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PHASE I REMEDIAL INVESTIGATION SUMMARY REPORT AND PRELIMINARY ANALYSIS OF SOIL DATA
(As Appendix 1)

Volume 1

Northwest Natural - Gasco Facility
7900 NW St. Helens Road
Portland, Oregon

October 9, 1998

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1. PURPOSE

The purpose of this report is to provide a summary and analysis of existing data collected as part of Phase I Remedial Investigation (RI) activities at the Gasco site to assist in the understanding of the site, and to guide decisions regarding additional data acquisition.

As the overall goals of RI activities are to characterize site conditions, provide for an evaluation of the risks to human health and the environment posed by the site, and to provide the basis for the identification and implementation of appropriate remedial actions based on those risks, the following investigatory objectives exist:

- To confirm the contaminants of concern at the site
- To determine the affected media at the site
- To characterize the nature and extent of the contaminants of concern in the affected media at the site
- To identify and characterize migration pathways for contaminants of concern
- To assess the risks to human health and the environment posed by the presence of contaminants of concern in the affected media
- To obtain information that can be utilized in a feasibility study to select appropriate remedial actions(s).

2. SITE DESCRIPTION

The Gasco site comprises approximately 47 acres in the North Doane Lake area of Portland and is bounded by St. Helens Road to the southwest, the Willamette River to the northeast, and industrial properties to the northwest and southeast (Figures 1 and 2). The ground surface at the site slopes gradually northeastward towards the Willamette River with surface elevations ranging from approximately 38 feet above mean sea level (msl-City of Portland datum) at the southwestern portion of the property to approximately 23 to 30 feet msl at the top of the river bank. The river bank, composed primarily of rip rap, slopes steeply to an elevation of approximately 5 to 8 feet msl, below which exists the shoreline with a more gradual slope. Average monthly river stages, as measured at the Portland Harbor from 1973 to 1990 and converted to the City of Portland datum, range from a low of approximately 6.3 feet msl during August and September, to a high of 10.9 feet msl during May and June (COE, 1991).

The Gasco site was the former location of the Portland Gas and Coke Company manufactured gas plant oil gasification facility from 1913 to 1956. Manufacturing processes at the site have involved the generation of town gas and pressed lampblack briquettes, aromatic generation and light oil recovery, tar recovery and refining, and the production of electrode grade coke and high Btu gas (Camp Dresser & McKee, Inc., 1987). Northwest Natural began construction of the liquefied natural gas (LNG) plant at the site in the late 1960's, at which time a majority of the old gasification plant facilities were demolished.

With regard to other uses of the property, Koppers operated a coal tar pitch manufacturing facility at the southern portion of the former gasification facility from 1966 to 1973. Koppers currently uses the facility as a terminal for the distribution of creosote oils.

Pacific Northern Oil (PNO) has operated a fuel storage and distribution facility at the northern portion of the site from the 1960's to the present.

The locations of former structures and features associated with the former manufactured gas plant, as well as current structures associated with the Northwest Natural, Koppers and PNO facilities, are shown on Figure 3.

3. EXISTING DATA AND DOCUMENTS

Northwest Natural and the Oregon Department of Environmental Quality (DEQ) entered into an Agreement for the completion of a Remedial Investigation/Feasibility Study (DEQ Agreement No. ECVC-WMCVC-NWR-94-13) for the Gasco site in 1994. RI activities were subsequently implemented by Northwest Natural at the Gasco site in September 1995, with investigatory activities being implemented by Hahn and Associates, Inc. (HAI) as provided within the approved RI Work Plan (HAI, 1995). RI activities conducted at the site to date are briefly summarized below.

3.1 Scope

The scope of work for the Phase I RI activities performed by Northwest Natural from September 1995 to the present include the following tasks (see Figure 4, Sample Location Map):

- Installation of 54 soil borings and well borings (B, G, GT, and MW-series), with the collection and analysis of soil samples
- Collection and analysis of groundwater samples from 7 temporary well point installations
- Installation of 18 groundwater monitoring wells with 8 rounds of sampling from the wells
- Twelve monthly groundwater level monitoring events and 7 subsequent quarterly events
- Installation of 11 vibra cores in the Willamette River with the collection and analysis of sediment samples
- Collection of 5 surface water and sediment samples from on-site ponds and a drainage ditch
- Collection of air and dust samples
- One 48-hour water level monitoring test
- Monitoring well slug test data collection and analysis
- Surface geophysical survey in area of former Tar Ponds with ground penetrating radar, magnetic, and electromagnetic methods

3.2 Previous Document Submittals

Results of Phase I RI activities at the Gasco site have been documented in numerous reports. The documents that provide the most comprehensive synthesis of available site data and data interpretation concerning RI investigatory results are as follows:

- Hahn and Associates, Inc., *Data Package for Remedial Investigation / Feasibility Study, Northwest Natural Gas Company, Gasco Facility,* July 22, 1996
- Hahn and Associates, Inc., *Geological and Hydrogeological Framework, Northwest Natural Gas Company, Gasco Facility,* May 13, 1997
- Hahn and Associates, Inc., *Monitoring Well Abandonment and Installation Activities, Northwest Natural Gas Company, Gasco Facility,* February 19, 1998

- Hahn and Associates, Inc., *Fourth Quarter 1997 Progress Report for Remedial Investigation / Feasibility Study Activities, Northwest Natural Gas Company, Gasco Facility,* February 23, 1998

- Hahn and Associates, Inc., *Second Quarter 1998 Progress Report for Remedial Investigation / Feasibility Study Activities, Northwest Natural Gas Company, Gasco Facility,* April 24, 1998

In addition to the above reports documenting Phase I RI results, the following are the primary documents that have been prepared to date in support of Risk Assessment activities for the Gasco site:

- Stoel Rives LLP, *Current and Reasonably Anticipated Future Land and Beneficial Water Uses in the Locality of the Facility, Northwest Natural Gas Gasco Facility,* April 1997

- Decision Management Associates and Montgomery Watson, *Data Summary and Exposure Pathway Analysis Technical Memorandum, Gasco Risk Assessment,* May 15, 1997

- Decision Management Associates and Montgomery Watson, *Comparison Between McCormick and Baxter Site and Gasco Site Technical Memorandum, Gasco Risk Assessment,* June 11, 1997

- Decision Management Associates and Montgomery Watson, *Exposure Assessment, Gasco Risk Assessment,* July 2, 1997

- Hahn and Associates, Inc., *Locality of Facility, Northwest Natural Gas Company, Gasco Facility,* August 1, 1997 (A Beneficial Use determination support document)

- Decision Management Associates and Montgomery Watson, *Toxicity Assessment, Gasco Risk Assessment,* December 16, 1997

3.3 Summary of Available Data

A general description of available RI data for the Gasco site, including identification of where this data may be found, is provided in the following Sections.

3.3.1 Soil Data

The majority of soil quality and lithologic data for the Site were collected from September 1995 to January 1996 during which time soil borings B-1 through B-35, MW-1 through MW-12, and M-11 were installed. More recently, soil quality data, geotechnical soil borings G-

1 and G-2 were installed by GeoEngineers, Inc. within the Koppers lease area in April 1997, geotechnical soil borings GT-1 through GT-4 were installed by GeoEngineers, Inc. within the PNO tank farm area in November 1997, and well boring MW-13 was installed down-gradient of MW-6 (PNO lease area) in December 1997.

For reference herein, a figure depicting all soil boring locations, as well as a summary of available soil quality data collected at the site to date, are included within Appendix G, and soil boring logs depicting lithologic and contaminant conditions at each boring location are provided within Appendices A (soil borings) and B (monitoring well borings).

3.3.2 Willamette River Sediment Data

Fourteen sediment core samples (SD-1 through SD-14) were collected by Northwest Natural from the Willamette River adjacent to, and up-stream of, the Gasco site in January 1996. With regard to additional sediment quality investigatory activities conducted in the vicinity of the site, The U.S. Environmental Protection Agency (EPA) conducted a Site Inspection (SI) of a six-mile reach of the Willamette River in September and October 1997, including the collection of sediment samples adjacent to the Gasco site (Weston, 1998). Also, several sediment studies involving the vicinity of the Gasco site have been undertaken by the U.S. Army Corps of Engineers (COE). Specifically, in 1989 and 1994 the COE conducted sediment studies within the dock area at the U.S. Moorings Station, located adjacent to, and down-river of, the Gasco site (Britton, 1990; Siipola and Britton 1994). Finally, in July 1997, the COE completed sediment sampling activities as part of their overall dredging material evaluation program, that included the collection of sediment samples within the Willamette River, including one adjacent to the Gasco site.

Sediment core logs from investigatory activities conducted by Northwest Natural depicting lithologic and contaminant conditions at each core location are provided within Appendix C. Figures depicting sediment sample locations, as well as a summary of available sediment data collected adjacent to the site to date (Northwest Natural, EPA, and U.S. Army Corps data), are included within Appendix J.

3.3.3 Groundwater Quality and Flow Direction Data

Groundwater quality data at the Gasco site has been collected from 7 temporary well points installed in 1995, as well as from 18 permanent monitoring wells that were installed in 1995 and 1998. Well MW-6-61 was decommissioned by removal in 1997. Eight groundwater quality monitoring events have been conducted at the Gasco site to data from the existing monitoring well network. Static groundwater level measurements from the monitoring well network were collected monthly during 1996, and have been collected on a quarterly frequency since that time.

For reference herein, a figure depicting all temporary well point and monitoring well locations, as well as a summary of available groundwater quality data collected at the site to date, including posting maps and time-concentration plots, are included within

Appendix H. Groundwater elevation data, hydrographs, and groundwater flow direction maps and hydrographs may be found within Appendix E. Monitoring well construction logs are provided in Appendix B.

3.3.4 On-Site Surface Water and Sediment Data

On-site surface water and sediment sampling activities were conducted at the Gasco site on January 30, 1996. These activities involved the collection of surface water samples at two locations within the on-site drainage ditch, as well as within each of the three on-site ponds. Additionally, a shallow sediment sample was collected from each of the three on-site ponds. A figure depicting sample locations, and tables summarizing the results of these activities, are included within Appendix I.

3.3.5 Air Quality Data

Sampling for airborne contaminants at the Gasco site has been conducted for chemical exposure monitoring during implementation of the early stages of RI investigatory activities (1995), as well as for ambient air quality monitoring (1996). All monitoring activities were conducted by Paul Carlson Associates, Inc. (PCA), a firm specializing in industrial hygiene issues and air monitoring.

In addition to the above described air monitoring activities, two samples of accumulated dust were collected from the site. A figure depicting air and dust sampling locations, and results of all air monitoring activities, are provided within Appendix K.

3.3.6 Geophysical Data

On November 22, 1995, a preliminary survey with ground penetrating radar (GPR), electromagnetic (EM), and magnetic geophysical methods was conducted in the vicinity of the former Settling Ponds / South Fill Area by GeoPotential of Gresham, Oregon. Three profiles were completed in an attempt to identify and map fill zones, tar zones, and lithologic changes. The results of this survey are included within Appendix L.

3.3.7 Aquifer Testing Data

In order to estimate hydraulic properties of the shallow and intermediate-depth water bearing zones at the Gasco site, rising head slug tests were conducted at a majority of the site wells in March 1996. The raw data summary of results of these testing activities was provided within RI Data Package Report (HAI, 1996). A summary of aquifer slug testing results is included within Appendix E (Table E-2).

4. SITE GEOLOGY

The geologic units of interest at the subject site can be subdivided as follows, from youngest to oldest:

- Surficial Fill Deposits
- Alluvial Deposits

  Willamette River Deposits
  Catastrophic Flood Deposits
- Columbia River Basalt Group

4.1 Columbia River Basalt Group

The oldest and lowermost geologic unit of interest at the site consists of the Columbia River Basalt Group. The Miocene-age Columbia River Basalt Group, composed of a series of individual lava flows, generally forms the base (bedrock) of the Portland Basin and outcrops immediately to the southwest of the Site in the Tualatin Mountains.

A bedrock surface elevation map, utilizing RI data as well as data obtained from historical boring logs from 19 geotechnical soil borings that were installed at the site in 1915 during the early stages of development activities, is included as Figure 5. As depicted on Figure 5, from the Tualatin Mountain outcropping, the basalt surface dips steeply to the northeast, with the top of the basalt lying at an elevation near mean sea level [a depth of approximately 36 feet below ground surface (bgs)] in the southern corner of the site (as observed at the MW-12-36 well location), to elevations deeper than -133 feet msl adjacent to the Willamette River (as observed at boring H-4). Based on the predicted slope of the bedrock surface as interpreted with available data, bedrock is likely the deepest beneath the eastern portion of the site, where based on the observed slope in bedrock surface, it is estimated that the bedrock surface could occur at an elevation deeper than -230 feet msl.

4.2 Alluvial Deposits

Overlying the eroded basalt surface at the site are Quaternary-Age alluvial deposits, composed of unconsolidated sands and silts, that range in thickness from approximately 30 feet near St. Helens Road, to an estimated thickness of greater than 200 feet adjacent to the Willamette River. These alluvial deposits have been differentiated by Geraghty & Miller (1991), into the Catastrophic Flood Deposits and Willamette River Deposits. Since these two units may be difficult to differentiate in places, the conceptual site model groups the two units together and refers to them as undifferentiated Alluvial Deposits. The uppermost unit of the undifferentiated Alluvial Deposits in the vicinity of the site has been identified as a clayey silt by Camp Dresser (1987), while Geraghty & Miller (1991) identified both silt and clay facies associated with the upper zone of the Alluvial Deposits.

Borings installed by HAI at the Gasco site encountered a laterally extensive silt unit, with typically little to no clay content, at the upper portion of the undifferentiated Alluvial Deposits. This silt unit exhibits coloration ranging from olive gray to green, with some areas of orangish-brown mottling. Small sand lenses and rootlet zones are present within portions of the silt unit. Fine to medium-grained sands, silty sands, and relatively thin interbedded silts were encountered below the silt unit at intermediate depths within the undifferentiated Alluvial Deposits.

As depicted in Figure 6, the top of the silt unit was encountered at elevations ranging from 20 to 35 feet msl at the southwestern portion of the site, sloping to the northeast towards the Willamette River where it was encountered at elevations of approximately 5 to 10 feet msl. In general, the top of the silt unit appears to slope more steeply beneath the southwestern portion of the Site at the area of the former Light Oil Plant, Pitch Plant, and Tar Processing Area, with the slope becoming more gradual and even reversing slightly, beneath the central and northeastern portions of the site.

As depicted on Figure 6, the existence of a northwest-southeast trending depression in the top of the silt unit is apparent across the central portion of the site. Two low spots within this depression were identified at locations corresponding to wells MW-6 and MW-11, both locations where dense non-aqueous phase liquids (DNAPLs) have been detected. The depression appears to be oriented roughly parallel to the location of a former creek bed, thought to be a former drainage feature associated with Doane Lake, remnants of which are located to the southeast of the Gasco site (Cameron, 1995). The location of the former creek was identified on a detailed elevation survey map for the Gasco site that was prepared in 1906. The location of the former creek, as surveyed in 1906, is depicted on Figure 6. Of additional note concerning the 1906 survey, it is found that, in general, the pre-fill ground surface elevations at the Gasco site roughly correspond with the elevation of the top of the silt unit at the site, thereby supporting the hypothesis that the silt unit does adequately define the top of the Alluvial Deposits / base of the Surficial Fill Deposits across the site.

With regard to the thickness of the silt unit, based on boring log data and depicted on Figure 7, the thickness of the silt unit is greatest in the central-southeast portion of the site, where thicknesses of up to 35 feet have been identified (boring MW-11). The silt unit appears to thin in all directions from this area of the site, with observed thicknesses of 4.5 (B-14), 6.0 (MW-5), and 2.5 (B-3 and B-8) feet. Although the silt unit appears to be laterally continuous across a majority of the site, because sands and silty sands were encountered across the anticipated depth of the silt unit at borings B-9 (drilled to a depth of -3.4 feet msl), GT-1 (drilled to a depth of –16.9 feet msl) and GT-4 (drilled to a depth of –31.8 feet msl), it appears that a thin silt unit was either missed at these locations as an artifact of the selected soil sampling interval, or that the silt unit may be locally absent at these locations.

4.3 Surficial Fill Deposits

A review of the site history and historical aerial photographs indicates that much of the property, especially to the northeast adjacent to the river, has been extensively filled-in through time. In addition to the overall build-up of ground surface elevations, these filling activities have resulted in the removal of two site drainage features, the creek discussed in Section 4.2, and a drainage ditch formerly located southeast of the southern PNO tank farm, where surface water run-off and manufactured gas plant waste-products were apparently formerly discharged to the Willamette River. Based on review of historical aerial photographs of the site, it appears that this ditch was filled in some time between 1941 and 1961. The axis of this former drainage feature is shown on Figure 3.

Based on results of site investigatory activities, the surficial fill zone was found to overlay the alluvial silt unit with variations in thickness ranging from approximately 2 feet along the southwestern portion of the site near the former Light Oil Plant, to a maximum of 30 feet in the central portion of the site. Much of the fill encountered at the site consisted of poorly graded sands and silty sands that apparently consist of hydraulically placed river-dredge material. However, lampblack, spent oxide materials, quarry reject rock, building debris, and solidified tars were also encountered within the surficial fill unit at the site, especially within the area of the former Tar Ponds and the former Spent Oxide Storage area.

5. SITE HYDROGEOLOGY

Groundwater occurs in three principal hydrologic zones at the site including the unconfined Surficial Fill water-bearing zone (WBZ), the semi-confined Alluvial Sand WBZ, and the confined bedrock aquifers in the Columbia River Basalts. A laterally extensive low permeability silt unit separates the Surficial Fill WBZ from the Alluvial Sand WBZ across a majority of the site.

With respect to the overall regional groundwater flow regime in the vicinity of the Gasco site, it is anticipated that the Tualatin Mountains form a regional groundwater recharge boundary to the southwest of the site, while the Willamette River likely forms a regional groundwater discharge boundary to the northeast, acting as a hydraulic barrier to groundwater flow to the opposite side of the river.

A generalized hydrologic cross-section, depicting the conceptualized groundwater flow regime beneath the site, is provided as Figure 8. General descriptions of each of the three principal hydrologic zones beneath the site are provided below.

5.1 Surficial Fill Water-Bearing Zone

The water table, generally found to be perched within the Surficial Fill WBZ, above the upper alluvial silt unit, has been identified at depths that fluctuate seasonally from 3 to 12 feet bgs (34 to 25 feet msl) at the southwestern portion of the site (well MW-9), and from 9 to 27 feet bgs (25 to 7 feet msl) at the eastern portion of the site (well MW-4-35). Based on the observed seasonal fluctuations of the water table elevation, the overall saturated thickness of this WBZ may be expected to fluctuate from approximately 3 to 25 feet at the northeastern boundary of the site, located adjacent to the Willamette River. Groundwater elevation data for monitoring wells at the site are provided in Appendix E (Table E-1).

As depicted on groundwater elevation maps generated for the site (Appendix E, Figures E1-E18), the groundwater flow direction within the Surficial Fill WBZ is northeasterly towards the Willamette River, with an overall average hydraulic gradient of approximately 0.017. As measured since December 1995, the observed groundwater flow direction within this WBZ has remained relatively constant through time. The calculated hydraulic gradient within this WBZ has been found to fluctuate from a low of 0.010 in February 1996, to a high of 0.020 in September 1996, and February 1997.

As depicted on water level hydrographs for well pairs installed at the site (Appendix E), a downward vertical hydraulic gradient typically exists between the Surficial Fill WBZ and the Alluvial Sand WBZ. An exception to this overall downward hydraulic gradient was noted at the central portion of the site (MW-8 and MW-10 clusters) during the February 1996 Willamette River flooding event, when an upward gradient existed between these units at these locations. A vertical gradient reversal was also noted at the MW-10 location in February and June 1997, as well as in June 1998. These gradient reversals appear to result from rapid increases in river stage, with the Alluvial Sand WBZ directly responding to increases in river stage, while responses in the Surficial Fill WBZ occur more slowly and are less pronounced with increased distance from the river.

Based on slug testing that was conducted by HAI in March 1996, an overall average hydraulic conductivity of 3.9 feet per day (ft/day) was calculated for the fill WBZ, with the lowest calculated hydraulic conductivity identified at well MW-8-29 (0.0067 ft/day), and the highest calculated hydraulic conductivity identified at well MW-4-35 (26 ft/day) (Table E-2).

Based on the referenced hydraulic conductivities, a calculated average hydraulic gradient of 0.020, and an assumed effective porosity of 0.20, the average groundwater flow velocity within the Surficial Fill WBZ is estimated to be 0.4 ft/day, ranging from an estimated 0.0007 ft/day at the MW-8-26 location, to an estimated 2.6 ft/day at the MW-4-35 well location. Such high variability of calculated flow rates is anticipated within the Surficial Fill WBZ, due to the significant heterogeneities identified within this zone, and the localized area of influence of each slug test.

5.2 Alluvial Sand Water-Bearing Zone

The Alluvial Sand WBZ, encountered below the silt unit at the site, extends to a total depth ranging from approximately 36 feet bgs (0 feet msl) at the southern portion of the site (MW-12-36), to greater than an estimated 265 feet bgs (-230 feet msl) adjacent to the Willamette River. Due to its great apparent thickness, the Alluvial Sand WBZ has been arbitrarily subdivided into intermediate and deep zones. Existing site monitoring wells installed in the Alluvial Sand WBZ are screened within the intermediate zone to depths of 36 to 61 feet bgs (-26 to –20 feet msl), while shallow zone monitoring wells are screened within the Surficial Fill WBZ.

As depicted in groundwater elevation maps generated for the site (Appendix E, Figures E19-E37), the groundwater flow direction within the Alluvial Sand WBZ is northeast towards the Willamette River, with an average hydraulic gradient of 0.016 (as measured between wells MW-10-61 and MW-3-56). As measured since December 1995, the observed groundwater flow direction within this WBZ has remained relatively constant through time. The calculated hydraulic gradient within this WBZ has been found to fluctuate from a low of 0.008 in February 1996, to a high of 0.022 in September 1996.

Based on slug testing that was conducted by HAI in March 1996, an overall average hydraulic conductivity of 0.79 ft/day was calculated for the Alluvial Sand WBZ, with the lowest calculated conductivity identified at well MW-8-56 (0.08 ft/day), and the highest calculated conductivity identified at well MW-6-61 (1.5 ft/day).

Based on the referenced hydraulic conductivities, a calculated average hydraulic gradient of 0.017, and an assumed effective porosity of 0.20, the average groundwater flow velocity within the alluvial WBZ is estimated to be 0.07 ft/day, ranging from an estimated 0.007 ft/day at the MW-8-56 location, to an estimated 0.13 ft/day at the MW-6-61 well location.

5.3 Basalt Unit / Bedrock Aquifer

A boring log for an abandoned bedrock zone industrial water supply well drilled on the southern portion of the Gasco site (exact location unknown) in 1948 indicated competent basalt bedrock to occur from a depth of approximately 61 feet bgs to a depth of 241 feet bgs, below which was an approximate 17 foot thick sand zone (corresponding to the zone of water production) that was underlain by fractured basalt to the total depth of the hole at 370 feet bgs. Notes provided on the boring log for this well indicate that pumping of the well at a rate greater than 140 gallons per minute (gpm) would result in the water level being dropped below the pump.

Boring logs for two 400-foot deep cathodic pipeline protection wells drilled on the southwestern portion of the Gasco site in 1976 and 1985 indicate alternating layers of broken rock with clay layers and competent basalt through the entire drilling interval, with a sandstone, perhaps equivalent to the water producing sand horizon identified within the well log for the supply well, being identified in one of the wells at a depth of 290 to 310 feet bgs. No information on the occurrence of water was provided for either of the cathodic protection wells. As both wells contain sacrificial anodes and bedding material for the corrosion protection of pipelines at the site, information on water within the bedrock is unavailable at these locations. Boring logs for the former water supply well, and the cathodic protection wells, are included within Appendix D.

Based on the site conceptual model, it is anticipated that groundwater within the basalt unit flows to the northeast towards the Willamette River (a regional discharge zone). An upward hydraulic gradient within the basalt aquifer is likely to occur in the vicinity of the Gasco site and Willamette River, potentially resulting in localized discharge from the basalt aquifer unit upwards into the Alluvial Sand WBZ (Figure 8).

With regard to water use within the bedrock aquifer within the vicinity of the Gasco site, a water well survey conducted for Northwest Natural (Stoel Rives, 1997), identified the presence of twelve documented water wells located on the western side of the Willamette River within a one-mile radius of the Gasco site. Of these twelve wells, eleven were identified as providing an industrial water source, and one was identified as providing a domestic/irrigation water source. None of the eleven industrial wells are currently in service, as the owners have all switched to the use of City of Portland water. The domestic well, located significantly upgradient of the Gasco site within the Tualatin Mountains, is currently used. The well survey did not identify the presence of water wells withdrawing groundwater from either the Surficial Fill WBZ or the Alluvial Sand WBZ.

6. NATURE, EXTENT, AND TRANSPORT OF CONTAMINANANTS

Field observations as identified in soil boring logs (Appendices A and B) indicate that residual tar, oil tar, and lampblack are present within soils at the Gasco site. Oil tar and tar are primarily differentiated herein by their physical characteristics, especially color and viscosity. Specifically, when described herein, tar will refer to a black, viscous to semi-solid petroleum hydrocarbon, while oil tar will refer to a brown to black hydrocarbon that is significantly less viscous than the aforementioned tar and is potentially mobile in the subsurface soils. Additionally, the presence of oil tars in soils as referenced herein, refers to product being visible in a soil sample, and may not include soils that show some other evidence of contamination, such as sheen, odor, or elevated headspace. Lampblack is a term referring to a hydrophobic black powder or sandy material, consisting primarily of carbon, that may contain minor concentrations of petroleum hydrocarbons (Gas Research Institute, 1996).

Free product oil tars, herein referred to as free product DNAPL, or just DNAPL, have been identified in three areas of the site. Free product DNAPL is potentially mobile and recoverable product.

The constituents of primary concern in tars and oil tars are the aromatic hydrocarbons benzene, toluene, ethylbenzene and xylene (BTEX) and polynuclear aromatic hydrocarbon (PAH) compounds. Other contaminants of concern at manufactured gas plant sites include cyanide, phenols, and metals. A discussion on the nature and extent of residual product, free product DNAPL, as well as identified soil and groundwater impacts is presented in the following sections.

6.1 Residual Product In Soil

Iso-contour maps depicting the distribution of residual oil tar and tar in soils at the Gasco site have been provided in Appendix F. Specifically, Figures F-1 and F-2 depict the depth to the top and the thickness of residual oil tar as observed at the Gasco site, while Figures F-3 and F-4 depict similar information with regard to the tar. These figures also depict the overall lateral extent of observed residual oil tar and tar within soils, as identified during the soil boring program at the site. Cross-sections provided in Appendix M depict the identified extent of observed oil tar and tar within soil borings installed at the site.

6.1.1 Residual Oil Tar

As depicted on Figures F-1 and F-2, residual oil tar has been identified in soil borings installed throughout the southeasterly and central portion of the site, primarily corresponding to the locations of the former Light Oil Plant, northeastward through the former Tar Ponds, and northwestward through the area of the former Retort Area. Additionally, two apparently small and isolated areas of residual oil contamination have also been identified in borings installed in the vicinity of the former Spent Oxide Storage area (MW-1 and B-1) and the PNO tank farm (GT-1).

With regard to the distribution of residual oil tar within soils across the site, it is apparent that several primary source areas for this product may be identified, including: 1) the former Light Oil Plant; 2) the former Retort Area; and 3) the former Tar Settling Ponds. Residual product found in the former Spent Oxide Storage area (MW-1 and B-1) was likely placed there as contaminated fill, while the minor diesel product found in the PNO tank farm area (GT-1) appears related to PNO tank operations.

6.1.1.1 Former Light Oil Plant / Retort Area

The depth to the surface of residual oil tar product (Figure F-1) at the Gasco site was found to be the shallowest (i.e., less than 5 feet bgs) in the immediate vicinity of the former Light Oil Plant (borings B-19 and B-22). In the vicinity of the former Retort Area, residual oil tar was found at a depth of 7.5 feet bgs at boring B-13. The depth to the top of the residual oil tar was typically found to increase with increasing distance from the former Light Oil Plant and Retort Area, with the residual oil tar surface generally corresponding with the top of the underlying silt unit. Based on the preceding, it appears likely that the former Light Oil Plant and the former Retort Area (including the adjacent railroad siding) are the two primary source areas for the oil tar observed throughout the current Northwest Natural LNG Plant and the Koppers Lease areas, with the oil tar subsequently having migrated from these source areas via gravity along the surface of the northeast sloping silt unit, with a preferential pathway being created due to the permeability contrast between the surficial fill and the underlying silt unit.

With regard to the lateral extent of the oil tar originating from the former Retort Area/Light Oil Plant source areas, it is noted that the northwest-southeast trending depression in the surface of the silt unit (Figure 6), appears to have acted as a barrier to the lateral migration of the mobile oil tar product, generically referred to as DNAPL, to the northeast towards the Willamette River. Lows within this silt unit depression also appear to have acted as preferential areas of DNAPL accumulation. Further discussion of DNAPL is presented in Section 6.2. In addition, the silt unit within the western portion of the Gasco site appears to have acted as a vertical barrier to oil tar product migration, with no oil tar observed below the silt unit in this area.

Evidence to support the above-identified barrier / DNAPL accumulation hypothesis for the depression in the surface of the silt unit is provided by the observed presence of DNAPL within wells MW-6-36 and MW-11-32, located at the overall low points within the depression, and in well MW-10-25, located on the up-dip, source area, side of the depression, while no residual oil tar product or DNAPL has been identified at the B-7, B-10, or MW-13 boring locations, all of which were installed on the opposite side of the depression from the former Retort Area. Although residual oil tar is found on the opposite side of the depression in the southern portion of the site, this is thought to be due to a different source area (see Section 6.1.2).

With regard to the vertical extent of the oil tar product that has apparently been sourced within the Light Oil Plant / former Retort Area, it is noted that a lack of BTEX and PAH detections in groundwater at monitoring well MW-13-61, screened beneath the silt unit downgradient from the apparent product-bearing depression, and a lack of BTEX or significant PAH detections at the MW-10-61 location, installed through the shallow DNAPL and screened below the silt unit at a location down-dip of the suspected source areas, indicates that the silt unit at this portion of the site appears to have acted as an effective barrier to the vertical migration of the DNAPL into the underlying Alluvial Sand WBZ.

In order to verify the lack of DNAPL migration into the Alluvial Sand WBZ at the former Light Oil Plant/Retort source area, a deep Alluvial Sand WBZ well, to be constructed on top of bedrock, has been proposed (HAI, 1998a) for installation in the vicinity of the depression in the silt unit surface, down-dip of the former Light Oil Plant (i.e., near boring B-26).

6.1.1.2 Former Tar Pond Area / B-29 Area

The greatest depth at which residual oil tar in soils has been identified at the Gasco site is in the area of the former Tar Ponds. Specifically, the depth to residual oil tar product at this portion of the site has been found to range from 20 feet bgs (14 feet msl at B-35) to 60 feet bgs (-25 feet msl at B-33). Based on observations made during the installation of borings within the former Tar Pond area, it appears that the observed oil tars have likely been sourced as emulsions or degradation of the thick accumulations of tar that had been disposed of at this portion of the site. Evidence for such a source is provided by boring logs that indicate the presence of viscous or hardened tar being underlain by vertical fingers of less viscous oil tar that were found to have migrated downward through rootlet casts within the underlying silt unit, and in some cases (B-29, B-32, B-33, B-34, and possibly MW-8), having extended into the upper portion of the underlying Alluvial Sand WBZ.

With regard to the vertical extent of the oil tar identified in the vicinity of the former Tar Ponds, it is noted that the depth to the bottom of the oil tar has been defined at virtually all borings installed at the Gasco site. In the Tar Pond area, the deepest that oil tar was found to extend was to a depth of 67 feet bgs (-32 feet msl) at the B-33 boring location.

Although it appears that the vertical extent of oil tar has been identified beneath the Tar Ponds, in order to more completely evaluate the potential that product may have migrated to greater depths in other areas of the former Tar Ponds, and to define the vertical extent of groundwater contamination at the site, the installation of two deep Alluvial Sand WBZ wells at locations down-gradient of the former Tar Ponds has been proposed (HAI, 1998a). Observations of soil and water quality at these locations will assist in determining the magnitude of deep oil tar impacts at, and down-gradient of, the former Tar Pond area.

Laterally, it is noted that oil tar was not found in soil borings located between the former Tar Ponds and the Willamette River (borings B-31, MW-4, and MW-5), however, oil tar was found to occur (below a thick zone of tar) from a depth of 27 to 39 feet bgs (4 to -8 feet msl) at the B-29 boring location, situated adjacent to the river in the area of the former discharge drainage feature. Although tar was identified in other borings (B-9 and MW-3) installed within drainage feature, no oil tar was found to be associated with the tars at these locations. It appears that the tars and oil tars present at B-9, B-29, and MW-3 are the result of placement during the filling of the drainage feature.

With regard to the lateral extent of oil tar to the south of the former Tar Ponds, based on the location of the former Tar Ponds adjacent to the southern property line, and based on knowledge that soils from the Gasco site were used as fill on the property to the south (i.e., Wacker Siltronic, Inc.), the potential exists that tar and associated oil tar impacts could extend to the Wacker Siltronic, Inc. property.

6.1.1.3 Spent Oxide Storage Area and Vicinity

Soil saturated with oil tar was identified in the vicinity of the former Spent Oxide Storage area at the MW-1 and B-1 boring locations in the northwest portion of the site. The zone of product saturation was found to consist of an interval approximately 5 feet thick located immediately above the silt unit at depths ranging from 16 to 22 feet bgs. Boring logs indicate that much debris had been deposited at this portion of the site as fill, including concrete, bricks, lampblack, and spent oxide. As borings B-2, B-3, B-4, B-5, and B-7, all of which did not show indications of soil impacts, are located between the area of observed oil tar and the primary oil tar source area (former Light Oil Plant / Retort Area at the site), it appears that the identified oil tar was likely directly deposited at this portion of the site as a component of the fill, and its presence is not a result of migration from other portions of the site. With regard to the character of the observed product, it is noted that well MW-1 is screened directly across the zone of observed oil tar saturation, and that free product DNAPL has not been found within this well. Based on the preceding, it appears that the observed oil tar at the MW-1 / B-1 portion of the site is likely in the form of residual product as opposed to a potentially mobile DNAPL.

As indicated on the lithological log for boring GT-1, a boring installed within the north end of the southern PNO tank farm, petroleum contamination was found to occur from a depth of 8.5 to 11 feet bgs. This product had a diesel odor uncharacteristic of the oil tar encountered at the site, and was found at a depth that indicated it to be likely floating on the water table. Analysis of a soil sample from the zone of product saturation indicated total petroleum hydrocarbons within the diesel range of 13,400 ppm, with no carcinogenic PAHs identified. The preceding, as well as the location of the product being within the PNO tank farm, an area where petroleum products are actively managed, indicates the source of the diesel is likely related to tank farm operations, and is not due to historic manufactured gas plant activities. Finally, the extent of the apparent diesel product in the subsurface appears to be limited, as no such product was identified at adjacent boring locations B-8 or GT-2.

6.1.2 Tar

In addition to tar distillates (oil tar), an extremely viscous / semi-solid, black tar was identified during the investigation in a number of soil borings at the site. Specifically, as depicted on Figures F-3 and F-4, the tar has been identified in soil borings installed throughout the eastern portion of the site corresponding to the location of the Former Tar Ponds and the former drainage feature. Additionally, isolated areas of tar were identified at the location of the former Naphthalene Plant (MW-10), and in the PNO Lease Area at B-6.

Based on tar thicknesses and depths at the site, it appears that the main source area for the observed tars is the former Tar Settling Ponds, where, according to Camp Dresser & McKee (1987), approximately 4,600,000 gallons, or 23,000 cubic yards (dry content) of tar were discharged. At the former Tar Pond area, tar and tar mixed with lampblack were placed (filled) to depths of approximately 25 feet bgs. Directly beneath the tar ponds, tar has migrated vertically into the underlying silt unit, likely due to the mass and weight of the overlying tar. At one location (B-33), tar was found to extend into the Alluvial Sand WBZ, where the maximum depth of tar observed at the site (60 feet bgs) was encountered. Tarry soils typically were encountered within 5 feet of the ground surface in the eastern portion of the site (Figure F-3).

As evidenced by the tars identified at the MW-3, and B-9 and B-29 locations, it appears that tar may have been discharged to the former drainage ditch, and/or used to fill the ditch feature. As observed on historical aerial photographs, this ditch was located to the southeast of PNO's southern-most tank farm, where it discharged into the Willamette River. Elevated PAH concentrations in river sediments collected in the vicinity of the likely confluence of the former drainage ditch with the river, as discussed in Section 6.6 of this report, tends to support the potential that tarry wastes may have historically been discharged to the river through this former ditch. As no tar was identified within borings GT-3 and GT-4, installed immediately to the northwest of the former ditch and within 50 feet of well MW-3, it appears that the tars are not migrating significantly from their apparent location of deposition within the former ditch feature.

Camp Dresser & McKee (1987) indicated that the drainage feature discussed above likely received the main waste discharges at the site up until 1941, at which time the tar ponds were brought on-line to act as a pollution abatement measure. With regard to the type of wastes discharged, Camp Dresser & McKee indicate that wastes discharged prior to 1925 would be characterized primarily as being wastewaters containing dissolved and suspended hydrocarbons, tar, and spent oxide. After 1925, the amount of tar within the waste stream would have been reduced such that it accounted for only a small amount of tar produced at the site, as tar refining operations were begun that year. Finally, with the start-up of the tar ponds beginning in 1941, the volumes of wastes discharged to the river would have been dramatically reduced at that time.

In summary, boring log data suggests that tars are present within the Fill Unit extending from the location of the former Tar Ponds at the eastern portion of the site, northwestward to the location of the former drainage ditch. Based on the thickness of residual tar in soils identified at the Former Tar Pond and drainage ditch areas, it is estimated that in excess of 250,000 cubic yards of tar and tar mixed with soils may be present in the subsurface at this portion of the site.

Approximately 9.5 feet of tarry soils were identified at the MW-10 location, situated at the area of the former Naphthalene Plant. With greater depth the tar at this location is found to become less viscous and more oil-like (oil tar). Although the oil tar extends throughout much of the former Light Oil Plant northward to the former Retort area (as discussed in Section 6.1.1), the tarry soils appear to be restricted to the general area of the former Naphthalene Plant at this portion of the site.

With regard to the tar identified in boring B-6 located near the former Oxide Building and Oxide Storage Area, because the tar was found mixed with sand and brick fragments and was of very limited vertical extent (up to 2.5 feet), it appears likely that the tar was present in fill placed at this portion of the site, and does not represent a source area of significance.

6.2 Free Product DNAPL

Free product DNAPL has been identified at three locations at the Gasco site, all located within the Surficial Fill WBZ and perched on top of the silt unit. Specifically, up to approximately 8 feet of DNAPL has been identified within the bottom of well MW-6-32, while up to 3.5 feet of DNAPL has been identified at the MW-10-26 location, and up to 2 feet of DNAPL has been identified at the MW-11-32 location. It is noted that the observed DNAPL thickness within the wells is apparent, and due to well hydraulics (i.e., a lower hydrostatic head within the well than in the surrounding formation) and screen placement (i.e., penetration below the surface of the impermeable barrier), DNAPL thickness within the wells may actually overestimate the DNAPL thickness that is present within the formation (Huling and Weaver, 1991). With specific respect to the Gasco site for instance, although up to eight feet of DNAPL has been identified within well MW-6, only 2.5 feet of product saturated soils were identified during well installation, suggesting the preceding conditions may be applicable.

The source for the DNAPL at the MW-6 location is likely the former Retort area, while the source for the DNAPL at the MW-10 and MW-11 locations is likely the former Tar Processing area and/or the former Light Oil Plant area. The location of these wells relative to the predicted source areas, as well as variations in the color and odor of the DNAPL between the MW-6 and MW-10/MW-11 locations supports this hypothesis.

With regard to DNAPL transport, it is likely that the DNAPL migrated downward within the Surficial Fill WBZ at the source areas until encountering the silt unit, at which point the permeability contrast between the fill and the silt unit would have caused the DNAPL to migrate laterally via gravity along the top of the silt unit in a down-dip direction. Lows within the silt unit located along the area of the former creek bed (i.e., the silt unit depression) appear to have acted as preferential areas of DNAPL accumulation, and also appear to have prevented the continued migration of DNAPL towards the eastern portion of the site (as detailed in Section 6.1.1.1).

As no DNAPL has been identified in wells installed to the northeast of the silt unit depression, the presence of free product DNAPL (versus residual product contamination) at this portion of the site has not been verified. As discussed in Section 6.1.1.1, in order to more completely ascertain the potential for the occurrence of free product DNAPL at depth below the former Tar Ponds, the installation of two deep Alluvial Sand WBZ wells at locations down-gradient of the former Tar Ponds has been proposed (HAI, 1998a).

Additionally, with regard to the areas of known DNAPL occurrence (within and to the west of the silt unit depression), a pilot test has been proposed by Northwest Natural (HAI, 1998b) involving the extraction of the DNAPL from the wells in which it has been identified. The objective of the testing is to evaluate the pumpability and recoverability of the free product in order to ascertain the viability of such an action as a potential remedy at the site.

6.3 Soil Quality Impacts

Laboratory analyses of soils at the site (Appendix G), including those that contain the residual petroleum products identified above, indicate that soils at the site have primarily been impacted by PAHs, BTEX constituents, and cyanide. Additionally, as discussed below, an area of slightly elevated arsenic concentrations appears to exist at one portion of the site.

6.3.1 Polynuclear Aromatic Hydrocarbons and BTEX Compounds

In total, 136 soil samples from 48 locations have been analyzed for PAHs, while 58 soil samples at 31 locations have been analyzed for BTEX constituents at the site. Detectable concentrations of total PAHs in soil at Gasco were found to range from less than 0.5 ppm to a maximum concentration 58,822 ppm (B-29 location), while detectable total carcinogenic PAHs in soil were found to range from 0.03 ppm to a maximum concentration of 5,214 ppm (B-29 location). Total BTEX concentrations were found to range from 1.0 ppm to a maximum concentration of 891 ppm (B-18 location), with detectable benzene concentrations ranging from 0.72 ppm to a maximum of 360 ppm (B-18 location). Maximum PAH concentrations tend to be associated with product saturated soils (oil tar and tar) identified in the former Tar Pond portion of the site, while the most significant BTEX contamination tends to be present in both product saturated soils (oil tar and tar) and in soils that bear a petroleum hydrocarbon sheen.

As depicted on the data tables and posting maps provided within Appendix G, the vertical extent of BTEX and PAH contamination within soil at the site has been well defined at most soil boring locations. The most significant impacts are generally restricted to the Surficial Fill Unit, with the exception of the former Tar Pond and drainage ditch areas, where residual tar and oil tar have been found to extend into the silt unit, and in some cases, into the upper Alluvial Sand Unit. At virtually all locations, including the Alluvial Sand Unit, it was found that PAH concentrations declined dramatically just a short distance below zones of observable residual product.

6.3.2 Phenols

In total, 25 soil samples from 20 locations have been analyzed for phenols at the site. Only one soil sample analyzed for phenols resulted in the identification of a phenolic compound. Specifically, pentachlorophenol was identified at the boring B-18 location at a concentration of 0.36 parts per million (ppm), a concentration only slightly above detection limits. The overall lack of phenolic impacts to soil is not unexpected as significant concentrations of phenolic compounds are typically restricted to manufactured gas plant sites that used a coal gasification process, not an oil gasification facility such as Gasco (Gas Research Institute, 1996).

6.3.3 Cyanide

Research conducted at manufactured gas plant sites indicates that cyanides typically exist in complexed forms, with iron complexes dominating (Gas Research Institute, 1996). These cyanide complexes would have been generated during the process of removing sulfur from the product gas, as cyanide within the gas, if any, would also be removed during this process. As oxides were used to remove the sulfur from the gas, the cyanide complexes would be associated with the spent oxide wastes. The iron complexed cyanide (ferrocyanide) within the spent oxide at manufactured gas plant sites may be recognizable by blue staining.

It is of note that the Gas Research Institute (1996) indicates that the most significant quantities of cyanide would be present at coal gasification plant sites, with the least (trace) amounts of cyanide being present at oil gasification sites (e.g., Gasco).

The toxicity of cyanide complexes pertains to the dissociation of free cyanide from the complexed cyanide. The availability of free cyanide is measured by a determination of cyanide that is amenable to chlorination (i.e. amenable cyanide). At the Gasco site, total cyanide data are available for soils, while both total and amenable cyanide data are available for groundwater.

In total, 46 soil samples from 25 locations have been analyzed for cyanide at the site. Detectable concentrations of total cyanide in soil at the Gasco site have been found to range from 0.17 ppm at the B-23 boring location to a maximum of 518 ppm at the MW-9 boring location (a sample of fill material with blue staining). A map depicting available cyanide data for soil at the site is provided in Appendix G (Figure G-4).

The presence of cyanide within soils at numerous locations throughout the site is not unexpected since spent oxide materials were included as fill materials for the site. As the EPA Region 9 Preliminary Remediation Goal (PRG) for free cyanide in industrial soils is 13,628 ppm, and because the free cyanide concentration cannot exceed the total cyanide concentration, it does not appear that the identified cyanide concentrations in soil at the Gasco site pose a significant risk with regard to an Industrial Land Use scenario. The soil to groundwater pathway for cyanide may require additional evaluation should concentrations in groundwater be deemed to pose an unacceptable risk.

6.3.4 Metals

Metals analyses at the Gasco site have primarily been conducted in the area of the former Spent Oxide Storage Area (borings B-1, B-2, and B-3) as the presence of trace metals within the spent oxide materials is deemed likely (Gas Research Institute, 1996). As such, the metals antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc were all analyzed in soil samples collected from the former Spent Oxide Storage area, with five samples being analyzed at this portion of the site. As a follow-up to the preceding, arsenic was analyzed for in soils collected from borings GT-1, GT-2, GT-3, GT-4, and MW-13, with a total of 19 samples being analyzed at these five locations.

With regard to above-identified metals analyses, with the exception of arsenic, sampling at the Gasco site has not identified the presence of metals at concentrations in excess of EPA Region 9 PRGs for industrial soils or DEQ Industrial Maximum Allowable Soil Concentrations. With regard to arsenic, soil samples collected in the area of the former Spent Oxide Storage area (borings B-1, B-2, and B-3) indicated elevated concentrations relative to samples collected from other portions of the PNO Lease Area, with concentrations ranging from 4.9 ppm to 21 ppm being identified. Arsenic concentrations from soil borings installed elsewhere at the site (GT-1 through GT-4, and MW-13) were all found to be less than 3 ppm, which is consistent with typical naturally-occurring background concentrations in the area. Some of the samples collected within these borings did exceed the 2.38 ppm EPA Region 9 PRG for arsenic.

6.3.5 Soil Quality Data Analysis

A detailed presentation and analysis of soil contamination data, prepared by Decision Management Associates LLC, entitled "Preliminary Analysis of Soil Contamination Data, Northwest Natural - Gasco Facility", provided in Appendix 1, includes:

- Evaluation of sampling strategy, duplicate results, and mixes of PAH compounds.
- 3-d scatter plots, histograms, and other plots to help visualize the spatial distribution of contaminants.
- Statistical evidence for and against breaking the site into areas based on surface location and on depth. Several area breakdowns are considered, and depths considered are "surface" (0-0.2 feet), "shallow" (0.2-15 feet), and "deep" (>15 feet).
- Analysis of how concentrations are related to soil odor, sheen, and the presence of residual product (oil tar and tar).
- Analysis of bias in sub surface sampling.
- Evaluation of data gaps and examples of how concentration probability distributions can be constructed from site data for risk analyses.

Conclusions of the above described data analysis are as follows:

- There is substantial small-scale variability superimposed on site-scale trends. The variability is consistent with placement of fill, mixing of soils, and preferential transport of contaminants.
- There appear to be significant differences in concentrations and variability by area and depth. For PAHs, site scale trends include increasing contamination towards the eastern corner of the site, and lower and less variable concentrations at the surface. For benzene, concentrations differ by area and appear consistent with a shallow source spreading down-gradient and deeper.
- The mix of PAHs differs between surface soil and subsurface soil. For surface soils the PAH mix is fairly uniform across the site, while subsurface PAHs show a diversity in mix.
- PAH concentrations are related to soil description (odor, sheen, presence of product). Benzene concentrations tend to be elevated when there is oil or sheen, but the relationship is weaker.
- Surface samples were placed randomly and may be used directly. Sub-surface samples were collected in part based on soil appearance, and are therefore biased. An analysis of the bias indicates that it: 1) increases representation of high-concentration PAH samples by approximately 25%, and 2) has no measurable impact on benzene values.
- Seventeen (17) new soil data samples are identified that would be helpful to improve the completeness and uniformity of samples at the surface and in shallow soil. In particular: 1) 10 approximate locations for the collection of additional surface samples

for PAH analyses have been identified, primarily within the PNO and office areas; and 2) 7 approximate locations for the collection of shallow soil samples for PAH and benzene analyses have been identified.

- Constructing concentration/probability distributions requires agreement in selection of approach and in implementation. Examples are provided for three methods (smoothing of empirical data, fitting and use of family of parametric distributions, and manual piece-wise construction of a distribution.). Other data needs may become apparent with construction of the 8 concentration/probability distributions that are needed for assessing risk.

6.4 Groundwater Impacts

Eight rounds of groundwater monitoring events have been conducted since the initiation of RI activities at the Gasco site. The groundwater monitoring network currently consists of 17 monitoring wells, of which, 12 are screened within the Surficial Fill WBZ (shallow zone), and 5 are screened within the intermediate-depth zone of the Alluvial Sand WBZ. Groundwater quality data collected at the Gasco site to date (Appendix H) indicates that groundwater within the Surficial Fill WBZ and the Alluvial Sand WBZ has primarily been impacted by PAHs, BTEX compounds, and cyanide. Additionally, areas of slightly elevated concentrations of metals have been identified at several monitoring well locations. No halogenated volatile organic compounds (HVOCs) have been identified in groundwater at the site, other than 2.2 ppb of tetrachloroethene detected at well MW-11-32 in March 1996. Only low concentrations of phenols have been detected in the groundwater at the site, generally being restricted to those well locations where groundwater is found to have the highest PAH concentrations. Finally, styrene was identified at a low concentration in groundwater within the Surficial Fill WBZ at the MW-12 location.

Reference levels utilized as a screening tool to evaluate the presence of contaminant concentrations in groundwater that would merit additional evaluation in a risk assessment, include the following:

- EPA Maximum Contaminant Levels (MCLs) established for drinking water
- EPA Region 9 Preliminary Remediation Goals (PRGs) established for tap water
- Ambient Water Quality Criteria (AWQC) established under the Federal Clean Water Act, and adopted by DEQ for the protection of aquatic life in surface water.

Although significant dilution will occur upon discharge to the Willamette River, the AWQC were included herein as a screen for identifying contaminants of concern within groundwater since contaminated groundwater at the site ultimately discharges to the river, where AWQC may be applicable. Once groundwater flux to the river is evaluated, an appropriate dilution factor will be applied to the identified groundwater concentrations to ascertain which contaminants may actually represent constituents of concern at the site.

Understanding that the current and likely future beneficial uses of the Willamette River are recreational, aquatic habitat, and aesthetic, the specific AWQC utilized as a screen herein were as follows: 1) For protection of aquatic life - freshwater acute criteria and freshwater chronic criteria, and 2) for protection of human health - fish consumption criteria were used. In utilizing the AWQC as a screen for groundwater quality, the specific AWQC guidance value with the lowest concentration was utilized. To reemphasize, due to the dilution that occurs when groundwater discharges to the Willamette River, the use of AWQC for screening groundwater contaminant concentrations is very conservative.

6.4.1 Polynuclear Aromatic Hydrocarbons

Maps depicting contoured total PAH concentrations within the Surficial Fill WBZ, as well as in the Alluvial Sand WBZ, during June 1998 are provided in Appendix H (Figures H-2 and H-3).

As sampled in June 1998, the maximum concentration of total PAHs in groundwater at the site was 32,376 parts per billion (ppb), as identified in Surficial Fill WBZ well MW-11-32. Well MW-11-32 contains several feet of free product DNAPL, is located down-gradient of the former Light Oil Plant, and is immediately up-gradient of the former Tar Ponds. Surficial Fill WBZ wells MW-6-32 (down-gradient of the former Retort Area) and MW-10-25 (down-gradient of the former Light Oil Plant and Tar Processing area at the location of the former Naphthalene Plant), also contain DNAPL, with total PAH concentrations in groundwater of 2,245 ppb and 12,162 ppb, respectively, as identified during the June 1998 sampling event.

In addition to the preceding, total PAH concentrations of 12,407 ppb and 17,720 ppb were identified in Surficial Fill WBZ well MW-8-29 and Alluvial Sand WBZ well MW-8-56, respectively, a well pair that has been constructed within the area of the former Tar Ponds. Down-gradient of the former Tar Ponds, at locations adjacent to the Willamette River, total PAH concentrations were found to range from 44 ppb and 95 ppb in Surficial Fill WBZ wells MW-4-35 and MW-5-32, respectively, to 2,299 ppb in Alluvial Sand WBZ well MW-4-57.

Elsewhere at the Gasco site, total PAH concentrations in groundwater typically range from non-detect (wells MW-9-29 and MW-13-61) to less than 1,200 ppb (MW-13-29).

As indicated on the total PAH concentration map for the Surficial Fill WBZ (Figure H-2), it is apparent that the most significant PAH impacts (i.e., greater than 1,000 ppb) within this unit correlate extremely well with that portion of the site where the presence of residual oil tar or free-product DNAPL are found to occur (see Figures F1 and F2), with total PAH concentrations attenuating rapidly down-gradient of the zone of residual product, likely due to the low solubility and mobility of PAH compounds in water.

To better identify a transport mechanism for PAHs in groundwater at the Gasco site, as indicated in the data tables within Appendix H, analyses were conducted in March 1996 for the dissolved fraction (i.e., less than 0.45 micron) of PAHs at well locations MW-6-32 (a DNAPL-bearing well), and MW5-32 (down-gradient of the former Tar Ponds). The results of these dissolved analyses showed that concentrations of total PAHs in groundwater dropped to non-detect at the MW-6 location (from 2,346 ppb), while total PAH concentrations dropped significantly (from 269 ppb to 45 ppb), and total carcinogenic PAH concentrations dropped to non-detect (from 30 ppb) at the MW-5-32 location. The preceding provides evidence that the primary mechanism for PAH transport in groundwater at the site is likely via advection of contaminants that are adsorbed to colloidal material. It is possible that some PAHs in the groundwater samples are the result of mobilizing colloidal material during purging of the wells for sampling.

As indicated on the total PAH concentration map for the intermediate depth zone of the Alluvial Sand WBZ (Figure H-3), the greatest total PAH concentration (17,720 ppb at MW-8) was found to correspond to the area of the former Tar Ponds, the area of the site where residual oil and/or oil tar were identified at the greatest depths and extending into the upper portions of the Alluvial Sand WBZ. Down-gradient of the former Tar Ponds at the MW-4-57 well location, relatively elevated concentrations of PAHs (2,299 ppb) are found to persist, indicating either a greater mobility of the PAH plume within the Alluvial Sand WBZ than there is within the Surficial Fill WBZ, or that their may be oil and/or tar product present within the Alluvial Sand WBZ in the vicinity of the MW-4-57 well location (as was observed at the adjacent B-29 boring location).

Of additional note with regard to the PAH contamination within the Alluvial Sand WBZ, is that although oil tar was found to exist within the Surficial Fill WBZ at the MW-10 (former Naphthalene Plant/ Tar Processing area) and MW-6 (former Retort Area) well locations, with free product DNAPL being identified immediately above the silt unit at these locations, total PAHs in the Alluvial Sand WBZ beneath the silt unit were found to be either non-detect (MW-13-61) or to occur at very low concentrations (6.2 ppb at MW-10-61), with BTEX constituents at both locations found to be non-detect, indicating that the vertical extent of groundwater contamination within the Alluvial Sand WBZ appears to have been adequately defined in the central portion of the site.

To summarize the preceding discussion, existing data indicates that the PAH contaminant plume within the Surficial Fill WBZ is primarily restricted to the portion of the site where residual tar or oil tar contamination has been identified, and that PAH concentrations attenuate rapidly down-gradient of these areas.

With regard to the Alluvial Sand WBZ, it appears that the PAH groundwater contaminant plume is primarily restricted to the eastern portion of the site, within and down-gradient of the former Tar Ponds. Across the central and southern portion of the site the confining nature of the silt unit is such that it appears to prevent the downward migration of contamination into the underlying Alluvial Sand WBZ.

As the screening criteria for numerous of the PAH constituents in groundwater have been exceeded, it appears that further evaluation of these constituents with regard to flux and potential impact to the Willamette River will be necessary.

6.4.2 BTEX Compounds

Maps depicting contoured total BTEX concentrations within the Surficial Fill WBZ, as well as within the Alluvial Sand WBZ, during June 1998 are provided in Appendix H (Figures H-4 and H-5).

As depicted on Figure H-4, the maximum total BTEX concentration identified at the site during the June 1998 groundwater sampling event was 129,270 ppb in Surficial Fill WBZ well MW-10-25, a well containing several feet of free product DNAPL. A temporary well point (BW-19) installed in 1995 adjacent to the former Light Oil Plant at an up-gradient location relative to well MW-10-25 identified the presence of 151,600 ppb total BTEX in the Surficial Fill WBZ, while a temporary well point (BW-21), installed immediately up-gradient of the former Light Oil Plant identified only 6.4 ppb total BTEX constituents. Based on decreasing concentrations of BTEX down- and cross-gradient of the former Light Oil Plant, dramatically decreasing concentrations immediately up-gradient of the plant, it appears likely that the former Light Oil Plant is the source for the bulk of the BTEX groundwater contaminant plume at Gasco. Additionally, based on soil sampling results of product-saturated soils, it appears that the residual oil tar may be a secondary, and ongoing, source for the BTEX contamination present in groundwater.

Down-gradient of the former Light Oil Plant, concentrations of total BTEX within the Surficial Fill WBZ are found to attenuate, with maximum concentrations of less than 100 ppb total BTEX common at the down-gradient limit of the site, adjacent to the Willamette River. In fact, during the June 1998 sampling event, groundwater samples collected from all Surficial Fill WBZ monitoring wells located adjacent to the river resulted in non-detect for BTEX constituents. As observed with the PAH groundwater contamination, and as discussed below, it appears that the primary migration pathway for BTEX-contaminated groundwater to the Willamette River is via the Alluvial Sand WBZ.

As depicted on Figure H-5, the maximum total BTEX concentration identified within the Alluvial Sand WBZ during June 1998 was 26,610 ppb, as detected at well MW-8-56. As previously stated, well MW-8-56 is installed within the area of the former Tar Ponds, the portion of the site where residual tar and oil tar have been found to extend to the greatest depths, having been identified in soils within and below the silt unit in the upper portion of the Alluvial Sand WBZ.

As indicated by the non-detection of BTEX constituents within the Alluvial Sand WBZ at well locations MW-13-61 and MW-10-61, and the relatively lesser concentrations of total BTEX constituents at the MW-3-56 well location (630 ppb) relative to the MW-4-57 location (10,868 ppb), it appears that the BTEX plume is likely migrating downward into the Alluvial Sand WBZ in the vicinity of the former Tar Ponds. Such a pathway would be similar to that described with regard to the PAH impacts identified in groundwater at this portion of the site, with the exception that the BTEX constituents would be expected to dissolve into groundwater from the residual product much more readily than the PAHs would, due to higher solubility limits.

The preceding indicates that the BTEX groundwater contaminant plume within the Surficial Fill WBZ is primarily restricted to the portion of the site where residual tar or oil tar contamination has been identified, and that BTEX concentrations attenuate rapidly down-gradient of these areas.

With regard to the Alluvial Sand WBZ, it appears that the BTEX contaminant plume is primarily restricted to the area of, and down-gradient of, the former Tar Ponds at the Gasco site.

As the screening criteria for each of the BTEX constituents in groundwater have been exceeded, it appears that further evaluation of these constituents with regard to flux into, and potential impact to, the Willamette River will be necessary.

6.4.3 Cyanide

In general, concentrations of total cyanide have been identified at all well locations (Surficial Fill WBZ and Alluvial Sand WBZ) at the site with the exception wells MW-10-61 and MW-12-36. Maximum detectable concentrations of total cyanide in groundwater at the Gasco site have been identified within the Surficial Fill WBZ at the former Spent Oxide Storage area (wells MW-1-22 and well point B-1) and in the area of the former Tar Ponds (MW-8-29). Specifically, a site-wide maximum cyanide concentration of 11 ppm has been identified at the former Spent Oxide area (MW-1), while a maximum of 4.9 ppm total cyanide has been identified at the former Tar Pond location (MW-8-29). Cyanide concentrations at most other well locations at the site are all relatively uniform, and are typically found to be less than 1 ppm.

The relatively uniform total cyanide concentrations across the site are not suggestive of any one particular source area, but rather appear to be the likely result of the presence of spent oxide within the fill unit across the site, with the cyanide potentially having been leached and transported vertically into the Alluvial Sand WBZ with the tar and oil tar.

Amenable cyanide data has been collected over the previous two groundwater sampling events (February and June 1998), with a maximum concentration of 0.045 ppm being identified at well MW-1-22, located at the former Spent Oxide Storage area.

As summarized in Section 6.2.3, the toxicity of cyanide is primarily associated with the available, or amenable, cyanide fraction. It is of note that amenable cyanide has not been identified in groundwater at any monitoring well location at concentrations in excess of the 0.730 ppm Region 9 EPA PRG for amenable cyanide in tap water. However, as the Fresh Chronic AWQC for cyanide in surface water is 0.0052 ppm, it appears that further evaluation of this constituent with regard to its flux and potential impact to the Willamette River will be necessary.

6.4.4 Metals

Arsenic, chromium, copper, lead, nickel, and zinc concentrations above the screening criteria have been identified in groundwater at the Gasco site. Arsenic, chromium, copper, lead, nickel and zinc have been found to occur at the site. No other of the Priority Pollutant metals have been identified in groundwater at the site at concentrations in excess of the screening criteria. It should be noted that some of the screening criteria are well below analytical method detection limits.

Arsenic has been identified at the Gasco site at concentrations in excess of the AWQC screening level of 0.000017 ppm and EPA PRG of 0.00004 ppm at numerous well locations, both within the Surficial Fill WBZ and within the Alluvial Sand WBZ. Dissolved arsenic data are not available for groundwater at the Gasco site other than one sample with the maximum total arsenic concentration identified in groundwater at the site (0.058 ppm within Surficial Fill WBZ well MW-10-25, as sampled in February 1997), where 0.052 ppm of dissolved arsenic was detected. This information suggests that most of the arsenic is in the dissolved state, at least at the MW-10 location.

With respect to chromium, concentrations of total chromium slightly elevated above the AWQC screening levels (0.011 ppm for hexavalent chromium and 0.210 ppm for trivalent chromium) have been identified at numerous well locations, with the greatest dissolved concentrations (0.23 ppm) being identified within the Surficial Fill WBZ at the well MW-10-25 location, the only location where dissolved concentrations have exceeded the MCL or PRG for this constituent.

Copper has been identified at the Gasco site at concentrations in excess of the AWQC screening level of 0.012 ppm at 6 well locations, both within the Surficial Fill WBZ and within the Alluvial Sand WBZ. Copper has not been identified in groundwater at any location in excess of MCLs or PRGs. Dissolved copper data are not available for groundwater at the Gasco site; however, the maximum total copper concentration identified in groundwater at the site was 0.41 ppm within Surficial Fill WBZ well MW-3-26, as sampled in October 1996.

Total lead has been identified within groundwater at 6 well locations at concentrations in excess of the screening criteria. It is noted that dissolved lead was not identified at concentrations above method detection limits at locations where filtered samples were collected, suggesting that the lead is sorbed onto soils and that transport, if any, would be limited to advection via colloidal particles. The maximum detected concentration of lead at the site was 0.099 ppm at well MW-3-26, as sampled in August 1997.

With respect to nickel, elevated concentrations of this constituent, relative to MCLs and AWQC have been identified at Surficial Fill WBZ wells MW-3-26 and MW-10-25, with maximum detected dissolved concentrations of 0.40 ppm and 0.53 ppm, respectively. Dissolved nickel concentrations in excess of screening values have not been identified at other well locations at the site.

Zinc has been identified at the Gasco site at concentrations in excess of the AWQC screening level of 0.110 ppm at numerous well locations, primarily within the Surficial Fill WBZ. Zinc has not been identified in groundwater at any location in excess of MCLs or PRGs. Dissolved zinc data are not available for groundwater at the Gasco site. The maximum total zinc concentration identified in groundwater at the site was 3.0 ppm within Surficial Fill WBZ well MW-10-25, as sampled in August 1997.

In summary, arsenic, chromium, copper, lead, nickel, and zinc concentrations elevated above the screening criteria have been identified in groundwater at the site. An evaluation of the identified metals with regard to flux into, and potential impact to, the Willamette River, will be conducted. Because metals are naturally occurring in the environment, an evaluation with respect to natural background water quality will be conducted, if metals issues remain at the site subsequent to the completion of the flux evaluation.

6.5 On-Site Surface Water and Sediment Impacts

On-site surface water and sediment sampling activities were conducted at the Gasco site on January 30, 1996. These activities involved the collection of surface water samples at two locations within the on-site drainage ditch, as well as within each of the three on-site ponds. Additionally, a shallow sediment sample was collected from each of the three on-site ponds. A figure depicting sample locations and tables summarizing the results of these activities have been included within Appendix I.

Results of the surface water sampling indicate PAH and BTEX compounds were present in the pond water and the water that was flowing within the drainage ditch. As the outfall from the on-site ponds to the drainage ditch has been sealed, the source of the water located within the ditch would have been one or more of the following: 1) stormwater runoff from the site; 2) LNG plant process cooling water; and 3) stormwater/groundwater removed by PNO from their tank farm containment basins. As there are no influents into the on-site ponds, and these ponds have been observed to only contain water during the rainy season, the water within these ponds would have been stormwater runoff.

With regard to the PAHs identified within the surface water samples, it is noted that PAH concentrations within all water samples were relatively uniform, with total concentrations ranging from 4.7 ppb to 23.7 ppb, while total PAH concentrations in sediments at the surface water sampling locations (ponds only) were found to range from 1,935 ppm to 21,665 ppm. Based on the large differential between PAH concentrations found in sediment and those found in surface water, and the relatively low concentrations identified in surface water, it appears that due to their relatively low aqueous solubilities and high partitioning coefficients, the PAHs will tend to remain within the sorbed phase in sediments and will not readily transfer to the dissolved phase in surface water. The identified sediment concentrations for PAHs exceed sediment screening levels provided within COE Draft Dredged Material Evaluation Framework, Lower Columbia River Management Area, April 1998.

Although benzene was not identified in any of the on-site sediment samples collected during the referenced investigatory activities, benzene was identified in surface water samples collected from the on-site ponds at concentrations ranging from 0.92 ppb to 3.1 ppb, while benzene was identified within the drainage ditch at concentrations of 110 ppb near the head of the ditch, and at 6.2 ppb near the outfall of the ditch. The benzene concentration identified near the outfall of the ditch does not exceed AWQC for protection of aquatic life or fish consumption.

6.6 Willamette River and Sediment Impacts

With regard to sediment-related investigatory activities conducted in the vicinity of the Gasco site, the following data are available: 1) data collected by Northwest Natural as part of 1996 RI activities; 2) data collected as part of the 1997 EPA Site Inspection of a six-mile reach of the Willamette River (Weston, 1998), 3) data collected as part of the 1997 COE dredging material evaluation program (COE, 1998), and 4) data collected as part of COE sediment evaluations conducted at the U.S. Moorings Station, located immediately down-river of the Gasco site (Britton, 1990; Siipola and Britton 1994). All data point locations within the vicinity of the Gasco site (River Mile 6.0 to 7.0) are provided on Figures J-1 and J-2. It is noted that due to the close spacing of samples collected at the U.S. Moorings Station, it was not possible to depict these locations on the referenced figure. Instead, Figure J-3 provides a COE map that depicts the U.S. Moorings sediment sampling locations.

Figure J-4 provides a bar chart depicting total PAH concentrations for sediment data (Northwest Natural, EPA, and 1998 COE data), posted in relative sampling order from up-stream to down-stream across the Gasco site. Again, due to the large number of sampling points over a relatively small area, the COE U.S. Moorings data was not included on the referenced chart. A summary of sediment data collected by Northwest Natural is provided in Table J-1. A summary of all available sediment PAH data for river miles 6.0 to 7.0 (Northwest Natural, EPA, and all COE data) is provided in Table J-2. Sediment core logs depicting lithologic and contaminant conditions at borings installed as part of Northwest Natural's RI program are provided within Appendix C.

Sediment boring logs indicate that solid to semi-solid tar is present within the river sediments at locations adjacent to the former Tar Pond and former drainage ditch discharge areas, with field evidence (i.e., sheen and/or odor) of petroleum hydrocarbon impacts at other sampling locations adjacent to the site. Tar was found to be present within sediments both at the riverbed surface (SD-7) and extending to depths of at least 8 feet below the riverbed surface (SD-8). It is suspected that this tar is depositional in nature, that is, it was deposited as discharges from the Gasco site during manufactured gas plant operations, as opposed to migrating to the sediments via the subsurface soils.

In general, total PAH concentrations in surface sediments between river mile 6.0 and 7.0 were found to be the greatest at locations adjacent to the central portion of the Gasco site near the discharge point of the former drainage ditch, with impacts found to extend towards the center of the river at least as far as the main shipping channel (approximately 750 feet from the shoreline), as observed at the WR-BC-22 sampling location. Specifically, total PAH concentrations in surface sediments adjacent to the Gasco site were found to range from 85 ppm at the SD-063 location, to 26,408 ppm at the SD-7 location (corresponding to a zone of tarry gravel), with a concentration of 1,418 ppm being identified at the WR-BC-22 location in the main shipping channel. Total PAH concentrations in sediments collected from depths of less than 6.5 feet at the U.S. Moorings Station, located immediately down-river of the Gasco site, were found to range from 89 to 142 ppm in 1989 (Britton, 1990), while total PAH concentrations in surface sediments were found to range from 8 to 59 ppm in 1994 (Siipola and Britton, 1994).

As depicted on Figure J-4, total PAH concentrations in sediment samples collected at upstream and downstream locations show a marked decline relative to those collected adjacent to the Gasco site. Also, sediment samples collected on the opposite side of the river from the Gasco site did not result in the identification of significant PAH impacts.

Vertically, as identified at the SD-8 boring location, elevated PAH concentrations were found to extend at least to 9 feet below the river bed surface, with tar being found at that location to a depth of 8 feet bgs.

With regard to the presence of tar within the river sediments adjacent to the Gasco site, it is known that discharges of waste waters to the river from manufactured gas plant operations and the Tar Ponds occurred via the former drainage feature during the operation of the manufactured gas plant at the site, and that such discharges may account for the presence of these tars. The tar identified in soil borings installed adjacent to the river (B-29, B-31) would not be expected to migrate to the river sediments due to the overall high viscosity/low mobility of this material.

As identified during monthly shoreline inspections conducted at the Gasco facility, an area of hardened tar balls, some with a viscous center, exists along the Gasco shoreline at a location downstream from the former drainage ditch. The zone of tar ball accumulation has been found to dissipate before the downstream property line is reached. The presence of these tar balls is indicative that tar is present within the river sediments, but that the tar, in hardened form, has not been significantly transported down-stream by river current.

With regard to oil tar, it is noted that a description matching that of oil tar was provided for shallow river sediments (upper 17 inches) at a location adjacent to the former Tar Ponds in sediment sample SD-067, collected as part of the EPA Portland Harbor Sediment Study Investigation (EPA, 1998). It is unclear whether the oil tar at this location is present as a result of former surface discharges to the river, is a result of separation from the tar known to be present within the river, or is actively being sourced from the upland portion of the Gasco site.

With regard to the ongoing upland source potential, sufficient data to resolve this issue with respect to the former Tar Pond area should exist once the proposed deep Alluvial Sand WBZ wells to be installed between the former Tar Ponds and the river are constructed (HAI, 1998a). Also, additional evaluation with regard to the oil tars identified at the B-29 boring location, within the former low-lying area adjacent to the former drainage ditch, appears necessary in order to completely evaluate the potential for an ongoing upland source of oil tar into the river. Finally, it is noted that additional evaluation with regard to the extent, transport, and toxicity of impacted sediments adjacent to the Gasco site is necessary.

With regard to site impacts to surface water in the Willamette River, although surface water samples have not been collected from the river, it will be possible to ascertain potential impacts to the river from the site by evaluating the predicted flux of contaminated groundwater to the adjacent river, as well as by direct analysis of the river water and sediment porewater. An evaluation of flux to the river will be conducted subsequent to the installation of the proposed deep Alluvial Sand WBZ wells at this portion of the site (HAI, 1998a), which will provide necessary information regarding the vertical extent of groundwater impacts.

6.7 Air Impacts

Sampling for airborne contaminants at the Gasco site has been conducted for chemical exposure monitoring during implementation of the early stages of RI investigatory activities, as well as for ambient air quality monitoring. The objective of the chemical exposure monitoring was to ensure an adequate level of respiratory protection during the investigatory activities. The objective of the ambient air monitoring was to provide a general assessment of ambient air quality at a location downwind from the LNG containment basin, the Koppers lease area, and the former Tar Pond area. All monitoring activities were conducted by Paul Carlson Associates, Inc. (PCA), a firm specializing in industrial hygiene issues and air monitoring.

With regard to the chemical exposure monitoring, representative breathing zone concentrations of PAHs, BTEX, metals, cyanide, and total particulate were measured during soil boring installation activities carried out at the Former Light Oil Plant (borings B-18 and B-19), the Former Koppers Land Treatment Area (B-27), and the Former Spent Oxide Storage Area (B-1, B-2, and B-3). Results of the monitoring indicated the presence of PAHs, BTEX, and the metal titanium in certain of the air samples, with no other metals or cyanide being identified in the air samples. Concentrations of the identified constituents all fell below the Oregon Occupational Safety & Health Administration (OR-OSHA) Permissible Exposure Limits (PELs), designed to ensure the health of employees. The air monitoring data, and the summary report prepared by PCA, is included within Appendix K. Figure K-1 depicts the location of the air monitoring station.

With regard to the ambient air monitoring, this monitoring was conducted with a pump sampler over a period of approximately 6 hours on February 27, 1996 at the downwind (north) side of the LNG containment basin. The air sample was analyzed for the presence of particulates, PAHs, and BTEX constituents. Results of the monitoring event indicated that particulates (i.e., dust), PAHs, and BTEX constituents were all non-detect during the period of the referenced event. The air monitoring data and the summary report prepared by PCA are included within Appendix K.

In addition to the above described air monitoring activities, two samples of accumulated dust were collected from the site (Figure K-1). Specifically, one dust sample was collected from within the fire hose containment box located within the Northwest Natural LNG process area (near well MW-9), and one dust sample was collected from within the fire hose box located directly adjacent to the vehicle exit doorway to the Koppers pencil pitch warehouse. The doors on both fire hose boxes had been ajar, allowing dust to accumulate on the shelving within. The timing of the dust accumulation (i.e., deposition caused by certain climatic conditions and / or site operations) is unknown.

Based on the proximity to the pencil pitch warehouse, the presence of pencil pitch on the ground in the vicinity of the fire hose box, and the black nature of the dust sample, it appeared that the dust sample collected adjacent to the Koppers pencil pitch warehouse was very likely pencil pitch dust derived from the Koppers warehouse operations. The dust sample collected in the Northwest Natural LNG process area did not have the appearance of pencil pitch. Both dust samples were analyzed for PAHs.

Results of the dust sample analyses indicate the presence of 381 ppm total PAHs within the dust sample collected from the LNG process area fire hose box, while 26,919 ppm total PAHs were identified within the sample of pencil pitch dust collected adjacent to the Koppers pencil pitch storage warehouse. A comparison of individual PAH fractions to the total PAH concentration was conducted for both of the dust samples. The comparison indicates a very close match exists between the ratio of individual PAHs to the total PAHs between the two samples, suggesting a common source. In this case, the source appears to be the Koppers pencil pitch storage warehouse. Laboratory sheets for the two dust samples, as well as a chart comparing the PAH ratios between the two samples, are provided within Appendix K, with additional discussion of PAH mixes provided within Appendix 1 (Decision Management Associates Report).

6.8 Contaminants of Concern

6.8.1 Soil

As summarized on the data tables provided in Appendix G, based on investigatory activities conducted at the site to date, PAHs, benzene, toluene, ethylbenzene, and arsenic have been detected in soils at the site at concentrations exceeding screening criteria. Specifically, PAHs and BTEX concentrations have been found to exceed DEQ Cleanup Levels as identified in the ODEQ Soil Cleanup Table (OAR 340-122-045) and/or Region IX PRGs, while arsenic concentrations exceed DEQ Industrial Maximum Allowable Soil Concentrations (OAR 340-122-045).

Pentachlorophenol, cyanide, and the metals antimony, cadmium, chromium, copper, lead, nickel, thallium, and zinc have all been identified in soil samples collected at the site, but none of these constituents were identified at concentrations exceeding EPA Region 9 PRGs, DEQ Soil Cleanup Levels, and/or DEQ Industrial Maximum Allowable Soil Concentrations, where established.

With regard to amenable cyanide, because the amenable cyanide concentration cannot exceed the total cyanide concentration, and because the maximum identified total cyanide concentration in soil (518 ppm) is well below the 13,628 ppm EPA Region 9 PRG for amenable cyanide, it does not appear that amenable cyanide is a concern with respect to soil quality at the site. However, the soil leaching to groundwater pathway may need further evaluation for cyanide.

Based on the results of the RI activities conducted at the Gasco site to date, the contaminants of concern with respect to soil impacts at the site appear to be limited to the following:

- PAHs
- Volatile aromatic hydrocarbons (benzene, toluene, ethylbenzene)
- Arsenic
- Cyanide

6.8.2 Groundwater

As summarized on the data tables provided in Appendix H, with respect to groundwater quality, PAHs, BTEX compounds, 2,4-dimethylphenol, total cresols (2-, 3-, and 4-methylphenol), styrene, tetrachloroethene, arsenic, chromium, copper, lead, nickel, zinc, and cyanide, have all been detected at concentrations exceeding one or more of the following screening criteria: EPA MCLs established for drinking water, EPA Region 9 PRGs for tap water, and/or the federal AWQC established under the Clean Water Act for the protection of aquatic life and human health. The AWQC were included herein as a screen for identifying contaminants of concern within groundwater since contaminated groundwater at the site does discharge to the Willamette River, where the AWQC may be applicable.

With regard to 2,4-dimethylphenol and total cresols, it is noted that these constituents have been identified at concentrations in excess of the screening criteria at two well locations (i.e., wells MW-10-25 and MW-11-32), both of which are DNAPL-containing wells. Concentrations of these constituents have not been identified above the screening criteria at down-gradient well MW-4-57, the most highly contaminated well located adjacent to the river. As such, it does not appear that these constituents are mobile within the subsurface. Based on the preceding, and assuming that the use of groundwater at the site for a drinking water source would not be a potential beneficial use, then it does not appear that a receptor would exist for the phenol impacted groundwater, and as such, 2-4-dimethylphenol and total cresols do not appear to pose a concern with regard to groundwater quality at the site. All other phenols were identified at concentrations below the referenced screening criteria.

With regard to styrene, this constituent has been identified at the MW-12-36 well location at a maximum concentration of 170 ppb, with styrene having never been identified at locations down-gradient from well MW-12 (i.e., wells MW-4-56, MW-5-32, MW-8-56, or MW-11-32). The drinking water MCL for styrene is 100 ppb, while the tap water PRG for this constituent is 1,641 ppb. No AWQC for this constituent has been developed. The lack of styrene detections down-gradient of well MW-12 indicates that this constituent does not appear to be migrating towards the river. Based on the preceding, and assuming that the use of groundwater at the site for a drinking water source would not be a potential beneficial use, then it does not appear that a receptor would exist for the styrene impacted groundwater, and as such, styrene does not appear to pose a concern with regard to groundwater quality at the site.

With regard to tetrachloroethene (PCE), this constituent was identified at the MW-11-32 well location in March 1996 at an estimated concentration of 2.2 ppb, below the 5 ppb MCL and 9 ppb AWQC screening values, but slightly above the 1.08 PRG for this constituent. Due to the low concentration identified, the lack of subsequent detections at the MW-11 location, as well as a lack of detection at the up-gradient and down-gradient well locations, it does not appear that PCE poses a concern with regard to groundwater quality at the Gasco site.

Based on the results of the RI activities conducted at the Gasco site to date, the contaminants of concern with respect to groundwater impacts at the site appear to be limited to the following:

- PAHs
- Volatile aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylenes)
- Cyanide
- Arsenic
- Chromium
- Copper
- Lead
- Nickel
- Zinc

7. CONCLUSIONS

The purpose of the data presentation and evaluation presented herein has been to provide a summary and analysis of existing data collected as part of Phase I RI activities at the Gasco site to assist in the understanding of the site, and to guide decisions regarding additional data acquisition. The conclusions presented below are based on the analysis of data presented herein.

7.1 Hydrogeological Conditions

- Groundwater occurs in three principal hydrologic zones at the site including the unconfined Surficial Fill WBZ, the semi-confined Alluvial Sand WBZ, and confined bedrock aquifers in the Columbia River Basalts.
- A silt unit, correlating to the depth of pre-fill ground surface elevations, separates the Surficial Fill WBZ from the Alluvial Sand WBZ across a majority of the site. A northwest-southeast trending depression in the surface of the silt unit exists across the center of the site, correlating with the location of a pre-fill creek bed.
- Groundwater within the Surficial Fill WBZ and the Alluvial Sand WBZ appears to be hydraulically connected to the Willamette River, with groundwater flow beneath the site being to the northeast towards, and discharging to, the river.
- A downward vertical hydraulic gradient between the Surficial Fill and the Alluvial Sand WBZ predominates, with reversals being identified at certain locations during times of high river stage.

9 Depth to bedrock across the site is estimated to range from 36 feet bgs at the southwestern portion of the site near NW. St. Helens Road, to more than 250 feet bgs at the southeastern portion of the site adjacent to the Willamette River.

7.2 Nature, Extent, and Transport of Contamination

Soil, sediment, and groundwater contamination has been found to be associated with the presence of residual manufactured gas plant wastes at the property, primarily tar and oil tar (PAHs and BTEX), and spent oxide materials (metals and cyanide).

7.2.1 Residual Tar, Oil Tar, and DNAPL

- Tar has been found to be primarily restricted to the southeastern portion of the site at the former Tar Pond area and the location of a former drainage feature, areas where tar-bearing wastes were discharged and/or mixed with fill.

- Residual oil tar has been identified throughout the southern, southeastern and west-central portions of the site, likely sourced from the former Light Oil Plant, former Retort area, former Tar Ponds, and a former drainage feature.

- The silt unit has likely prevented oil tar impacts derived from the Light Oil Plant/Retort Area from migrating vertically into the underlying Alluvial Sand WBZ, with oil tar having migrated from these areas via gravity along the surface of the northeast sloping silt unit. The northwest - southeast trending depression in the surface of the silt unit has acted as a barrier to the lateral migration of the mobile oil tar product to the northeast and towards the Willamette River.

- Oil tar has been found to extend through the silt unit and into the upper portions of the Alluvial Sand WBZ at several locations within the southeastern portion of the site (former Tar Ponds), correlating to areas with the greatest accumulations of tar.

- Oil tar was found within the Alluvial Sand WBZ within the former drainage feature, the only location where oil tar is found adjacent to the Willamette River.

- Soil boring data indicates that the lateral and vertical extent of tar and oil tar have been generally defined across the site. Laterally, tar and oil tar may likely extend across the southeastern property boundary, where placement of these materials as fill may have occurred.

- Three areas of free product DNAPL (oil tar) have been identified within the Surficial Fill WBZ at the site. Two areas of DNAPL occurrence are located on top of the silt at areas where the silt surface is depressed. The third is located up-slope of the depression, but down-slope of the identified oil tar source area.

7.2.2 Soil Quality Impacts

10 Based on the evaluation conducted to date, constituents of concern with regard to soils at the site are PAHs, benzene, toluene, ethylbenzene, and arsenic.

- BTEX and PAH concentrations above EPA Region 9 PRGs are found in the zones of tar and oil tar contamination.

- The vertical extent of BTEX and PAH contamination within soil has been well defined at most soil boring locations, with the most significant impacts being restricted to the surficial fill unit, except in the former Tar Pond area, where contaminants have extended into the alluvial sand unit.

- Cyanide was identified in soils throughout the site, likely as the result of spent oxide materials within fill materials. The maximum total cyanide detection in soil was 518 ppm, well below the 13,628 ppm EPA Region 9 PRG for free cyanide in industrial soils. However, cyanide in soil may be an issue at the site with regard to leaching to groundwater, should it be determined that an unsatisfactory risk with regard to groundwater concentrations exists.

- Elevated concentrations of arsenic, relative to screening levels and to soils from other portions of the site, were identified within the former Spent Oxide Storage Area.

Statistical evaluation of the data, as conducted by Decision Management Associates LLC developed the following conclusions with respect to soil quality at the site:

- Data visualization and analysis show substantial small-scale variability superimposed on site-scale trends, with the variability consistent with fill placement, mixing, and preferential transport of contaminants.
- The primary site-scale trend for PAHs is for greater contamination towards the southeastern corner of the site.
- Significant differences in concentrations and variability exist by area and depth.
- PAH concentrations are related to field evidence of contamination (odor, sheen, presence of product), with a lesser relationship being identified with benzene.
- For Risk Assessment purposes, since surface samples were collected randomly this data may be used directly, while sub-surface samples were collected in part based on soil appearance, and are therefore biased. However, the bias in the sampling was found to: 1) increase representation of high-concentration PAH samples by about 25%, and 2) has no measurable impact on benzene values.

7.2.3 Groundwater Impacts

- Groundwater contamination, primarily PAH, BTEX, and cyanide related, has been identified within both the Surficial Fill WBZ and the Alluvial Sand WBZ.
- The former Light Oil Plant is the likely source for the bulk of the BTEX groundwater contaminant plume at Gasco, with the residual oil tar at the site being a secondary, and ongoing, source for the BTEX contamination present in groundwater.
- Oil tar and tar-saturated soils appear to be the source of the PAH impacts to groundwater at the site.
- With regard to the Surficial Fill WBZ, both the BTEX and PAH groundwater contaminant plumes tend to be primarily restricted to the portion of the site where residual tar or oil tar contamination has been identified, with concentrations attenuating rapidly down-gradient of these areas. However, the vertical extent of BTEX and PAH groundwater contamination down-gradient of the former Tar Ponds has not been defined.

- With regard to the Alluvial Sand WBZ, it has been found that the BTEX and PAH contaminant plume is primarily restricted to the eastern portion of the site, within and down-gradient of the former Tar Ponds.

- Areas of metals concentrations elevated above screening criteria have been identified in groundwater at the site. Specifically, arsenic, chromium, copper, lead, nickel and zinc have been found at concentrations above AWQC, a potential concern because of discharge to the Willamette River.

7.2.4 On-Site Surface Water Impacts

- Results of surface water sampling of the on-site pond water and within the water that was flowing within the on-site drainage ditch indicates that only benzene, at the head of the ditch, was found to exceed screening criteria (AWQC). The benzene concentration identified near the outfall of the ditch does not exceed AWQC for protection of aquatic life or fish consumption.

7.2.5 Sediment Impacts

- Sampling activities identified the presence of solid to semi-solid tar within Willamette River sediments at locations adjacent to the former Tar Pond and former drainage ditch discharge areas, with field evidence of petroleum hydrocarbon impacts at other sampling locations adjacent to the site. Tar was found to be present within sediments at the riverbed surface, extending to depths of at least 8 feet below the riverbed surface at one location.

- It is suspected that the tar identified in the sediments adjacent to the Gasco site is depositional in nature, having been deposited as discharges from the Gasco site during manufactured gas plant operations.

- An area of hardened tar balls exists along the Gasco shoreline at a location downstream from the former drainage ditch. The zone of tar ball accumulation has been found to dissipate before the downstream property line is reached. The presence of these tar balls is indicative that tar is present within the river sediments, but that the tar, in hardened form, has not been significantly transported down-stream by river current.

- Total PAH concentrations in surface sediments in the vicinity of Gasco were found to be the greatest at locations adjacent to the central portion of the site near the discharge point of the former drainage ditch, with impacts found to extend towards the center of the river at least as far as the main shipping channel (approximately 750 feet from the shoreline).

- Total PAH concentrations in surface sediments adjacent to the Gasco site were found to range from 85 ppm to 26,408 ppm (corresponding to a zone of tarry gravel), with a concentration of 1,418 ppm being identified within the main shipping channel. Total PAH concentrations in sediment samples collected at upstream and downstream locations show a marked decline relative to those collected adjacent to the Gasco site.

- PAHs were identified within sediment samples collected from the three on-site ponds located at the southeastern portion of the site, with concentrations ranging from 1,935 ppm too 21,665 ppm being identified.

7.2.6 Air Quality

- Breathing zone monitoring conducted during drilling activities at the site indicated the presence of PAHs, BTEX, and the metal titanium in certain of the air samples. Concentrations of the identified constituents all fell below limits designed to ensure the health of employees.

- Ambient air monitoring conducted downwind of the LNG containment basin indicated that PAHs and BTEX constituents were all non-detect during the period of the referenced event.

- Analysis and evaluation two dust samples at the site indicate that Koppers pencil pitch may be a contributing factor with regard to PAHs identified in surface soils at the site.

7.3 Existing Data Needs

Based on the findings of RI activities conducted at the site to date, as evaluated herein, the following data needs have been identified such that the objectives of the RI may be satisfied:

7.3.1 Risk Assessment Data Needs

- Statistical data evaluation indicates a need for the collection of ten additional surface soil samples at the site, primarily within the northwest (former office area), and northeast (PNO lease area) portions of the site.

- Statistical data evaluation indicates a need for the collection of seven shallow (<15 feet) soil samples at the site.

7.3.2 Contaminant Nature, Extent and Transport Data Needs

- The vertical extent of groundwater contamination at the site is not defined. The installation of three deep (up to 160 feet bgs) Alluvial Sand WBZ wells, two down-gradient of the former Tar Ponds, and one down-gradient of the former Light Oil Plant area, have been proposed to satisfy this data need (HAI, 1998a).

- Verification should be obtained that the vertical extent of DNAPL (oil tar) migration has been adequately defined at the site. The installation of the referenced deep Alluvial Sand WBZ wells to be installed down-gradient of the former Tar Ponds, and the deep well to be installed down-gradient of the former Light Oil Plant have been proposed to satisfy this data need (HAI, 1998a).

- Conclusions with regard to the active migration of DNAPL to the Willamette River within the area of the former Tar Ponds and the former drainage feature (B-29 boring) are necessary. The two deep Alluvial Sand WBZ wells to be installed down-gradient of the former Tar Ponds will satisfy this data need with respect to former Tar Pond portion of the site. Additional evaluation appears necessary to satisfy the data need with respect to the B-29/former drainage feature area.

- The lateral extent of on-site groundwater contamination should be defined. The installation of an intermediate-depth (65 feet bgs) monitoring well to be installed within the PNO area at the northeastern portion of the site, and depth-discrete groundwater data to be collected from temporary well points installed at the eastern corner of the site (MW-5 location) will satisfy this data need (HAI, 1998a).

- The on-site lateral extent of residual tar and oil tar in soil should be defined to the northeast of the LNG containment basin.

- An evaluation of the physical and chemical make-up of the free product DNAPL (oil tar) should be conducted to assist in the feasibility study and to assess contaminant transport issues. Additionally, the recoverability of DNAPL from wells at the site should be evaluated. Activities necessary to satisfy these data needs have been proposed (HAI, 1998b).

- Additional evaluation with regard to the extent of contamination in Willamette River sediments is necessary. Such an evaluation may include toxicological studies, porewater and sediment sampling activities, as well as an evaluation of river dynamics with regard to contaminant transport.

- An evaluation of contaminated groundwater flux to the Willamette River should be conducted following the completion of groundwater quality-related data gaps described herein.

8. LIMITATIONS

The samples discussed in this report were collected, analyzed, and interpreted following the standards of care, skill, and diligence ordinarily provided by a professional in the performance of similar services as of the time the services were performed. This report and the conclusions and/or recommendations contained in it are based solely upon physical sampling and analytical activities that were conducted at the Client's request. The data presented in this report document only the concentrations of the target analytes in the particular sample and not the property as a whole.

(HAI 10/95)

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10. GLOSSARY OF ABBREVIATIONS

AWQC	Ambient Water Quality Criteria
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
DEQ	Oregon Department of Environmental Quality
DNAPL	dense non-aqueous phase liquid
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
gpm	gallon per minute
GPR	ground penetrating radar
HAI	Hahn and Associates, Inc.
HVOCs	halogenated volatile organic compounds
LNG	liquefied natural gas
MCL	Maximum Contaminant Level
msl	mean sea level
OAR	Oregon Administrative Rule
OR-OSHA	Oregon Occupational Safety and Health Agency
PAHs	polynuclear aromatic hydrocarbons
PCA	Paul Carlson Associates, Inc.
PEL	permissible exposure level
PNO	Pacific Northern Oil
ppb	parts per billion
ppm	parts per million
PRGs	Preliminary Remediation Goals
ppb	parts per billion
RI	remedial investigation
SI	Site Inspection
WBZ	water-bearing zone

Any questions regarding the information presented in this report are welcome and should be referred to the undersigned. Thank you for the opportunity to be of service to Northwest Natural in this manner.

Hahn and Associates, Inc.

Prepared by:

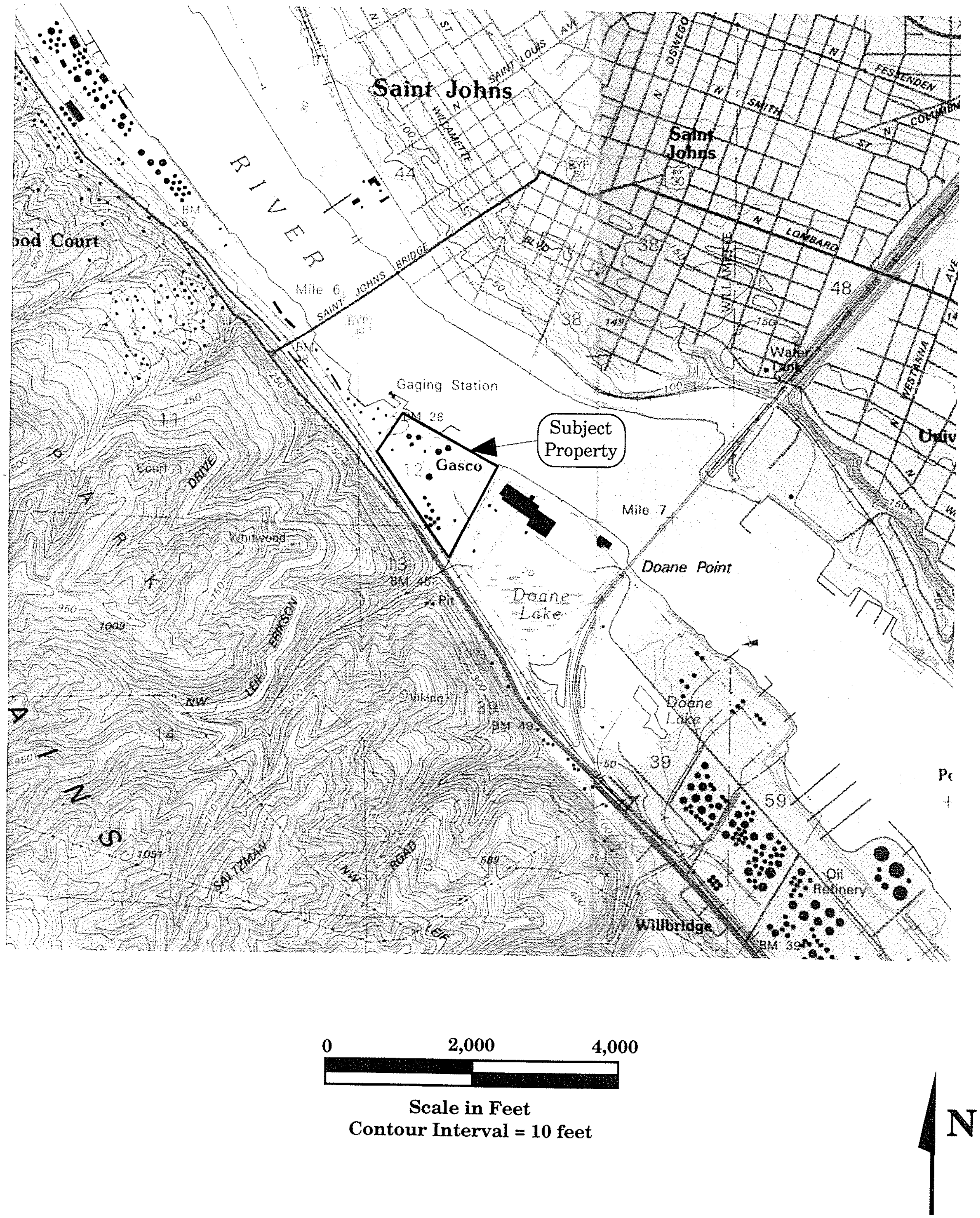
Robert B. Ede, R.G.
Sr. Project Manager

Reviewed by:

Roger E. Brown, R.G.
Principal

Date 10/9/98

FIGURES



Note: Base Map from Linnton (1990) and Portland (1990), Oregon, USGS 7.5 Minute Quadrangles

Project No. 2708	**HAHN AND ASSOCIATES** **INCORPORATED**	**LOCATION MAP**	**FIGURE**
September 1998	ENVIRONMENTAL MANAGEMENT 434 NW SIXTH AVENUE, SUITE 203 PORTLAND, OREGON 97209 (503) 796-0717	Northwest Natural Gasco Facility 7900 NW St. Helens Road Portland, Oregon	1

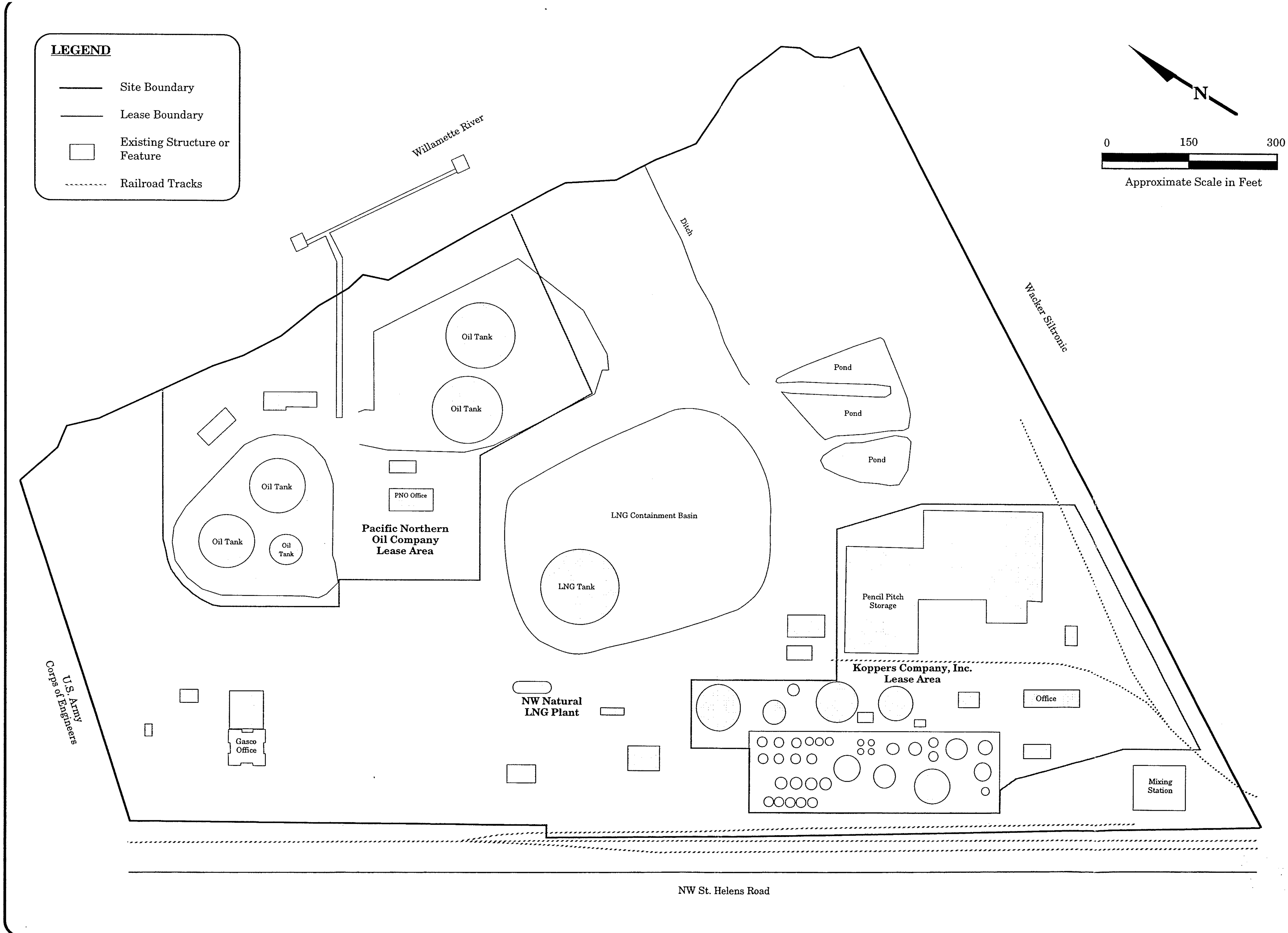


Figure 2

Site Map

Remedial Investigation
Northwest Natural – Gasco Facility
7900 NW St. Helens Road
Portland, Oregon

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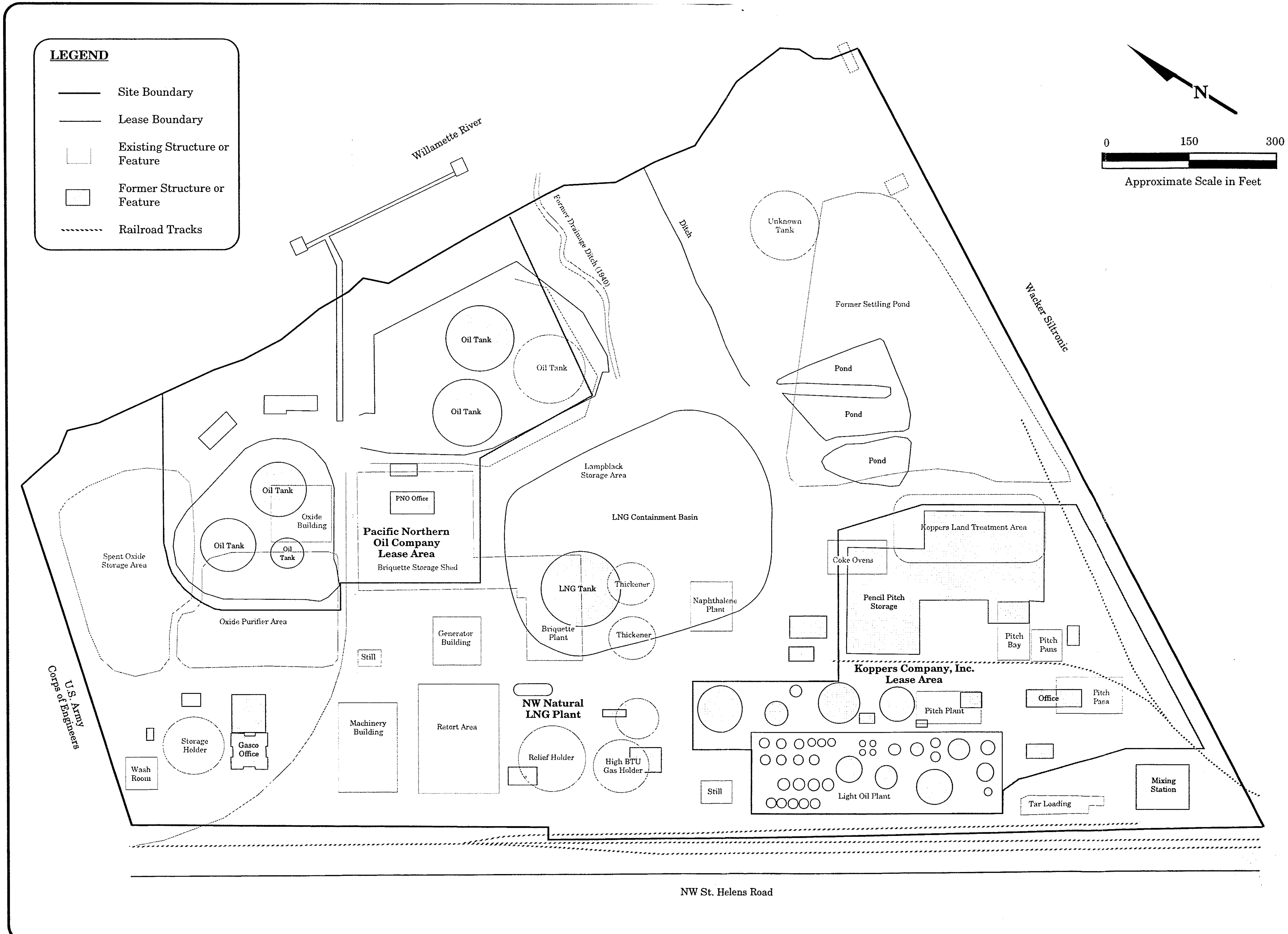

Figure 3

Historical Features Map

Remedial Investigation
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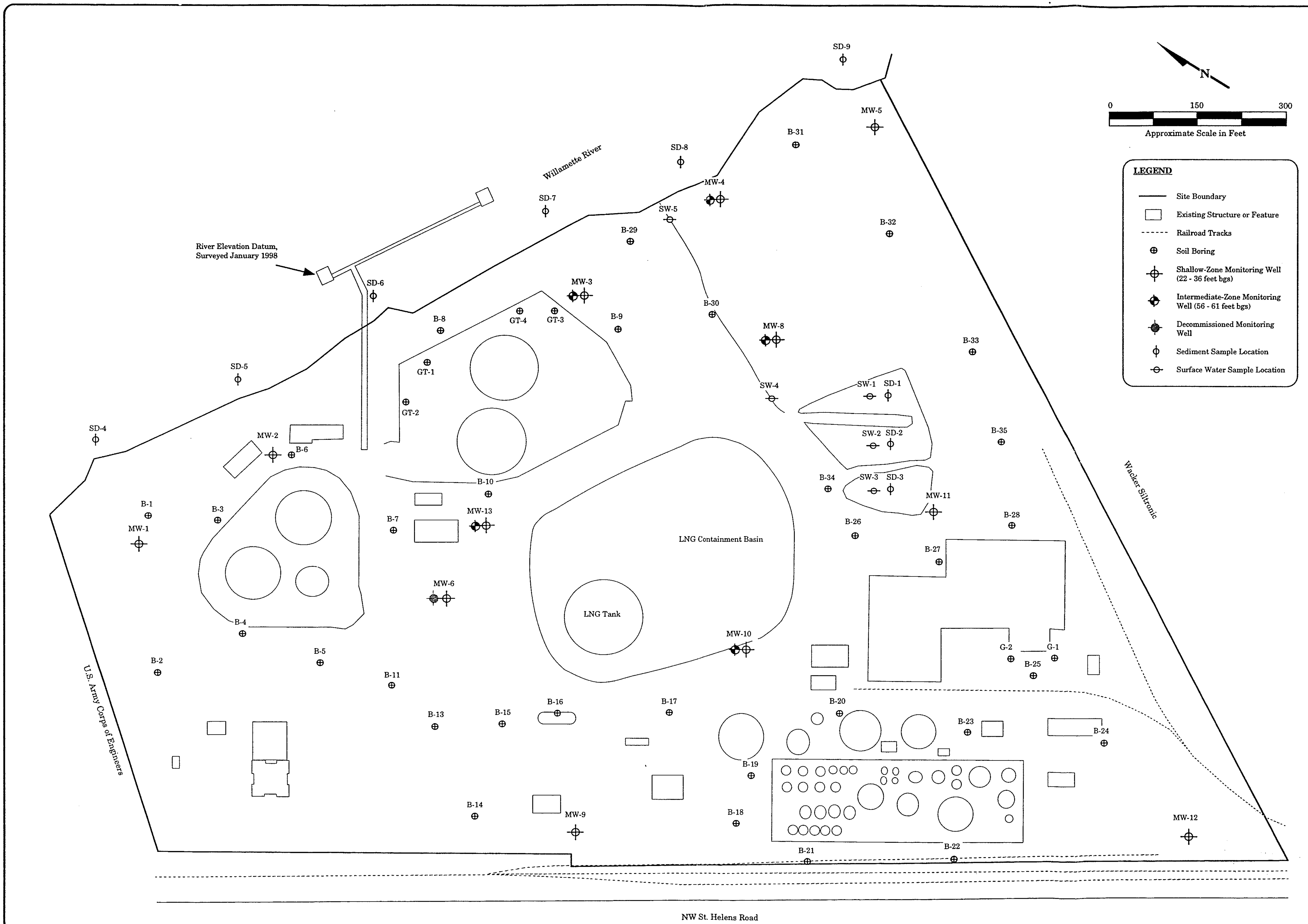

Figure 4

Sample Location Map

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7900 NW St. Helens Road
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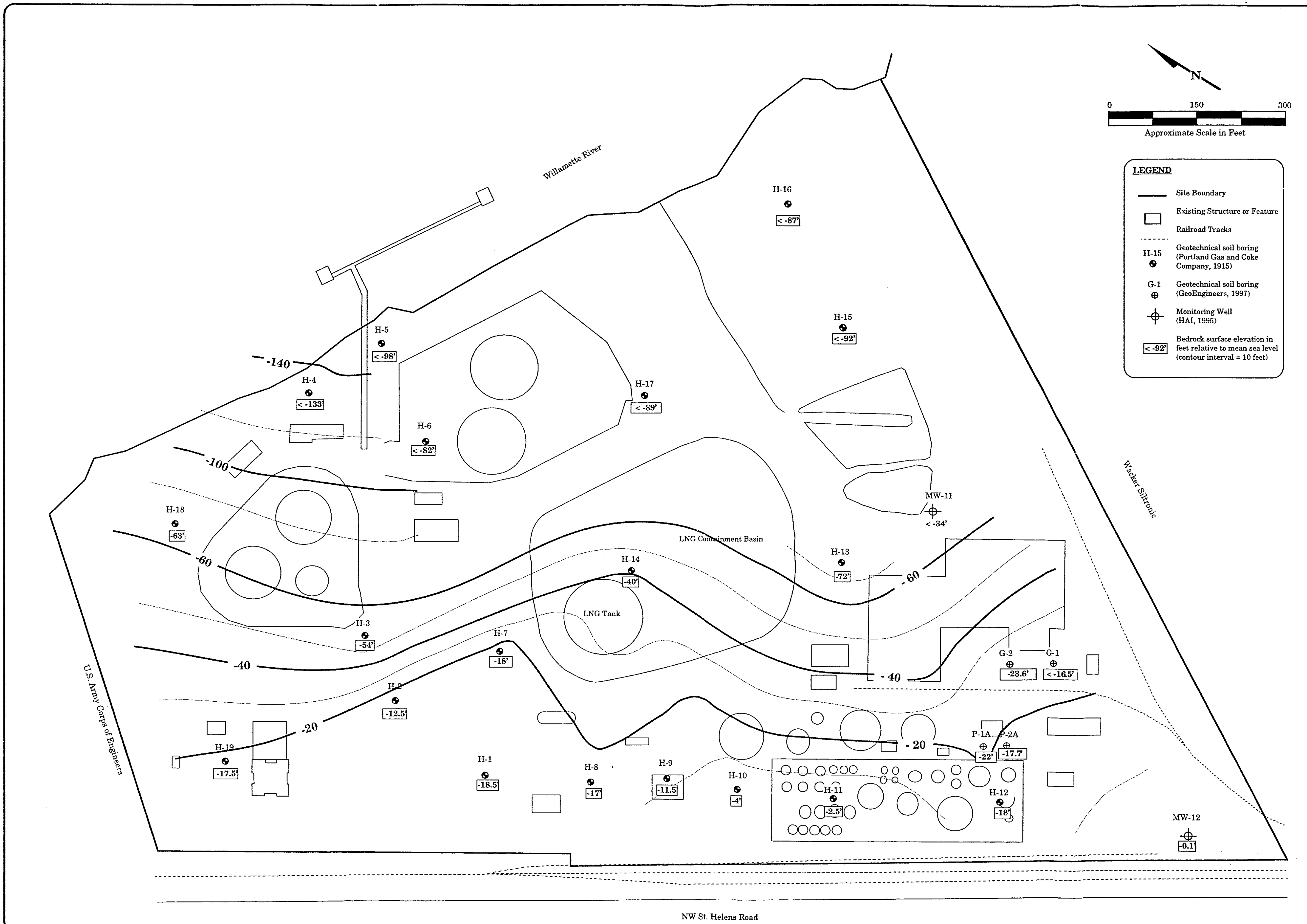

Figure 5

Bedrock Surface Elevation Map

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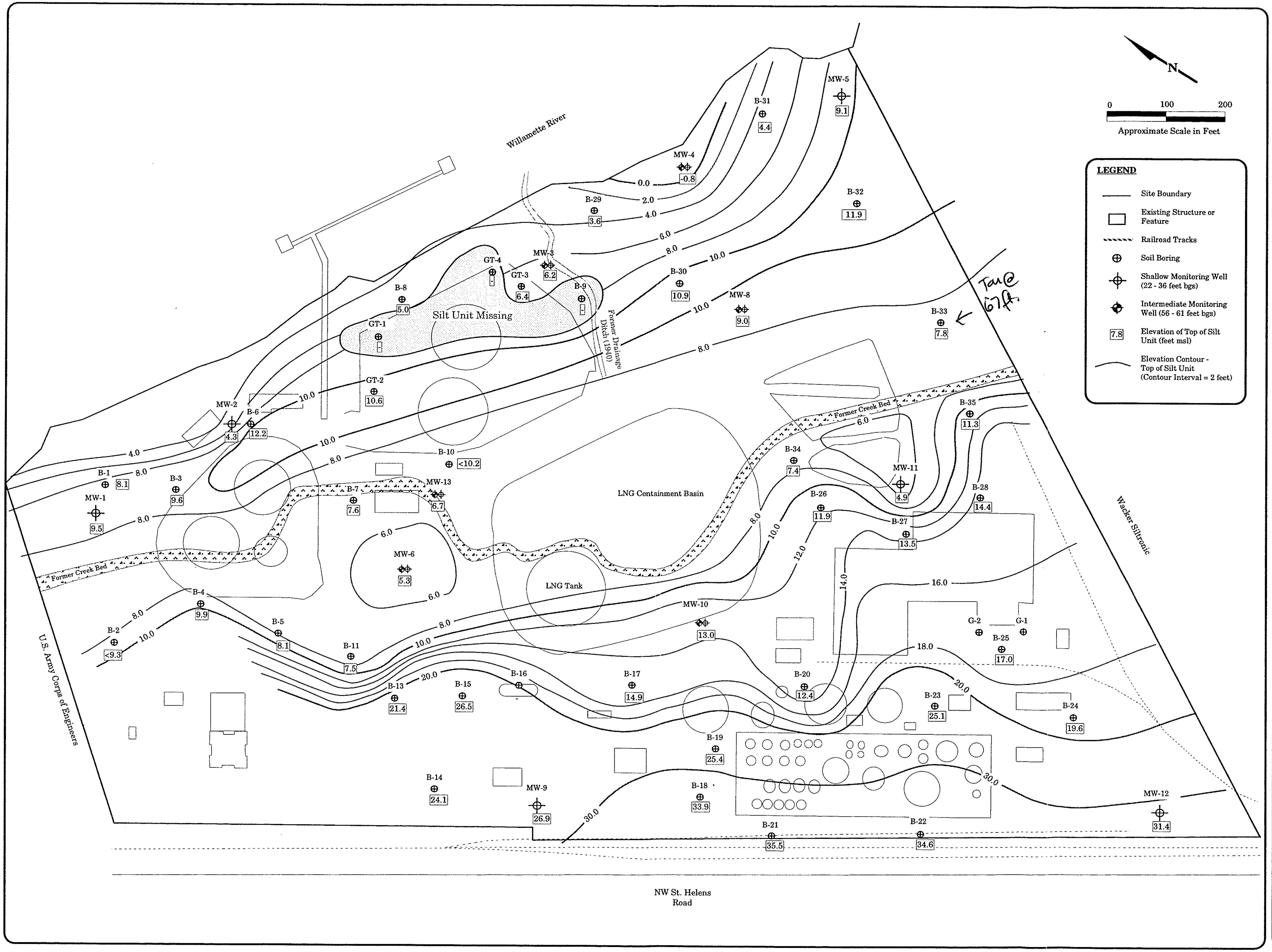

Figure 6

Elevation Map: Top of Silt Unit

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Northwest Natural Gas Company Gasco Facility
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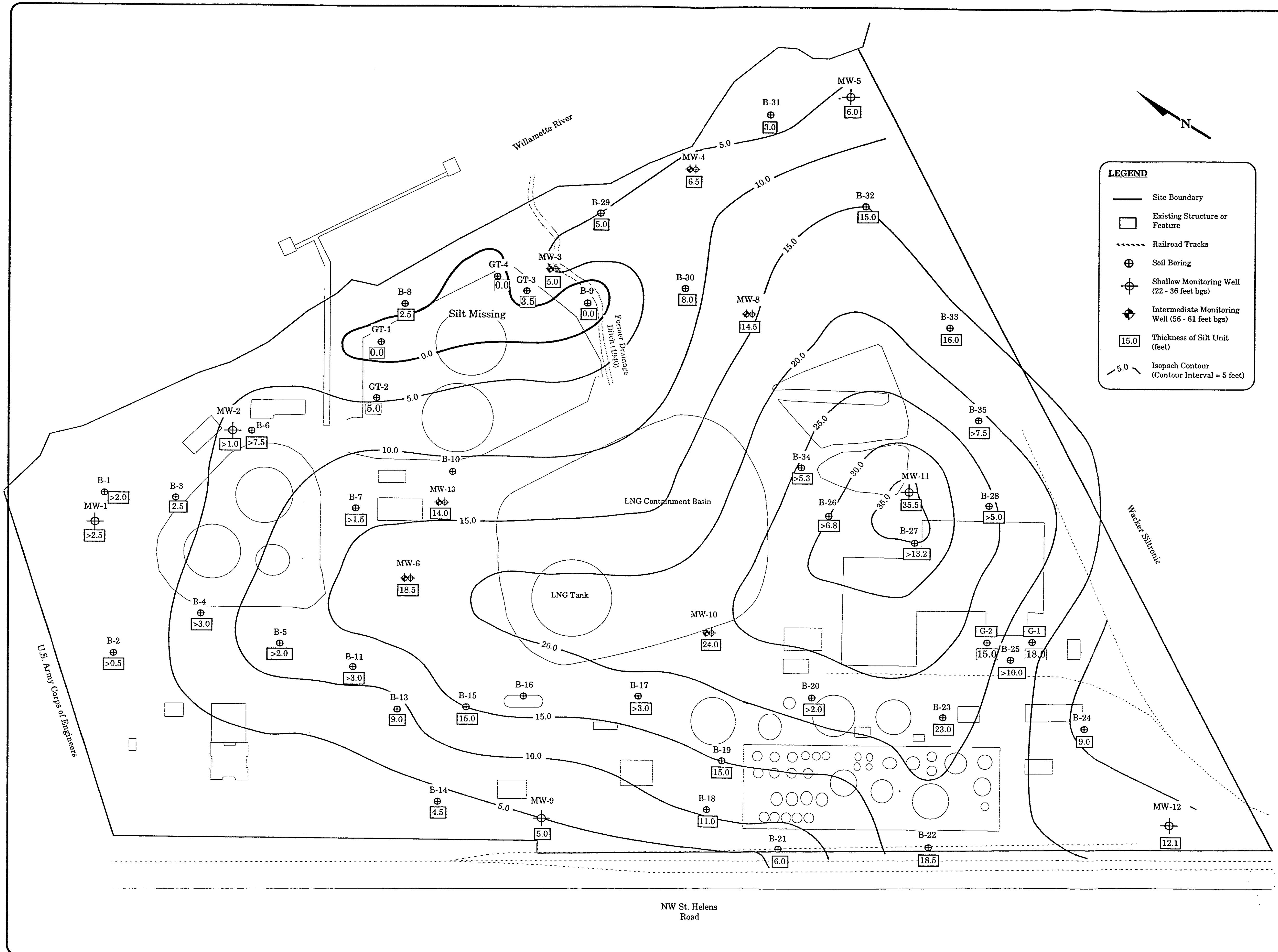

Figure 7

Isopach Map: Silt Unit

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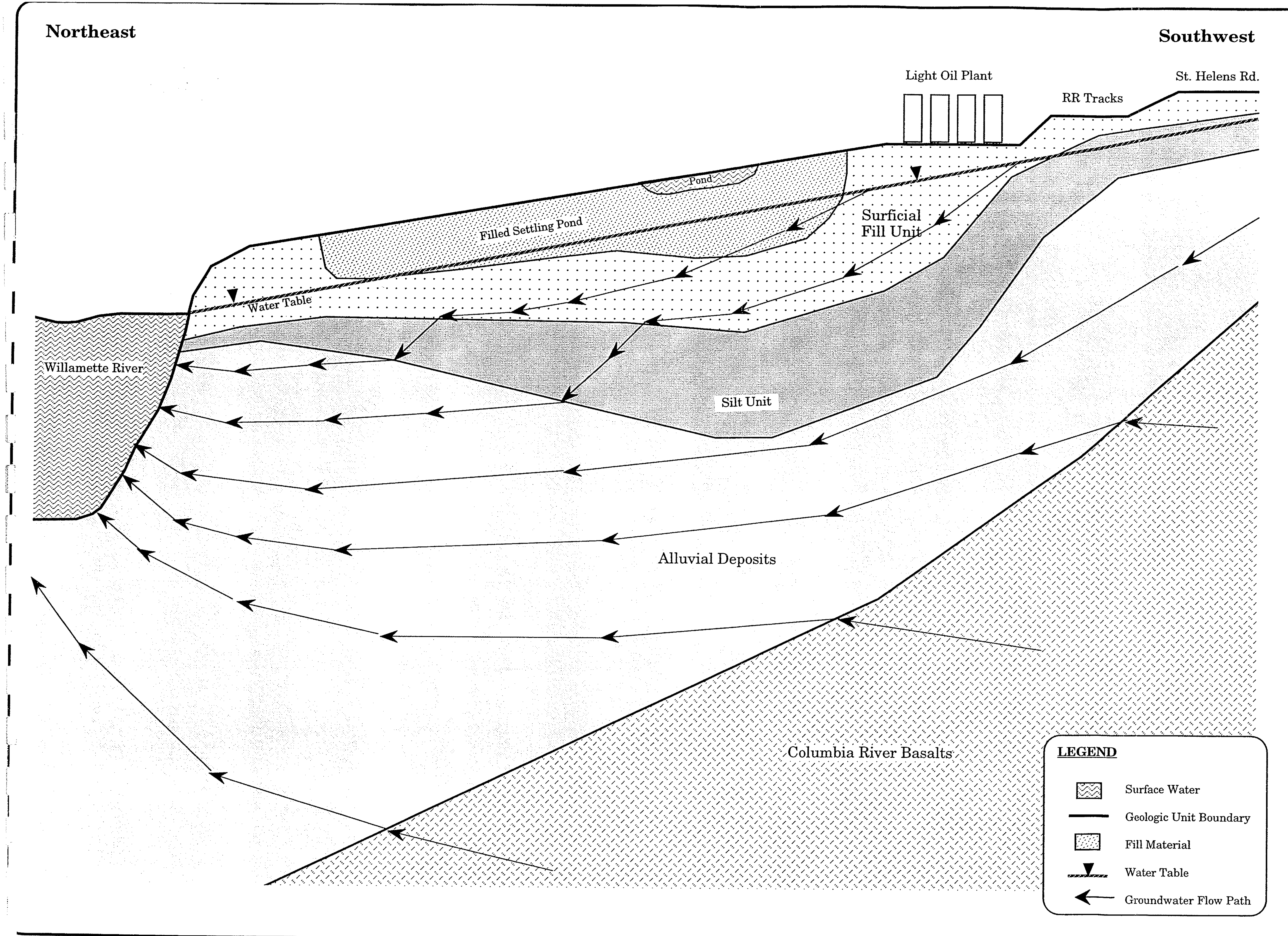

Figure 8

Hydrogeologic Conceptual Model

Northwest Natural Gas Company
Gasco Facility
7540 NW St. Helens Road
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