were collected to provide fractionated petroleum hydrocarbon data. Data were added to the project database.

Work was performed consistent with the site Sampling and Analysis Plan (SAP) (MFA, 2001f) and the SRI Work Plan, unless otherwise noted. Deviations from the general sampling procedures were brought to the attention of the MFA project manager, and a Sample Alteration Checklist was completed. Copies of the checklists are provided in Appendix A.

Data generated during the SRI were validated following procedures identified in the SAP, and entered into the project database.

All RI, SRI and Interim Action sampling locations are displayed on Drawing 1, Lower Yard Exploration Map.

4.1 Soil

4.1.1 Off-site Soil Sampling (Admiral Way Geoprobes)

Ecology's request for supplemental investigation data included an assessment of a storm drain line that exits the Terminal at the northwest site boundary. This request related to the potential for off-site migration of petroleum hydrocarbons from the Terminal onto the Port of Edmonds' (Port's) South Marina property located west of the Terminal (Figure 4-1). The assessment of the storm drain line and the potential for off-site migration was performed and reported in the SRI Work Plan. Unocal elected to augment that assessment by conducting off-site sampling along Admiral Way. Procedures related to the collection of soil samples are described below. Procedures related to the collection of off-site groundwater samples are described in Section 4.2.3.

Procedures. Off-site sampling was performed on August 23 and 24, 2001. Subsurface soil samples were collected at seven soil boring locations along Admiral Way (Figure 4-1). Borings SB-1 through SB-6 were advanced in locations proposed in the Work Plan. Boring SB-7 was advanced along Admiral Way southwest of boring SB-1, based on the results of field screening. Borings SB-1 through SB-6 were advanced to 20 feet bgs and boring SB-7 was advanced to 12 ft bgs.

Soil borings were advanced using a truck-mounted Geoprobe hydraulic push rig equipped with nominal 1¼-inch-diameter probes. Soil was sampled continuously from the ground surface to total depth drilled. Soil samples were collected using acetate sampling sleeves placed inside the sampling probe. After advancing the probe to the bottom of the borehole, the tip of the sampling probe was retracted and undisturbed soil was collected into the acetate sampling sleeve.

The planned work was modified as follows: a blind duplicate soil sample was not collected due to the small volume of soil recovered for each sample. Instead, the laboratory was instructed to split an aliquot from one submitted sample and analyzed the aliquot as a non-blind duplicate. This modification is documented on a Sampling Alteration Checklist (Appendix A). Boring logs, including screening results, are included in Appendix B.

A total of 65 subsurface soil samples were collected for soil identification and/or chemical analyses.

Soil Sample Analyses. Eight soil samples from the soil borings were submitted for chemical analyses of: total petroleum hydrocarbons (TPH) as gasoline range organics (GRO); TPH as diesel range organics (DRO); TPH as heavy oil range organics (HO); BTEX; and PAHs. Soil samples submitted for chemical analysis were chosen based on observations during drilling. If field screening observations (including photoionization

detector measurements, appearance, and odor) did not indicate that hydrocarbons were present in the sampled soil, the deepest unsaturated soil sample was submitted for analysis.

4.1.2 Lower Yard Interim Action Soil Sampling

Procedures. An interim action was performed in the lower yard between August and November 2001. The interim action consisted of the removal of petroleum-saturated soil from four areas of the lower yard. Excavations extended laterally until product-saturated soil was not observed in the sidewalls or until structural concerns made it prudent to cease excavation. Excavations extended vertically across the groundwater table to between 6.5 and 10.5 feet bgs. The excavations remained open for several weeks to allow floating product to be removed from the groundwater surface.

After excavation, sidewall samples were collected to evaluate TPH concentrations in the unsaturated soil at the extent of the excavation. Soil samples were collected on 50-foot centers.

Thirty subsurface soil samples were collected at the extents of the excavations and submitted for chemical analyses.

The interim action was documented in *Lower Yard Interim Action As-built Report, Unocal Edmonds Terminal, Edmonds, Washington*, November 30, 2002 (MFA, 2002). Soil sampling results were included in the as-built report. The tabulated post-excavation soil sampling results have also been included in this SRI report.

Soil Sample Analyses. Thirty post-excavation samples were submitted for analysis of GRO, DRO, HO, BTEX, and PAHs.

4.1.3 Test Pits along Southwest Lower Yard Property Boundary

Procedures. As noted above, during the 2001 Lower Yard Interim Action, Unocal elected to excavate 17 test pits along the southwest property boundary of the lower yard (Figure 4-1). The test pits were excavated on September 24, 25 and 26, 2001, to observe the presence of groundwater and any product on the groundwater. Test pit excavation depths ranged from 7.5 to 10 feet bgs. Soil samples were also collected from the test pits, from the unsaturated zone just above the groundwater level. Sampling depths ranged from 4.5 to 5.8 feet bgs. A total of 17 subsurface soil samples were collected for chemical analyses.

Soil Sample Analyses. Seventeen samples from the test pits were submitted for analysis of GRO, DRO, HO and BTEX.

4.1.4 Lower Yard Replacement Wells and MW-134x

Procedures. Monitoring well installation and sampling was performed between January 22 and February 12, 2002. Eleven shallow soil borings were drilled in the lower yard and monitoring wells were installed in each of the borings. A total of 13 subsurface soil samples were collected for soil identification and/or chemical analyses.

One intermediate-depth boring was advanced in the lower yard and a monitoring well (MW-134x) was installed in the boring. A total of 28 subsurface soil samples were collected for soil identification and/or chemical analyses.

All borings were advanced using a truck- or trailer-mounted, hollow-stem auger drilling rig. The rig was equipped with nominal 6-inch inside diameter (i.d.) and nominal 8-inch outside diameter (o.d.) auger flights. The shallow borings were advanced to between 14 and 15.5 feet bgs. Boring MW-134x was advanced to 44.5 feet bgs. Monitoring wells were installed after the total depth was reached in each boring. Monitoring well construction details are provided in Section 4.2.2. Boring logs, including screening results, are included in Appendix B.

Soil Sample Analyses. Six of thirteen subsurface soil samples from the shallow soil borings and three of twenty-eight subsurface soil samples from the intermediate-depth boring were submitted for chemical analyses. The samples were analyzed for: GRO, DRO, HO, BTEX, and PAHs. One sample from monitoring well MW-143 and one sample from MW-134x was also analyzed for total organic carbon (TOC).

4.2 Groundwater

4.2.1 Biannual and Site-wide Monitoring Events

SRI groundwater monitoring was performed in June 2001, November 2001, February 2002, and May 2002. The site-wide monitoring event was performed in June 2001; this event included approximately 45 monitoring wells. Biannual events were performed in November 2001 and February 2002, and included wells in the perimeter well network (Figure 4-2). Biannual events are typically performed in August and February. Because the site-wide event was performed in June 2001, the biannual event was moved from August to November 2001. An unscheduled, limited monitoring event was performed in May 2002, in order to sample the lower yard replacement wells, well MW-134x, and the wells along the BNSFRR tracks.

4.2.1.1 Groundwater Sampling and Analysis

Procedures. Wells were purged and sampled using low flow procedures as described in the SRI Work Plan. Groundwater parameters were measured and recorded in the field. Groundwater field sampling data sheets are presented in Appendix C.

The planned work was modified as follows: The wells located along the BNSFRR tracks (MW-28, MW-105, MW-106, MW-107, MW-137, and MW-138) could not be sampled during the February 2002 sampling event because the BNSF flagger required for the work was not available when requested. These wells were sampled during the unscheduled sampling event in May 2002.

Groundwater Sample Analyses. Groundwater samples from the four sampling events were submitted for analysis of: GRO, DRO, and HO; BTEX; PAHs (including 1- and 2-methylnapthalene); total and dissolved arsenic, copper, lead, and zinc; total suspended solids (TSS); total dissolved solids (TDS) (site-wide event only); and iron (site-wide event only). Selected wells were sampled for volatile petroleum hydrocarbons (VPH) and extractable petroleum hydrocarbons (EPH).

4.2.1.2 Groundwater and Product Measurements

Groundwater and product levels were measured and recorded in all four monitoring events. In June 2001, groundwater and product measurements were recorded from the approximately 45 wells included in the site-wide groundwater monitoring event. During November 2001 and February 2002 (perimeter groundwater sampling events) and May 2002 (a limited groundwater sampling event), groundwater and product levels were measured only in wells that were sampled.

4.2.2 Lower Yard Replacement Wells and MW-134x

Procedures. Twelve new wells were installed in the lower yard (Figure 4-3). Three wells (MW-140, MW-141, and MW-142) were installed within the 2001 lower yard excavation areas. Two wells (MW-143 and MW-144) were installed outside and to the south of the excavation areas, and five wells (MW-145, MW-20R, MW-102R, MW-103R, and MW-112R) were installed to replace wells abandoned during excavation activities. One well (MW-146) was installed near abandoned wells MW-10 and MW-11.

Monitoring well MW-134x was installed approximately 15 feet northwest of monitoring well MW-134 (Figure 4-3). MW-134x was installed here in order to monitor the site-wide aquifer in the eastern part of the Terminal area. Monitoring data collected for existing well MW-134 indicated that this well was screened in a water-bearing zone perched above the site-wide aquifer. New well MW-134x was screened in the site-wide

aquifer, with the screen placed from approximately 15 feet deeper than the screen for well MW-134.

Each new well was constructed of 2-inch-diameter, flush-threaded Schedule 40 PVC, with a 10-foot section of 0.020-inch slotted well screen. The shallow monitoring well screens were placed across the water table from approximately 3.5 to 13.5 feet bgs. For MW-134x, the monitoring well screen was placed from approximately 34 to 44 feet bgs.

The annular space around the screen of each monitoring well was backfilled with clean 20 x 40 silica sand, and the annular space above the monitoring well filter pack was sealed with 3/8-inch (medium) bentonite chips (hydrated). The top of each well was secured with a flush-mount, lockable security casing. Well construction details are included in the borings logs in Appendix B. Following well installation, the wells were developed to remove fine-grained material from the filter pack.

Two wells (MW-10 and MW-11) were abandoned during SRI activities. Two well monuments (for wells MW-W and MW-131) were replaced during the work. Wells MW-128 and MW-111 were over-excavated during the 2001 Interim Action.

Groundwater Sample Analyses. The lower yard replacement wells and MW-134x were installed in January and February 2002, and were sampled during the February 2002 and May 2002 monitoring events as follows:

- February 2002 event: MW-141, MW-142, MW-143, MW-20R, MW-134x. MW-102R and MW-140 were not sampled due to measurable product in these wells.

- May 2002 event: MW-140, MW-141, MW-142, MW-143, MW-144, MW-145, MW-146, and MW-134x.

Groundwater sampling and analysis are described in Section 4.2.1, above.

4.2.3 Off-site Groundwater Sampling (Admiral Way Geoprobes)

Procedures: Grab groundwater samples were collected at the seven soil boring locations along Admiral Way (Figure 4-1). The samples were collected after the total depth was reached in each soil boring. Temporary well screens were placed in the borings to allow collection of the groundwater samples. The temporary screens were set at (and the samples were collected from) the top of the water table, as observed in each boring at the time of drilling. A small volume of water (generally 0.5 to 2.5 gallons) was purged from each well to help remove silt from the temporary casing prior to collecting samples. The purge water was removed and the grab groundwater samples were collected using a peristaltic pump.

Groundwater field sampling data sheets are presented in Appendix C.

Groundwater Sample Analyses. Seven grab groundwater samples were collected from the temporary wells and submitted for analyses. All grab groundwater samples were analyzed for GRO, DRO, HO, BTEX, and TSS (except TSS in SB-7; see sampling alteration checklist, Appendix A). Observations of water quality were recorded in the field on the groundwater field sampling data sheets.

4.2.4 Test pits along Southwest Lower Yard Property Boundary

Procedures. Seventeen test pits were excavated along the southwest property boundary of the lower yard on September 24 through 26, 2001 (Figure 4-1). Test pit excavation depths ranged from 7.5 to 10 feet bgs. Groundwater and product observations were recorded from the time of excavation to October 2, 2001. Groundwater grab samples were collected from the test pits on October 2, 2001, by peristaltic pump. A total of 17 groundwater grab samples were collected for chemical analyses.

Groundwater Sample Analyses. Seventeen groundwater grab samples from the test pits were submitted for analysis of: GRO, DRO, HO, BTEX and TSS.

4.3 Surface Water

4.3.1 Surface Water Measurements

Surface water levels were monitored during groundwater monitoring events conducted in November 2001 and February 2002, and during the surface water sampling event performed in September 2001.

4.3.2 Surface Water Sampling and Analysis

Procedures. Five surface water samples were collected on September 25, 2001, from Willow Creek and Detention Basin No. 1. The five surface water sampling locations were designated SW-1 through SW-5 (Figure 4-2). SW-1 was located near the fish hatchery, approximately 150 feet downstream of the point at which off-site drainage (from Pine Street/south residential area) is discharged into Willow Creek. SW-2 and SW-3 were located in Willow Creek, SW-4 was located in the tidal basin, and SW-5 was located in Detention Basin No. 1.

Samples were collected during a no-runoff period. During the sampling event, surface water samples were collected from Willow Creek (SW-2 and SW-3) and the tidal basin station (SW-4), then at upstream station SW-1, and finally from Detention Basin No. 1

(SW-5). The samples at SW-2, SW-3, and SW-4 were collected during the falling tide. The samples at SW-1 and SW-5, which are unaffected by tides, were collected during the subsequent slack tide.

Surface Water Sample Analyses. The five surface water samples were analyzed for GRO, DRO, HO, BTEX, VPH, EPH, TSS and TDS. Temperature, pH, conductivity, dissolved oxygen and redox potential were measured and recorded in the field.

4.4 Detention Basin Material

While not included in the SRI work plan, three additional samples of the material in Detention Basin No. 1 were collected in November 2002 (Drawing 1). Samples were collected for purposes of providing fractionated TPH data.

4.4.1 Sampling and Analysis

Procedures. Three samples of the asphalt- and petroleum-contaminated material in Detention Basin No. 1 were collected on November 27, 2002. Samples were collected with a hand auger, advanced from the surface of the basin material to 6 to 12 inches below the surface. Samples were designated BSS-112, BSS-113 and BSS-114.

Basin Material Sample Analyses. The three samples were analyzed for GRO, DRO, HO, BTEX, PAHs, VPH, and EPH.

5 SRI FINDINGS

Results of the SRI are summarized in the following sections using Indicator Hazardous Substances (IHSs) defined during the RI. Laboratory and data validation reports associated with the SRI sampling events are provided in Appendices D and E, respectively.

Indicator hazardous substances (IHSs) are defined by MTCA as a subset of hazardous substances present at a site that are selected per WAC 173-340-708 for monitoring and analysis during any phase of remedial action, for the purpose of characterizing the site or establishing cleanup requirements for that site (WAC-173-340-200). IHSs were identified for the site during the RI as follows (MFA, 2001a):

Soil IHSs

- Chrysene
- TPH-GRO
- TPH-DRO
- TPH-HO
- Benzene
- Antimony
- Arsenic

Groundwater IHSs, Site-wide Aquifer Beneath Upper Yard

- TPH (the sum of GRO, DRO, and HO)
- Benzene

Total arsenic was also identified during the RI as a tentative groundwater IHS for the site-wide aquifer beneath the upper yard.

Groundwater IHSs, Site-wide Aquifer Beneath Lower Yard

- TPH
- Benzene
- Chrysene
- Lead
- Zinc

Arsenic and copper were also tentatively identified during the RI as groundwater IHSs for the site-wide aquifer beneath the lower yard.

5.1 Soil

5.1.1 Off-site Soil Sampling (Admiral Way Geoprobes)

Similar to the lower yard of the site, two geologic units were identified in the off-site investigation area along Admiral Way. The uppermost unit occurring in the off-site investigation area is fill. Fill material is found across the entire off-site investigation area, and generally varies from approximately 4 to 14 feet thick. Grade fill is present from the surface to between 4 and 11 feet bgs. The grade fill consists of gravel and sand mixtures. Finer-grained fill underlies the grade fill. The finer-grained fill consists of mixtures of sandy silt, silty sand, and sand with silt, with occasional horizons of organic material.

Native soil underlies the fill throughout the off-site investigation area. The native soil is present from the base of the fill to the maximum explored depth of 20 feet bgs. The native soil typically consists of gray to brown-gray, fine to medium sand and gravelly sand with trace organic material. Interbedded sand with silt, silt with sand, and silty sand are abundant. The interbeds range in thickness from a few inches to several feet, and appear to be laterally discontinuous. The unit is interpreted to be alluvium. The water table was observed between 7 and 9 feet bgs at the time of drilling and sample collection.

Figure 5-1 presents a cross section of the site that also includes the off-site investigation area along Admiral Way. The location of the cross section is shown on Drawing 1 (B-B'). Tables 5-1 and 5-2 summarize the soil sample analytical results for borings completed along Admiral Way.

TPH/BTEX. Field observations (staining, odors, photoionization detector [PID] readings) indicated no TPH contamination from the ground surface to at least 5 feet bgs. Samples collected at 3.5 feet bgs (SB-1 and SB-4) and 5 feet bgs (SB-7) supported the field observations, showing no detections of BTEX or TPH in the GRO, DRO, or HO ranges (Table 5-1). PID readings greater than background levels and hydrocarbon-like odors were noted in one boring, SB-1, between approximately 5 and 11 feet bgs. GRO and BTEX compounds were detected only in SB-1 at 6 feet bgs; the GRO concentration

was estimated at 366 mg/kg. GRO was not detected in SB-2 through SB-7. Benzene was not detected in any of the samples.

Where detected, DRO was found at 5 to 9 feet bgs, with concentrations ranging from 15.1 mg/kg (SB-3) to an estimated 2,190 mg/kg (SB-1). DRO detections above 2,000 mg/kg were present only in soil from borings SB-1 and SB-4. These borings were located in the generally southern and central part of the Admiral Way study area, respectively. HO was detected in four of the seven borings (SB-2, SB-3, SB-4 and SB-6), at concentrations ranging from 43.8 mg/kg (SB-2) to 1,190 mg/kg (SB-4).

PAHs. No PAH constituents were detected in soil samples collected from SB-3, SB-5 or SB-7 (Table 5-2). Chrysene was detected in SB-1, SB-2, SB-4 and SB-6 at concentrations ranging from an estimated 0.0343 mg/kg to 0.803 mg/kg.

Consistent with the highest TPH results, the highest PAH concentrations were detected in 6-foot-bgs soil samples from borings SB-1 and SB-4, located in the southern and central part of the Admiral Way study area, respectively. In the uppermost few feet of soil, PAHs either were not present, or were present at concentrations at least an order of magnitude lower than in SB-1 and SB-4 at 6 feet bgs.

5.1.2 Lower Yard Interim Action Soil Sampling

Product-saturated soil was removed from four areas of the lower yard as part of the 2001 Interim Action. As previously noted, excavations extended laterally until product-saturated soil was not observed in the sidewalls or until structural concerns made it prudent to cease excavation. Excavations extended vertically across the groundwater table to between 6.5 and 10.5 feet bgs.

Tables 5-3 and 5-4 summarize the soil sample analytical results for samples collected from the excavation sidewalls. Results are also displayed on Figure 5-2.

TPH/BTEX. GRO was detected in 24 of the 30 excavation sidewall samples, with concentrations ranging from 7.11 to an estimated 2,020 mg/kg (Table 5-3). BTEX constituents were detected in 19 of the 30 samples; benzene concentrations (detected in 10 samples) ranged from 0.0681 to 3.13 mg/kg. DRO was detected in 25 of the 30 samples, with concentrations ranging from 25.1 mg/kg to 35,100 mg/kg. HO was detected in 16 of 30 samples, ranging in concentrations from 16.1 to 10,900 mg/kg. At the higher DRO and HO concentrations, samples consisted of petroleum-saturated soil.

The highest TPH concentrations were found approximately 50 to 75 feet southwest of Detention Basin No. 2 (Figure 5-2).

PAHs. PAHs were detected in 28 of the 30 samples (Table 5-4). Chrysene was detected in 12 of the 30 samples, with concentrations ranging from an estimated 0.003 mg/kg to 1.3 mg/kg.

5.1.3 Test Pits along Southwest Property Boundary

Table 5-5 provides the depth of each test pit excavated along the southwest property boundary and observations made during the period the excavations remained open. Tables 5-6 and 5-7 summarize the soil sample analytical results for the test pit samples.

TPH/BTEX. GRO and DRO were detected in soil samples collected from all test pits except TP-4 (Table 5-6; Figure 5-3). For GRO, concentrations ranged from an estimated 51.6 mg/kg (TP-20) to an estimated 2,180 mg/kg (TP-10 and TP-13). For DRO, concentrations ranged from 84.2 mg/kg (TP-5) to 13,600 mg/kg (TP-18). HO was detected in samples collected from 6 of the 17 test pits. Concentrations ranged from 32.4 mg/kg (TP-9) to 1,240 mg/kg (TP-18). Benzene was detected in samples collected from 5 of 17 test pits, with concentrations ranging from an estimated 0.0446 mg/kg (TP-14) to an estimated 0.734 mg/kg (TP-18).

The highest TPH concentrations were found in samples collected from test pits TP-9 through TP-20 (Figure 5-3).

PAHs. PAHs were detected in samples collected from all 17 test pits (Table 5-7). Chrysene was detected in soil samples from 12 of 17 test pits, with concentrations ranging from 0.007 mg/kg (TP-5) to 1.1 mg/kg (TP-18).

5.1.4 Lower Yard Replacement Wells and MW-134x

As previously noted, monitoring well MW-134x was installed adjacent to existing well MW-134 in order to monitor the site-wide aquifer in the eastern part of the Terminal area. New well MW-134x was screened in the site-wide aquifer, with the screen placed from approximately 34 to 44 feet bgs (about 15 feet deeper than the screen for well MW-134).

Subsurface soil encountered in the MW-134x boring consisted of fill material (sand with gravel) to approximately 9 feet bgs, underlain by gray-brown, fine to medium silty sand, interpreted to be transitional beds, to a depth of approximately 15.5 feet bgs. The silty sand was underlain by brown, fine to medium sand with trace to some fine to coarse, subrounded gravel, interpreted to be part of the Whidbey Formation. The brown sand contained occasional interbeds of gray sandy silt.

Soil samples were collected at replacement monitoring wells MW-143, MW-144, MW-145 and at MW-134x to gather additional soil data in those areas. Tables 5-8 and

5-9 summarize the soil sample analytical results for the lower yard replacement well borings and for boring MW-134x.

TPH/BTEX. GRO was detected only in the sample collected at 5 feet bgs in boring MW-144, at 3,590 mg/kg (Table 5-8). BTEX constituents were detected in borings MW-144 and MW-145; benzene was detected at an estimated 0.532 mg/kg in boring MW-144 (5 feet bgs). The soil data for MW-144 are consistent with results from the RI: GRO was detected at a concentration of 4,300 mg/kg in a soil sample collected from 2.5 feet bgs in RI boring SB-125, located just east of MW-144.

GRO and BTEX constituents were not detected in boring MW-134x.

DRO was detected in borings MW-143 and MW-144, at concentrations up to 212 and 5,740 mg/kg, respectively. HO was also detected in these borings, at concentrations up to 196 and 222 mg/kg, respectively. DRO soil data for MW-144 are consistent with results from the RI: DRO was detected at concentrations of 3,600 and 9,900 mg/kg in SB-123 and 1,300 mg/kg in SB-125. Both RI borings are in the vicinity of MW-144.

DRO and HO were not detected in boring MW-134x.

PAHs. PAHs were detected in soil samples from each of the new borings (Table 5-9). Chrysene was not one of the detected PAHs. One PAH (2-methylnaphthalene) was detected in samples collected from 15.5 feet bgs (0.0181 mg/kg) and 32.5 feet bgs (0.0202 mg/kg) in boring MW-134x.

TOC. TOC was measured in the analyzed soil sample from MW-143 at concentrations ranging from 5,450 to 10,900 mg/kg; the average concentration measured was 7,540 mg/kg. TOC was not measured at or above the reporting limit of 1,000 mg/kg in the analyzed soil sample from MW-134x.

5.2 Groundwater

5.2.1 Groundwater Quality- Biannual Monitoring Events

Biannual events were performed in November 2001 and February 2002, and included wells in the perimeter well network. Biannual events are typically performed in August and February; due to the site-wide event performed in June 2001, the August 2001 event was moved to November 2001. An unscheduled, limited monitoring event was performed in May 2002, in order to sample the lower yard replacement wells, well MW-134x, and the wells along the BNSFRR tracks that were inaccessible in February.

Analytical results for the SRI biannual monitoring events are provided in Tables 5-10 through 5-15. Post-RI and SRI groundwater data collected between 1998 and 2002 from

the perimeter well network are presented on Figures 5-4 through 5-6. TPH results are discussed below.

TPH/BTEX. During the SRI biannual (perimeter well) monitoring events, GRO and benzene were not detected above method reporting limits (MRLs) at any of the perimeter wells except MW-20, MW-104, MW-101, MW-102, and LM-3 (product was present in LM-3) (Table 5-10; Figures 5-4 and 5-5). The wells with detectable GRO and benzene concentrations are all located along the northwest boundary of the lower yard.

GRO and benzene were not detected above MRLs in any of the BNSFRR wells off the southwest property boundary, in MW-138 (located on the far side of Willow Creek), or in wells MW-108, MW-109, MW-135, and MW-136 (located adjacent Willow Creek on the northeast property boundary).

DRO and HO were detected above MRLs in perimeter monitoring wells MW-20, MW-104, MW-139 and MW-136 (Figure 5-6). Concentrations were all below 0.5 mg/L, except at MW-136, where DRO was detected at 1.04 mg/L in the November 2001 event and at an estimated 0.715 mg/L during the February 2002 event. DRO and HO were also observed or detected in LM-2 and LM-3, which are located in the Detention Basin No. 1 berm. Product is routinely observed in LM-3. In LM-2, DRO concentrations were an estimated 0.329 mg/L and an estimated 1.14 mg/L.

DRO and HO were not detected in any of the BNSFRR wells off the southwest property boundary, in MW-138 (located on the far side of Willow Creek), or in wells MW-108, MW-109, and MW-135 (located adjacent Willow Creek on the northeast property boundary).

A comparison of the perimeter well groundwater data indicate that the SRI data are very consistent with post-RI data (Figures 5-4, 5-5 and 5-6). From 1998 to 2002, GRO and BTEX concentrations were non-detect or very low in all perimeter wells except MW-20, MW-104, MW-101, MW-102, and LM-3. DRO and HO concentrations were non-detect or very low in all perimeter wells except LM-3.

5.2.2 Groundwater Quality- Site-wide Monitoring Event

A site-wide monitoring event was performed in June 2001, for purposes of assessing changes in groundwater quality since the last site-wide monitoring event (performed in November 1996). Samples were collected from approximately 45 wells, located in the lower and upper yards of the Terminal.

TPH, BTEX, PAH and metals results for the lower yard monitoring wells are included with the biannual (perimeter well) monitoring event results in Tables 5-10 through 5-13. Sample results for VPH and EPH are provided in Tables 5-14 and 5-15, respectively.

TPH, BTEX, PAH and metals results for the upper yard monitoring wells are provided in Tables 5-16 through 5-19.

Figures 5-7, 5-8 and 5-9 present TPH distributions in groundwater. Concentration contours reflect TPH concentrations detected during the June 2001 site-wide monitoring event, as well as petroleum product detected in the wells during this event.

TPH/BTEX. GRO, benzene, DRO and HO were not detected in samples collected from any of the upper yard monitoring wells (Tables 5-16 and 5-17). These wells are screened in the site-wide aquifer.

In the lower yard, GRO concentrations ranged from non-detect to 5.68 mg/L in MW-125, located in the southwestern portion of the lower yard (Figure 5-7). Benzene concentrations ranged from non-detect to 1.84 mg/L in MW-125. DRO and HO concentrations ranged from non-detect to 6.93 mg/L and 1.61 mg/L, respectively. The highest DRO and HO concentrations were detected in LM-2, located along the northern property boundary in the berm of Detention Basin No. 1 (Figures 5-8, 5-9).

GRO concentration contours are displayed on Figure 5-7. GRO was not detected in any of the off-site wells located along the BNSFRR tracks or the wells adjacent Union Oil Marsh, excepting MW-136, where GRO was detected at 0.105 mg/L. The highest GRO concentrations were detected near wells containing free petroleum product.

DRO concentration contours are displayed on Figure 5-8. DRO was not detected in any of the off-site wells located along the BNSFRR tracks or the wells adjacent Union Oil Marsh. Concentrations near or below 1 mg/L were detected in wells adjacent Willow Creek as it moves along the northwest property boundary. The highest DRO concentrations were detected near wells containing free product. Samples collected from LM-2 and LM-3, located in the berm of Detention Basin No. 1, contained 6.93 mg/L and a product film, respectively.

HO concentration contours are displayed on Figure 5-9. HO was not detected in any of the off-site wells located along the BNSFRR tracks, wells adjacent Willow Creek as it moves along the northwest property boundary, or in the wells adjacent Union Oil Marsh. Samples collected from LM-2 and LM-3, located in the berm of Detention Basin No. 1, contained 1.61 mg/L and a product film, respectively. The highest HO concentrations were assumed to be present near wells containing free product.

PAHs. PAHs were not detected in samples collected from any of the upper yard monitoring wells (Table 5-18).

In the lower yard, 1-methylnaphthalene was the most frequently detected non-carcinogenic PAH, found in 11 of 29 wells sampled during the June 2001 event. Of the

carcinogenic PAHs, benzo(a)anthracene was detected in 1 of 29 samples, benzo(a)pyrene in 1 of 29 samples, and chrysene was detected in 1 of 29 samples.[2]

Metals. Arsenic, copper, lead and zinc were detected in samples collected from each of the upper yard monitoring wells, including background monitoring well MW-7U (Table 5-19). Total arsenic was detected at concentrations ranging from 0.00058 to 0.0247 mg/L.

Arsenic, copper, lead and zinc were also detected in samples collected from each of the lower yard monitoring wells. Total arsenic ranged from non-detect to an estimated 0.0774 in MW-126, located near the Unocal office building (Drawing 1). Total copper ranged from non-detect to 0.0366 in MW-122, located off the southeastern corner of Detention Basin No. 1. Total lead ranged from non-detect to 0.0132 mg/L in MW-137, located along the BNSFRR tracks. Total zinc ranged from non-detect to 0.146 mg/L in MW-106, also located along the BNSFRR tracks.

General Chemistry. Total dissolved solids (TDS) ranged from 120 to 4,300 mg/L, with concentrations generally below 1,000 mg/L in lower yard monitoring wells and generally below 300 in the upper yard wells (Table 5-20). Maximum concentrations were found in wells located near Willow Creek (MW-20, MW-138, MW-139, LM-2, MW-108, MW-109, and MW-136), indicating the presence of marine water.

Iron concentrations ranged from less than 0.05 to 70.7 mg/L in the upper yard wells and from less than 0.2 to 65 mg/L in lower yard wells (Table 5-20).

Total suspended solids (TSS) concentrations for the period November 1996 through May 2002 are provided in Table 5-21. Specific to the June 2001 monitoring event, TSS concentrations ranged from less than 4 to 770 mg/L in the lower yard wells and less than 4 to 810 mg/L in the upper yard wells.

On-site and off-site wells located along the property boundary were sampled for hardness, ammonia, nitrate-nitrogen, sulfide, magnesium, potassium and sodium. Hardness (as $CaCO_3$) ranged from 21.3 to 974 mg/L; ammonia (as nitrogen) ranged from less than 0.100 to 18 mg/L; nitrate-nitrogen (as nitrogen) ranged from less than 0.1 to 4.34 mg/L; sulfide was not detected at 20 mg/L; magnesium ranged from 3.20 to 125 mg/L; potassium ranged from 2.11 to 68.7 mg/L; and sodium ranged from 1.79 to 494 mg/L (Table 5-20).

Field Parameters. Table 5-22 provides groundwater field measurements and observations from February 2000 to May 2002. Specific to the June 2001 site-wide monitoring event, specific conductance ranged from 75 µS/cm in interior well MW-17 to 7,940 µS/cm in perimeter well MW-108 in the lower yard. Upper yard measurements

[2] Carcinogenic PAHs are benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene.

showed less variation, ranging from 205 to 770 µS/cm. Turbidity ranged from 5.8 to 638 NTU in the lower and upper yard wells. Temperature averaged about 13.8° C in the lower yard wells and about 14.4° C in the upper yard wells measured in June 2001. Dissolved oxygen ranged from 0 to 8.63 mg/L in the lower yard wells and 0.35 to 9.05 in the upper yard wells.

All RI, post-RI and SRI groundwater data collected at the Terminal through May 2002 have been tabulated and provided in Appendix F.

5.2.3 Groundwater Elevations- Biannual Monitoring Events

During the SRI biannual (perimeter well) monitoring events, depth to the site-wide aquifer in the perimeter wells ranged from 0.78 feet bgs at LM-3 in November 2001 to 9.10 feet bgs at MW-135 in February 2002 (relative to MLLW datum). During the SRI investigation period, perimeter well groundwater elevations varied from 8.39 feet at MW-139 in February 2002 to 12.05 feet at MW-135 in November 2001 (relative to the MLLW datum). Water level measurements obtained during the perimeter monitoring events are presented in Appendix G. Due to the limited number of measurements, contour figures were not prepared for the biannual monitoring events.

5.2.4 Groundwater Elevations- Site-wide Monitoring Event

During the site-wide monitoring event in June 2001, depth to the site-wide aquifer in the lower yard ranged from 1.62 ft bgs at LM-2 to 10.41 ft bgs at MW-102 (relative to MLLW datum). Groundwater depths beneath the majority of the lower yard ranged from 4 to 9 feet bgs. Groundwater elevations for the June 2001 monitoring event varied from 7.14 feet at MW-127 to 12.06 feet at MW-136. Groundwater elevations in the majority of the lower yard ranged from 7.5 to 10 feet, with the highest elevations in the central part of the lower yard and the lowest elevations in the southwest part of the lower yard. Water level measurements obtained during the June 2001 site-wide monitoring event are presented on Figure 5-10 and in Appendix G.

5.2.5 Off-Site Groundwater Sampling (Admiral Way Geoprobes)

Table 5-23 summarizes the groundwater analytical results for grab samples collected from borings completed along Admiral Way in September 2001.

TPH/BTEX. No DRO, HO, GRO or BTEX compounds were detected in the grab groundwater samples collected from borings SB-2, SB-3, SB-4, SB-5, and SB-7. TPH-DRO (up to 1.65 mg/L), GRO (up to 891 µg/L), benzene (up to 2.54 µg/L) and total xylenes (up to 6.25 µg/L) were detected in the grab groundwater samples collected from

borings SB-1 and SB-6. In addition, ethylbenzene (1.37 µg/L) was detected in boring SB-1 and toluene (0.669 µg/L) was detected in boring SB-6.

Figure 5-11 presents the TPH distributions in groundwater. TPH and BTEX were detected in groundwater samples collected from borings SB-1 and SB-6, located generally in the southern and northern part of the Admiral Way study area, respectively.

5.2.6 Test pits along Southwest Lower Yard Property Boundary

Table 5-5 provides the depth of each test pit excavated along the southwest property boundary and observations made during the period the excavations remained open. Table 5-24 summarizes the groundwater analytical results for grab samples collected from the test pits.

TPH/BTEX. During the period the test pits remained open, a product sheen or film was observed in all test pits but TP-4, TP-7 and TP-8 (Table 5-5). GRO concentrations ranged from non-detect to 8.7 mg/L (TP-7) and benzene concentrations ranged from non-detect to 0.53 mg/L (TP-7). DRO concentrations ranged from non-detect to 2.61 mg/L (TP-18). There were no HO detections.

Figure 5-11 presents the TPH distributions in groundwater. GRO and DRO were detected all along the southwest boundary, from TP-6 to TP-20. GRO concentrations were highest at TP-7 and TP-8 (8.7 and 4.60 mg/L, respectively).

5.3 Product Level Measurements

Product level measurements collected during the SRI are provided on Table 5-25. Additional measurements were made during the groundwater monitoring events; these data are shown on the field sampling data sheets (Appendix C).

Numerous monitoring wells were abandoned/removed during the 2001 Interim Action, including MW-2, MW-5, MW-19, MW-21, MW-110, MW-113, MW-114, MW-115, MW-117, MW-118, MW-123, MW-128, and MW-132 (Drawing 1). These wells historically contained measurable product or product films. Replacement wells were installed in the backfill of the Interim Action excavation areas (MW-140, MW-141, MW-142). Only limited product measurements were collected between well installation in January 2002 and the end of the SRI period (May 2002). As of May 2002, a product film was detected (February and May 2002) in MW-140. No product was observed in MW-141 or MW-142. Product measurements will continue to be collected in the former product plume/excavation areas to monitor the extent of residual product in these areas.

MW-112, also removed during the Interim Action, historically did not contain measurable product. Replacement well MW-112R, located 31 feet east of MW-112, contained measurable product in May 2002 (0.04 feet corrected product thickness).

Measurable product or product films were detected in MW-124 and MW-13 (located in the southwest lower yard), and in MW-129, MW-130 and MW-133 (located west of Detention Basin No. 1). Findings are consistent with RI and post-RI findings; these wells have historically contained measurable product.

5.4 Surface Water

Tables 5-26 through 5-28 summarize the surface water sample analytical results for samples collected in September 2001. Field parameters for the surface water sampling event are displayed on Table 5-30.

No GRO, DRO, HO, or BTEX constituents were detected in the surface water samples collected from Willow Creek. The sample collected at SW-5, located in Detention Basin No. 1, contained DRO at an estimated 350 µg/L. These results are consistent with the RI surface water sampling results. No VPH compounds were detected in the surface water samples collected from Willow Creek or Detention Basin No. 1. EPH compounds were detected in Detention Basin No. 1 (SW-5); all detections were estimated values, except for aromatic compounds in the C-12 to C-16 range, which were detected at a concentration of 0.084 mg/L.

5.5 Detention Basin Material

Tables 5-31 and 5-32 summarize the TPH, BTEX and PAH results for the three samples collected from Detention Basin No. 1 for fractionation purposes. GRO, DRO and HO concentrations are comparable to those detected in samples collected during the RI. VPH and EPH results are provided in Table 5-33 and 5-34, respectively.

6 DISCUSSION OF SRI FINDINGS

6.1 Off-Site Contamination

The potential for off-site migration of petroleum hydrocarbons from the Terminal onto the Port's South Marina property was evaluated during the scoping phase of the SRI. The South Marina property is located west of the Terminal (Figure 4-1). It has been suggested that the Terminal could be the source of petroleum contamination detected at the south marina site (LAI, 1998), either via transport under the BNSFRR track or via the backfill of the Washington State Department of Transportation (WSDOT) storm drain line (Figure 4-1). A review of soil and groundwater data collected from the southwest lower yard and from the Port property was performed, and the likelihood that the south marina contamination originated from the Terminal was considered. Findings were discussed in Section 4 of the SRI Work Plan (MFA, 2001c), which is reproduced in Appendix H of this report.

Based on the TPH concentrations detected in soil at the Port (up to 20,000 mg/kg) and the presence of free product in soil at the Port, TPH would have had to migrate from the Terminal as free-phase product. The distribution of petroleum hydrocarbons in soil and groundwater in the southwest lower yard provided no indication of the off-site migration of free-phase petroleum hydrocarbons to the Port's south marina property. Additionally, data did not support the hypothesis that product was conveyed from the Terminal to the Port property via the backfill around the WSDOT storm drain line. All results indicated the Port contamination derived from a separate source.

To resolve continued concerns expressed by the Port, Unocal advanced seven soil borings along the east side of Admiral Way to 20 feet bgs (SB-7 was advanced to 12 feet bgs). The water table was observed between 7 and 9 feet bgs. The highest concentrations of DRO found in the Admiral Way borings were 2,010 mg/kg in SB-4 at 6 feet bgs and an estimated 2,190 mg/kg in SB-1 at 6 feet bgs. The highest concentrations of HO were 1,190 mg/kg in SB-4 at 6 feet bgs and an estimated 159 mg/kg in SB-6 at 5 feet bgs. Concentrations were orders of magnitude below those found on the Port's property, where diesel and oil concentrations were found up to 17,000 and 20,000 mg/kg, respectively (boring P-1) (LAI, 1998). DRO and HO concentrations in Admiral Way borings SB-2 and SB-3 were below 100 mg/kg. These two borings are located 70 to 80 feet upgradient of Port boring P-1, where diesel and oil

concentrations were detected at concentrations of 17,000 and 20,000 mg/kg, respectively (Figure 5-2).

Additionally, 17 test pits were excavated along the southwest lower yard property boundary to depths between 7.5 and 10 feet bgs. Test pits TP-4 through TP-9 were located approximately 150 feet upgradient of the Port's sampling location P-1. Soil samples collected from the saturated zone in TP-4 through TP-9 contained a maximum of 811 and 1,180 (estimated) mg/kg DRO and HO, respectively. TP-18 and TP-19 contained 13,600 and 12,300 mg/kg DRO, respectively; however, these test pits were located more than 350 feet southeast of P-1, whose location was not hydraulically downgradient of these test pit locations.

Groundwater data collected from the Admiral Way borings, the 17 test pits excavated in the southwest lower yard, and from monitoring wells MW-106, MW-28, MW-107 and MW-137, do not suggest the off-site migration of free-phase petroleum to the Port property (Figures 5-4, 5-5, 5-6, and 5-11). The historical and SRI groundwater and soil data continue to indicate that the Port contamination derived from a separate source.

6.2 Soil

As reported in the preceding sections, additional soil data were collected during the SRI and also during the 2001 Interim Action performed in the lower yard. These soil data were added to the site database and are included in the following drawings. Drawings 2, 3, 4 and 5 display all RI, SRI, and Interim Action soil data collected from 0 to 6 feet bgs, except that data from sampling locations that were excavated during the 2001 Interim Action are not displayed (as the associated soil has been removed). The 2001 excavation areas are shown on the drawings. TPH in the gasoline, diesel, and heavy oil ranges is displayed on Drawings 2, 3 and 4, respectively. Drawing 5 shows the "total TPH" concentrations (i.e., the sum of TPH concentrations in the gasoline, diesel and heavy oil ranges) detected at each sampling location.

The 0- to 6-foot depth interval reflects soil samples collected in the vadose (unsaturated soil) zone. Soil data collected deeper than 6 feet bgs were tabulated and are provided in Table 6-1. This table excludes data from sampling locations that were excavated during the 2001 Interim Action. Due to the limited number of these saturated soil samples and limited TPH detections in these samples, the data were not displayed in a figure. As shown in Table 6-1, significant concentrations of TPH were detected at depths greater than 6 feet bgs only at location MW-110 (located mid-lower yard) and in the area of SB-180 and SB-181 (located in the eastern part of the lower yard) (Drawing 1).

Concentration contours were prepared using the summed TPH concentrations at each sampling location. Concentration contours for the 0- to 6-foot depth interval are shown on Drawing 6. Contours were estimated using sampling point concentrations,

surrounding sampling point concentrations, site features, assumptions on TPH distribution based on the data and historical site activities, and site reconnaissance. Drawing 7 displays the same information as Drawing 6; however, the areal extent of soil containing TPH above 1,000, 10,000 and 100,000 mg/kg is highlighted on Drawing 7. The drawings will be used to develop cleanup alternatives in the feasibility study.

The highest concentrations of TPH are found in the far eastern corner of the lower yard, in Detention Basin No. 1, and in the central portion of the lower yard.

6.3 Groundwater

6.3.1 Groundwater Quality, Site-wide Aquifer

TPH results from the site-wide monitoring event performed in June 2001 were compared with the May 1996 site-wide monitoring event performed during the RI. The groundwater concentration contours prepared during the RI are reproduced in this SRI report as Figures 6-1, 6-2, and 6-3, for TPH in the gasoline, diesel and oil ranges, respectively.

GRO distributions in groundwater do not appear to have changed appreciably between May 1996 and June 2001 (Figure 6-1 and 5-6); i.e., GRO was not found in concentrations greater than 1 mg/L beyond the property boundary in 1996 or in 2001. The distribution of DRO and HO also appears consistent, with the exception of the eastern site perimeter where DRO and HO were detected in concentrations greater than 1 mg/L in 1996 (MW-135 and MW-136) but not in 2001 (Figures 6-2, 6-3, 5-7, and 5-8). The 1996 results may reflect analytical interference caused by natural organics in groundwater at these locations. Today's laboratory methods reduce the amount of "biogenic interference" caused by naturally occurring organics. Samples collected from these wells in 1998 through 2002 contained significantly lower DRO and HO concentrations than those observed in 1996 (Figure 5-5).

An estimated 9,500 gallons of floating (free) petroleum product were recovered from beneath the lower yard between 1988 and 2001 (MFA, 2001a). During the 2001 Interim Action performed in the lower yard, an additional estimated 2,500 gallons of petroleum product were removed (MFA, 2002). Thus, TPH concentrations in groundwater beneath the site have been reduced significantly over these years. TPH concentrations along the site perimeter remain consistently low, typically non-detectable or at concentrations less than 1 mg/L.

GRO, benzene, DRO, HO and PAHs were not detected in samples collected from any of the upper yard monitoring wells during the SRI. Arsenic, copper, lead and zinc were detected in samples collected from each of the upper yard monitoring wells, including

background monitoring well MW-7U. Metals concentrations were consistent with those detected during the RI.

6.3.2 MW-136

Prior to the SRI, Ecology requested that an additional monitoring well(s) be installed along the eastern boundary of the Terminal near MW-136 (Figure 4-2), based on its proximity to Willow Creek and the TPH concentrations measured in this well during the RI. Based on field observations, MW-136 lies at the eastern edge of a lobe of fill, next to the southern edge of the marsh. This is the closest possible well placement to the marsh and Willow Creek. The well is located approximately 15 feet from the organic-rich marsh.

Following a March 2001 discussion of the MW-136 location by Ecology and representatives of the Edmonds Citizens' Awareness Committee (ECAC), Unocal collected additional groundwater samples from monitoring wells MW-203 and MW-134 located west and southwest of MW-136, respectively (Drawing 1). This was done in response to a concern expressed by ECAC that petroleum hydrocarbon detections in well MW-136 may originate from the upper yard. The additional groundwater data augmented those collected during the RI and SRI monitoring events. Laboratory results for the March 2001 samples collected at MW-203 and MW-134 showed no detections above MRLs for GRO, DRO, HO, BTEX, or PAHs. Including the March 2001 results, GRO has been detected above the MRL in MW-203 in 0 of 7 sampling events (RI, post-RI, and SRI, 1995 to 2002); DRO in 1 of 7 sampling events (0.72 mg/L in 1996); and HO in 0 of 7 sampling events. Including the March 2001 results, GRO has been detected in MW-134 in 0 of 7 sampling events; DRO in 1 of 7 sampling events (at 0.40 mg/L in 1996); and HO in 0 of 7 sampling events.

Based on groundwater data collected since the RI, additional wells in this area were not proposed. However, well MW-134x was installed, in order to monitor the site-wide aquifer in this area. The well was screened from approximately 34 to 44 feet bgs, about 15 feet deeper than the screen for well MW-134, which was screened in a perched zone. GRO, BTEX, DRO, and HO were not detected in soil samples collected from boring MW-134x. One PAH (2-methylnaphthalene) was detected, at 0.0181 and 0.0202 mg/kg.

Groundwater samples were collected from MW-134x in February and May 2002; no GRO, BTEX, or PAHs were detected. No DRO or HO were detected in the February 2002 groundwater samples, but were detected at 0.311 and 2.00 mg/L, respectively, in samples collected in May 2002.

As previously reported (EMCON, 1998; MFA, 2001a), the lobe of fill in the eastern part of the Terminal is impacted with TPH. DRO was detected in soil boring SB-178, located about 40 feet west of MW-136, at 15,000 mg/kg. HO and GRO were detected at 7,100

and an estimated 2,600 mg/kg, respectively (Drawings 2 through 7). This impacted soil may be causing or contributing to the sporadic TPH detections in groundwater at MW-136.

Based on the TPH concentrations in soil near MW-136, results of the soil samples collected from boring MW-134x, and groundwater data collected from MW-134, MW-134x, and MW-203, continued groundwater monitoring in the existing wells (rather than installation of additional wells) is appropriate.

6.4 Surface Water

As with the 1996 RI results, no GRO, DRO, HO, or BTEX constituents were detected in the surface water samples collected from Willow Creek during the SRI. The only detected analytes were in the water sample collected from Detention Basin No. 1 (SW-5), where DRO was detected at an estimated concentration of 350 µg/L. The Willow Creek sample results and perimeter-well groundwater monitoring results continue to indicate that the off-site movement of TPH is limited.

Site hydrogeology, the termination of site operations, chemical and product characteristics, product recovery operations, and the removal of product-saturated soil from four former plume areas, have combined to limit the rate at which chemicals have migrated within the Terminal boundaries and to the surrounded vicinity.

LIMITATIONS

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of segregated portions of this report.

The purpose of an environmental assessment is to reasonably evaluate the potential for or actual impact of past practices on a given site area. In performing an environmental assessment, it is understood that a balance must be struck between a reasonable inquiry into the environmental issues and an exhaustive analysis of each conceivable issue of potential concern. The following paragraphs discuss the assumptions and parameters under which such an opinion is rendered.

No investigation is thorough enough to exclude the presence of hazardous materials at a given site. If hazardous conditions have not been identified during the assessment, such a finding should not, therefore, be construed as a guarantee of the absence of such materials on the site, but rather as the result of the services performed within the scope, limitations, and cost of the work performed.

Environmental conditions that cannot be identified by visual observation may exist at the site. Where subsurface work was performed, our professional opinions are based in part on interpretation of data from discrete sampling locations that may not represent actual conditions at unsampled locations.

Except where there is express concern of our client, or where specific environmental contaminants have been previously reported by others, naturally occurring toxic substances, potential environmental contaminates inside buildings, or contaminate concentrations that are not of current environmental concern may not be reflected in this document.

The purpose of a geology/hydrogeology study is to reasonably characterize existing site conditions based on the geology/hydrogeology of the area. In performing such a study, it is understood that a balance must be struck between a reasonable inquiry into the site conditions and an exhaustive analysis of each conceivable environmental characteristic. The following paragraphs discuss the assumptions and parameters under which such an opinion is rendered.

No investigation is thorough enough to describe all geologic/hydrogeologic conditions of interest at a given site. If conditions have not been identified during the study, such a finding should not, therefore, be construed as a guarantee of the absence of such conditions at the site, but rather as the result of the services performed within the scope, limitations, and cost of the work performed.

We are unable to report on or accurately predict events that may change the site conditions after the described services are performed, whether they occur naturally or are caused by external forces. We assume no responsibility for conditions we were not authorized to evaluate, or conditions not generally recognized as predictable when services were performed.

Geologic/hydrogeologic conditions that cannot be identified solely by visual observation may exist at the site. Where subsurface exploratory work was performed, our professional opinions are based in part on interpretation of data from discrete sampling locations. These data may not represent actual conditions at unsampled locations.

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SRI WORK PLAN SECTION 4