CONTAMINANT CHARACTERIZATION STUDY
WILLIAMS ALASKA PETROLEUM, INC.
NORTH POLE REFINERY
NORTH POLE, ALASKA

October 2001

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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1.0 INTRODUCTION

Shannon & Wilson has completed additional soil and groundwater sampling at the Williams Alaska Petroleum refinery in North Pole. The objective of this study was to fill data gaps identified following an earlier site characterization effort for an Alaska Department of Environmental Conservation (ADEC) and Environmental Protection Agency (EPA) mandated Corrective Measures Study. Those results were presented in a Shannon & Wilson report entitled *Draft Site Characterization and Corrective Action Plan, Williams Alaska Petroleum, Inc., North Pole Refinery*, dated December 2000. This contaminant characterization study was conducted in general accordance with Shannon & Wilson's refinery monitoring plans outlined in the document *Monitoring Program, Williams Alaska Petroleum, Inc., North Pole Refinery*, dated April 20, 2001.

Following a review of available water and soils contaminant data from the refinery, Shannon & Wilson identified a number of analytes in groundwater and soils that had been present at concentrations greater than the established cleanup levels as of the latest sampling events. These analytes were designated "contaminants of interest" (COIs). However, as many of the analytes had been detected in samples collected more than 10 years ago, we indicated these designations should be considered preliminary, and suggested additional sampling would be appropriate in areas at the refinery likely to exhibit contamination before a final characterization of COIs was completed. This study was designed to assess the types of groundwater and soil contamination possibly present at the refinery, and entailed drilling several soil borings and installing additional groundwater monitoring wells.

The cleanup levels used to establish COIs were the Alaska groundwater cleanup levels (18 AAC 75.345, Table C) and the Alaska soil cleanup levels for the migration to groundwater (MTG) pathway in the less than 40 inches of annual precipitation zone (18 AAC 75.341, Table B1). Based on the earlier data set, the list included hydrocarbons, metals, and one chlorinated solvent, and is summarized in the following table:

Analyte	Matrix	Cleanup Level
Benzene	Water	5 µg/L
Toluene	Water	1000 µg/L
Ethylbenzene	Water	700 µg/L
Antimony	Water	6 µg/L
Cadmium	Water	5 µg/L
Lead	Water	15 µg/L
Benzene	Soil	0.02 mg/Kg
Ethylbenzene	Soil	5.5 mg/Kg
Toluene	Soil	5.4 mg/Kg
Xylenes	Soil	78 mg/Kg
Methylene chloride	Soil	0.015 mg/Kg
Antimony	Soil	3.6 mg/Kg
Arsenic	Soil	2.0 mg/Kg
Chromium (total)	Soil	26 mg/Kg
Selenium	Soil	3.5 mg/Kg

As the refinery's activities involve the processing of crude oil into refined products and generally do not involve the use of chlorinated solvents or heavy metals, the main focus of our investigation was the distribution and types of organic petroleum contaminants potentially present in soil and groundwater at the facility. The sampling we recently completed generally focused on areas known to be contaminated from historical releases at the refinery, to provide the greatest opportunity for assessing as wide a variety of potential environmental contaminants as possible. We also collected samples from areas anticipated to be free of contamination to assess potential background concentrations of naturally occurring metals, as well as establish the absence of contamination at these locations.

In addition to the planned sampling activities, discovery of subsurface contamination in areas previously anticipated to be free of contamination led to further subsurface investigations and additional groundwater analyses. New monitoring wells were placed west of the truck loading area and monitoring well MW-127 (Figure 1), which allowed the successful delineation of the western extent of the groundwater benzene plume in that area. Detection in an otherwise hydrocarbon-free well of an unknown organic analyte eluting in the range of diesel hydrocarbons prompted the collection of additional water samples from several existing monitoring wells to discover the identity of the analyte. The analyte was found to be sulfolane, an organic compound used in the refining process to elevate the aromatic hydrocarbon content of some refined fuels. Sulfolane does not have an identified groundwater cleanup standard, is not listed in the EPA risked-based concentration tables, and has been found to be of low toxicity. Details regarding the locations and types of samples collected are addressed in the Methods section, below, and the results of the various analyses are considered in the Discussion section.

One set of data from the planned suite of soil samples is not yet available and not included in this report. MW-128, a monitoring well north of the northernmost gravel pit at the refinery, was destroyed during the pit's recent enlargement. A replacement well in that area was due to be installed during the other well installation activities, but access to the site was not possible due to soft, wet ground conditions. A gravel road was recently placed north of the enlarged gravel pit, and the replacement well (MW-141) was installed in October, but the analytical data are not yet available. The location of this boring is in an area historically free from subsurface contamination, and soils from the boring were to be used in an assessment of background metals concentrations. Other data are available for assessing background soil concentrations, so the missing information from this location is not required for the determination. A letter report detailing the replacement well's installation will be generated when the data are in hand.

This report presents the results of the contaminant characterization work at the Williams North Pole refinery, including identification of COIs based on the latest data available. We also provide a comparison of some of the metals data with information we obtained from studies evaluating naturally occurring metals in local soil and water samples.

2.0 METHODS

Depending on the location, samples were collected for various determinations of hydrocarbons, metals, chlorinated organic compounds, and sulfolane. This study included drilling eight soil borings and completing four as monitoring wells; each boring yielded soil samples for analysis, as described below. Water samples were obtained from 12 existing monitoring wells, as well as from four of the wells installed in 2001. Sampling details for each type of sample are addressed below.

2.1 Soil Samples

Eight soil samples plus two duplicates were collected from eight borings drilled in March, May, and August 2001 using Shannon & Wilson's drill rig equipped with a hollow-stem auger. In some cases the borings were completed as monitoring wells (MW-135, MW-139, MW-140, and MW-142); in these instances, soil samples were collected from the borings at 2.5-foot intervals until groundwater was encountered (typically about 10 feet below ground surface [bgs]) and at 5-foot intervals thereafter. For samples retrieved from borings not planned for monitoring wells (MWs), soil samples were collected from the hole at 2.5-foot intervals until the groundwater table was reached. In each type of boring, the soils were characterized in the field using the Unified Soil Classification System and field-screened using a photoionization detector (PID). For borings placed in contaminated areas, the sample with the highest PID reading was selected for laboratory analysis; otherwise the sample was collected at or just above the groundwater table. Williams personnel were responsible for disposing of the cuttings removed from the borings. The locations of soil borings drilled for contaminant characterization are shown in Figure 1; location, sample depth, and types of analyses for each soil sample are presented in Table 1. Boring logs for the monitoring wells and soil borings are presented in the Appendix.

Monitoring well MW-135 was drilled in March 2001 as part of an exercise to track migration of a propylene glycol release in the area; its screen was set from 10 to 20 feet bgs. MW-139 was placed west of the truck loading area to delineate the western extent of subsurface benzene contamination in this area. Discovery of benzene above groundwater cleanup levels in MW-139 prompted the installation of another well (MW-142) further to the west. Monitoring well MW-140 was drilled in an area north of the refinery chosen for its potential to reveal permafrost soils in the area; no permafrost was detected to the depth of this boring (25 feet bgs). Monitoring wells MW-139 and MW-140 were completed with screened intervals from approximately 5 to 25 feet bgs; well MW-142 had a screened interval from approximately 5 to 20 feet bgs.

Samples from each soil boring location were analyzed for gasoline range organic compounds (GRO; Method AK101), or GRO plus benzene, toluene, ethylbenzene, and xylenes (BTEX; EPA Method 8021) if the boring was placed in an uncontaminated area. All but one of the soil samples were also analyzed for diesel range organics (DRO; AK102), residual range organics (RRO; Method AK103), and the metals antimony, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver (EPA Method 6000/7000 series). One soil sample, from monitoring well MW-142, was only analyzed for GRO/BTEX and DRO, as this boring was placed for the purpose of delineating the subsurface extent of benzene contamination. In addition to the above analytes, volatile organic compounds (VOCs; EPA Method 8260) and semivolatile organics (SVOCs; EPA Method 8270) were determined in soil samples considered to be hydrocarbon-contaminated based on PID field screening. Samples were placed in pre-cleaned containers supplied by the analytical laboratory (CT&E Environmental Services, Inc.), and kept cold while awaiting analysis.

Quality assurance and quality control (QA/QC) for the sample analyses included several measures to check that sample handling and analysis were performed properly to generate analytical data of acceptable quality. Temperature and trip blanks accompanied the samples during the collection activities and were used to check that samples were kept at the appropriate temperatures, and that no cross-contamination between samples occurred during sampling or transportation to the laboratory. For QA purposes, two field duplicate samples were collected (monitoring well MW-135 and boring B-1) and analyzed for metals, whole fuels (GRO, DRO, and RRO), VOCs, and SVOCs. The relative percent difference (RPD) was calculated where possible to evaluate error associated with sampling and laboratory variability. RPDs are calculable only if both field duplicate samples contain an analyte at concentrations above its practical quantitation limit (PQL). Further QA/QC included the analytical laboratory's standard procedures as outlined in their QA plan on file with ADEC.

2.2 Groundwater Samples

Groundwater was collected from 12 of the previously existing monitoring wells, six of which were expected to be free of hydrocarbons based on previous sampling episodes, and from four of the new wells installed in 2001. Samples were collected after purging each well of at least three well casing volumes; prior to sampling, new monitoring wells were developed until relatively nonturbid water was produced. Each MW at the refinery has its own dedicated pump and tubing, and samples were collected directly into the appropriate laboratory-supplied containers. Well purge water was either discharged to the ground surface (wells historically free of hydrocarbons) or to the oily water sump system at the refinery for treatment. The MW sample locations are presented in Figure 1, and screening depth and sample types are presented in Table 2.

Samples from each MW were analyzed for GRO, or GRO plus BTEX if the well had previously been identified as being free of hydrocarbon contamination. Samples from each location also were analyzed for DRO and RRO, except for MW-142 for which RRO was not determined. Samples from several of the wells (Table 2) also were analyzed for the same metals determined in soil samples (see above). Groundwater from wells anticipated to be contaminated with hydrocarbons was analyzed for VOCs and SVOCs in addition to the analytes above. Samples were collected into pre-cleaned containers supplied by the analytical laboratory, and kept cold while awaiting analysis.

Monitoring wells MW-105 and MW-105A were resampled following detection of GRO and BTEX in MW-105, and toluene, ethylbenzene, and xylenes in MW-105A. These wells are upgradient from the refinery and have been free of hydrocarbons for several years; we therefore suspected the initial contaminant data were spurious. The subsequent additional samples were collected for analysis of GRO/BTEX only.

Following detection of a single DRO analyte in samples from wells historically free of hydrocarbon contaminants (MW-101 and MW-101A), verification samples from these wells were collected for DRO analysis by CT&E and for sulfolane analysis by the refinery laboratory. The refinery laboratory commonly analyzes their process waste water for this compound. A single analyte was detected in each of these analyses, confirming that sulfolane was the unknown DRO compound. Additional water samples subsequently were collected from 23 monitoring wells, six observation wells, and one recovery well at the facility (Table 11), with all sulfolane analyses performed by the refinery's laboratory using their standard sulfolane protocol.

As with the soil samples, temperature and trip blanks accompanied the groundwater samples submitted to CT&E during the collection activities to check that sample temperatures were within the proper limits, and that no cross-contamination between samples occurred during sampling or transportation to the laboratory. Field duplicate samples were collected from MW-125 and analyzed for metals, whole fuels VOCs, and SVOCs; the RPD was calculated to assess sampling and laboratory error if both duplicates contained analytes above their PQL. Duplicate samples also were collected from MW-105A and MW-142 for analysis of GRO/BTEX and from MW-101 for analysis of DRO. Further QA/QC included the analytical laboratory's standard procedures as outlined in their QA plan on file with ADEC.

3.0 RESULTS

3.1 Soils

3.1.1 Metals

The soil samples collected from borings at the refinery were found to contain antimony, arsenic, barium, cadmium, chromium, lead, and silver. Mercury and selenium were not detected in soils. Of the metals detected, only arsenic exceeded the Alaska soil cleanup levels for the MTG pathway, with values ranging from 2.29 mg/kg in boring B-1 to 5.42 mg/kg in boring B-3 (Table 3). The soil cleanup level for arsenic is 2 mg/kg.

3.1.1.1 Metals QA/QC

RPDs calculated for metals detected in field duplicate samples were generally within Shannon & Wilson's acceptable range of 50 percent, with two exceptions. The RPDs calculated for samples collected from MW-135 were 15.5 percent for arsenic, 38.4 percent for chromium, and 57.8 percent for barium; RPDs were not calculable for the other metals determined in these samples, as the analytes were below their respective PQLs. For the soils collected from boring B-1, the RPDs were 5.1 percent for arsenic, 2.1 percent for barium, 0.3 percent for lead, and 66.3 percent for chromium; RPDs could not be calculated for the other metals determined in these samples, as the analytes were below their PQLs in one or both of the duplicates. The relatively high RPDs for barium in the MW-135 samples and chromium in the boring B-1 samples are likely due to soil sample heterogeneity; as noted above, both of these analytes were not detected at concentrations exceeding the Alaskan cleanup levels in any soil sample.

The laboratory reports indicated that the matrix spikes for barium, cadmium, and chromium were outside QC limits for the soil sample from MW-135, and outside the limits for antimony in the sample from MW-139. Post-digestion spikes (PDS) were performed for these samples and were within QC limits; therefore the data for these samples were not compromised.

3.1.2 Whole Fuels

Soil samples were found to contain GRO, DRO, and RRO, and three of the eight soil samples collected contained GRO and DRO at concentrations exceeding the soil cleanup levels (Table 4). These locations were: monitoring well MW-135 at the northern end of the refinery, south of the truck loading area; boring B-1 in the old bolted tanks area; and boring B-4 west of the rail loading area (Figure 1). The GRO MTG cleanup level is 300 mg/kg, and the DRO cleanup level is 250 mg/kg. No soil sample exceeded the cleanup level for RRO.

Samples collected from MW-135 (Figure 1) contained GRO at 7,730 mg/kg, DRO at 1,630 mg/kg, and RRO at 127 mg/kg. The data report stated the chemical pattern was consistent with a weathered middle distillate fuel or a possible crude oil pattern. Conversations with the analyst at CT&E, following a detailed review of the GRO and DRO chromatograms, indicated the observed patterns reflect the presence of Diesel #1 and Diesel #2, as well as gasoline range hydrocarbons.

Boring B-1 (Figure 1) also yielded samples exceeding the MTG soil cleanup levels for GRO and DRO. GRO were detected at 1,980 mg/kg, and DRO were present at 3,460 mg/kg; RRO were not detected in these samples. The chromatographic pattern for these samples was consistent with a middle distillate or weathered middle distillate.

Samples from boring B-4 (Figure 1) contained GRO at 381 mg/kg and DRO at 331 mg/kg; RRO were not detected. The observed chromatographic pattern was consistent with weathered middle distillate.

A sample from MW-139, west of the truck loading area and MW-127 (Figure 1), contained low levels of GRO (2.23 mg/kg; Table 4), as did a sample from boring B-2 (4.69 mg/kg; Table 4), located just east of the asphalt tanks (Figure1). Soil from MW-142, west of MW-139 (Figure 1), contained DRO at 17.3 mg/kg, and the chromatogram suggested the DRO was attributable to highly weathered middle distillate; GRO was not detected above the PQL in this sample, and an analysis for RRO was not performed. A sample from boring B-3 north of Crude Unit #1 (Figure 1) was found to contain DRO at 79.1 mg/kg and RRO at 82.4 mg/kg, and exhibited a chromatographic pattern with contributions from heavier molecular weight hydrocarbons, showing a possible lubricating oil pattern (Table 4). The sample from MW-140 did not contain detectable GRO, DRO, or RRO (Table 4). None of these samples exceeded the soil MTG cleanup levels.

3.1.2.1 Whole Fuels QA/QC

Field duplicate samples were collected from monitoring well MW-135 and from boring B-1, and RPDs were calculable for GRO and DRO in both these sample sets. The RPDs for the MW-135 samples were 2.1 and 40.6 percent for GRO and DRO, respectively. The RPDs calculated for the samples from boring B-1 were 71.4 percent for GRO and 95.8 percent for DRO. These latter RPDs exceed Shannon & Wilson's data quality objective of 50 percent; the reasons for RPD exceedances for these samples are not known, but it is likely soil sample heterogeneity accounts for much of the data variation.

The laboratory reports indicated that surrogate recoveries for GRO/BTEX did not meet QC goals for samples from MW-135, boring B1, and boring B4 due to sample dilution or matrix interferences; the reports stated the results were not adversely affected. Surrogate recoveries for DRO/RRO were outside the laboratory control limits for the same reasons as the samples from MW-135, boring B1, and boring B3.

3.1.3 Volatile Organic Compounds

VOCs were detected in five of the eight soil samples collected, with at least one analyte exceeding its MTG soil cleanup level in each of these. Samples from the boring for MW-140 north of the truck loading area (Figure 1), MW-142 and MW-139 west of the truck loading area (Figure 1), and boring B-3 north of Crude Unit #1 (Figure 1) did not contain detectable VOCs (Table 5). No chlorinated solvents were detected (excepting trichlorofluoromethane, or Freon 11, which is likely a laboratory contaminant; see below).

The sample from MW-135 (Figure 1) contained each of the BTEX analytes in excess of their respective MTG soil cleanup levels (Table 5); this sample was retrieved from the water table interface. Benzene was detected at 82.0 mg/kg, toluene at 398 mg/kg, ethylbenzene at 96.0 mg/kg, p- and m-xylenes at 348 mg/kg, and o-xylene at 134 mg/kg. In addition, a number of other alkylated benzenes were detected, but these analytes do not have ADEC soil cleanup levels.

A sample from MW-139, west of the truck loading area and MW-127 (Figure 1), was found to contain benzene at 0.0587 mg/kg at the water table interface, exceeding the MTG cleanup level of 0.02 mg/kg (Table 5). No other VOC analytes were detected in the sample.

Samples from 7.5 feet bgs in boring B-1, in the old bolted tanks area (Figure 1), contained a number of measurable VOCs, five of which exceeded their MTG soil cleanup levels (Table 5). These analytes were benzene (1.61 mg/kg), ethylbenzene (49.1 mg/kg), p- and m-xylenes (202 mg/kg), o-xylene (87.7 mg/kg), and naphthalene (53.7 mg/kg). Other alkylated benzenes also were detected (Table 5); no ADEC soil cleanup levels exist for these compounds.

The sample from the water table interface in boring B-2 near the asphalt tanks (Figure 1) contained benzene and several alkylated benzenes, but only benzene (at 0.0719 mg/kg) exceeded the soil MTG cleanup level (Table 5). Boring B-4 west of the rail loading area (Figure 1), yielded a sample at 7.5 feet bgs containing benzene (3.08 mg/kg) and ethylbenzene (5.58 mg/kg) above their respective MTG soil cleanup levels; several other alkylbenzenes also were detected (Table 5), but they do not have soil cleanup levels.

3.1.3.1 Volatile Organic Compounds QA/QC

Field duplicates were collected from MW-135 and from boring B-1. The RPDs, when calculable, were each below Shannon & Wilson's data quality objective of fifty percent, ranging from zero percent RPD to as high as 17.2 percent (data not shown). Temperature blanks accompanying the samples during sampling and transport to the laboratory demonstrated the samples were kept at the appropriate temperatures.

The trip blank for samples collected from MW-135 on March 8, 2001 (Table 5), contained trichlorofluoromethane (Freon 11), an analyte also detected in the samples from the boring. Conversations with the chemist at CT&E indicated they had been having problems with their refrigeration units in the laboratory, and this analyte is likely a laboratory contaminant. This same trip blank also contained p- and m-xylenes at 0.0146 mg/kg, which the CT&E chemist indicated was likely attributable to a "dirty station" in the laboratory (i.e., carryover from a previous sample analysis); at the low level detected, it was his opinion this result does not reflect cross-contamination among samples. No other anomalies were seen in this or the trip blank from the May 29th and 30th sampling event, and the sample results are considered representative of the soil conditions at the time of sample collection.

The laboratory reports indicated that laboratory and field surrogate recoveries did not meet QC goals in the MW-135 sample due to sample dilution; the QC RPD goals for the analyte chloroethane also were not met in this sample, resulting in an estimated value for chloroethane. Chloroethane was not detected in any refinery sample, so it is unlikely QC for this analyte was an issue for this sample. Surrogate recoveries for the field surrogate in the sample from boring B1 and the laboratory surrogate in the boring B4 sample did not meet QC recovery goals. Despite these variances from laboratory QC goals, the laboratory chemist indicated the analytical results were not significantly affected.

3.1.4 Semivolatile Organic Compounds

Five semivolatile analytes were detected in the soil samples collected from borings at the refinery, and only one sample contained an analyte exceeding the soil MTG cleanup level. This was the di-aromatic compound naphthalene, found in boring B-1 at a depth of 7.5 feet bgs at a concentration of 47.4 mg/kg (Table 6). The soil MTG cleanup level for naphthalene is 43 mg/kg. This analyte also was detected in the same sample in the VOC analysis (see above).

The other SVOC analytes detected were 2-methylnaphthalene, dibenzofuran, fluorene, and phenanthrene (Table 6). These analytes do not have an ADEC Method 2 MTG cleanup level.

3.1.4.1 Semivolatile Organic Compounds QA/QC

The internal standard, perylene-d12, was biased low in the MW-135 sample, possibly causing the result for phenanthrene to be biased high in this sample. The laboratory surrogate recovery was also biased high in this sample due to matrix interferences. The laboratory surrogate and internal standard recoveries were outside QC goals for the samples from boring B1. Other than causing a potentially high phenanthrene value, there was no indication from the laboratory that these anomalies adversely affected the data quality in these samples.

3.2 Groundwater

3.2.1 Metals

Of the nine metals determined in water samples collected from the monitoring wells (Table 7), eight were detected above their PQLs, though only arsenic in two samples (MW-110 and MW-116) was found to exceed the 18 AAC 75.350 Table C groundwater cleanup level. Antimony, barium, cadmium, chromium, lead, selenium, and silver also were detected; no water sample contained mercury.

A sample from MW-110 near the northeast corner of Lagoon B (Figure 1) contained arsenic at 55.1 µg/L; this well is screened from 13.5 to 18 feet bgs. MW-116, located beneath Crude Unit #1 (Figure 1) and screened from 12 to 17 feet bgs, yielded a sample containing arsenic at a concentration of 68.5 µg/L (Table 7). The groundwater cleanup level for this analyte is 50 µg/L. No other water samples contained metals exceeding their respective cleanup level.

3.2.1.1 Metals QA/QC

RPDs were able to be calculated for four metal analytes in the duplicate samples from MW-125. The RPDs were 6.4 percent for arsenic, 2.0 percent for barium, zero percent for cadmium, and 0.2 percent for silver; RPDs were not calculable for the other analytes as they were not detected in the samples above their PQLs. The calculated RPDs were each within Shannon & Wilson's data quality objective of 50 percent. No laboratory QA/QC problems were reported.

3.2.2 Whole fuels

Whole fuels analysis performed on water samples from the monitoring wells demonstrated the presence of GRO and DRO in groundwater at some areas of the refinery. RRO was not found above its PQL (about 0.990 mg/L) in any water sample. GRO exceeded the groundwater cleanup level in samples from MW-110, MW-115, MW-116, MW-135, and MW-139; DRO also exceeded the cleanup level in these wells, as well as in MW-130 (Table 8). GRO and DRO were seen in some other water samples at levels below their respective groundwater cleanup levels.

The sample from MW-110 at the northeast corner of Lagoon B (Figure 1) contained GRO at 8.69 mg/L and DRO at 2.87 mg/L, both exceeding their groundwater cleanup levels of 1.3 mg/L and 1.5 mg/L, respectively. The laboratory report indicated the chromatographic pattern was consistent with weathered middle distillate or highly weathered gasoline.

The MW-115 water sample, from the well just west of the blending and metering unit and north of Crude Unit #2 (Figure 1), also contained GRO and DRO above the groundwater cleanup levels. GRO was present at 5.62 mg/L and DRO was found at 2.44 mg/L. The chromatographic patterns for this location indicated the presence of weathered gasoline or weathered middle distillate.

Samples taken from MW-116 beneath Crude Unit #1 (Figure 1) contained the highest whole fuel concentrations seen in water samples, with GRO at 36.8 mg/L and DRO at 4.57 mg/L (Table 8). The chromatograms indicated the hydrocarbon pattern was consistent with weathered gasoline.

The sample from MW-130 near the asphalt tanks (Figure 1) contained both GRO and DRO, though only DRO was found at a concentration (1.66 mg/L) above the groundwater cleanup level (Table 8). The chromatographic pattern was consistent with weathered gasoline or weathered middle distillate.

MW-135 yielded water samples containing the second highest levels of whole fuels, with GRO at 32.9 mg/L and DRO at 3.38 mg/L (Table 8). The laboratory report indicated the DRO was an unknown hydrocarbon with several peaks. As noted above, the soils from this boring contained high levels of GRO and DRO as well, and the analyst at CT&E suggested the chromatograms showed the presence of a mixture of Diesel #1 and Diesel #2 as well as gasoline hydrocarbons. The report of an "unknown hydrocarbon with several peaks" in water samples from this well is consistent with the mixture of fuel hydrocarbons seen in soil data from this boring.

Water from MW-139 also exceeded the Alaska GRO and DRO groundwater cleanup levels. The GRO concentration was 2.98 mg/L, and the DRO concentration was 1.59 mg/L. The laboratory report indicated the DRO chromatographic pattern showed an "unknown hydrocarbon with several peaks." This suggests the potential presence of a mixture of petroleum products.

GRO was found in duplicate samples from MW-125 (at 0.184 mg/L and 0.214 mg/L) and in a sample from MW-127 (1.01 mg/L; Table 8). Neither of these locations exhibited DRO above its PQL, and the GRO concentrations were below the groundwater cleanup level.

GRO was also detected in a sample collected on May 10, 2001, from MW-105 (0.153 mg/L; Table 8), located at the southern and upgradient end of the refinery (Figure 1) and screened from 58 to 63 feet bgs. As this datum conflicted with the historical data set at that location, this and the adjacent well MW-105A (screened from 18 to 23 feet bgs) were subsequently resampled on June 13, 2001, to verify the result. The resampling indicated GRO was not present in water from this well or MW-105A, and there is no explanation for the initial observation of GRO in the original sample.

An analyte in the DRO range was detected in May 10, 2001, water samples from the cluster of wells MW-101 and MW-101A located northwest of the main part of the refinery (Figure 1), yielding DRO values of 0.818 mg/L and 1.20 mg/L, respectively (Table 8). The analytical laboratory stated there was an unknown hydrocarbon peak in the C_{12} to C_{13} alkane range, indicating the elevated DRO concentrations were likely not attributable to whole fuels, which would show a pattern with a broader distribution of analytes. These wells were subsequently resampled for DRO analysis only on July 26, 2001; duplicate samples were collected at the same time for analysis by the refinery laboratory in order to determine whether the unknown DRO analyte was sulfolane. The same single analyte was present in the July DRO analysis samples from these wells, and only sulfolane was detected in the water samples analyzed by the refinery laboratory. It was therefore apparent that sulfolane was the unknown analyte eluting in the DRO range. This prompted collection of additional water samples from other monitoring wells for sulfolane analysis, the results of which are addressed below.

3.2.2.1 Whole fuels QA/QC

RPDs for the duplicate samples collected from MW-125 could only be calculated for GRO, as DRO and RRO from duplicate samples were not detected above their PQLs. The RPD for GRO from this well was 15.1 percent. The additional samples collected from MW-101 for concurrent DRO and sulfolane analyses were submitted to CT&E in duplicate; the resulting RPD for the DRO analysis was 11.2 percent. Duplicate samples from MW-142 yielded RPDs of 1.2 percent for GRO and 8.3 percent for DRO. These RPDs are within Shannon & Wilson's acceptable limit of 50 percent. No RPD could be calculated for GRO duplicates from MW-105A, as this analyte was not detected above the PQL.

The laboratory reports indicated that surrogate recoveries were biased high or low due to matrix interference or sample dilution, respectively, for water samples from MW-110, MW-115, MW-116, MW-127, and MW-139. The analyst stated these biases did not affect the results for any of these samples. For the MW-140 sample the GRO calibration validation was high; this did not affect the analytical results.

3.2.3 Volatile Organic Compounds

Volatile organic compounds were detected in a number of groundwater samples from the refinery. Of the 15 VOC analytes detected in groundwater samples (Table 9), three (benzene, toluene, and ethylbenzene) were found that exceeded the groundwater cleanup levels. Two chlorinated hydrocarbon analytes (1,1-dichloroethene and cis-1,2-dichloroethene) also were detected in a few water samples, but their concentrations were below the Table C cleanup levels. A number of alkylated benzene derivatives were also detected in a few wells, but these analytes do not have groundwater cleanup levels.

The sample from MW-110 near Lagoon B (Figure 1) contained benzene at 3,080 µg/L, exceeding the Table C benzene cleanup level of 5 µg/L (Table 9). The other BTEX analytes, as well as a number of alkylated benzenes and naphthalene, were also detected in this sample. Naphthalene was present below its Table C cleanup level, and no cleanup levels exist for the alkylated benzenes. No chlorinated compounds were detected at this location.

Monitoring well MW-115 yielded a sample also exceeding the groundwater cleanup level for benzene, with a concentration of 966 µg/L (Table 9). Other BTEX analytes, alkylated benzenes, and naphthalene also were detected; the other BTEX compounds and naphthalene were below their respective cleanup levels, and no cleanup levels exist for the other detected analytes. The chlorinated compound 1,1-dichloroethene (1,1-DCE) also was detected in this sample at 1.57 µg/L but below its Table C cleanup level of 7 µg/L.

Benzene and ethylbenzene were detected above their Table C levels in MW-116 (Table 9) located under Crude Unit #1 (Figure 1). Benzene was detected at 3,960 µg/L, and ethylbenzene at 753 µg/L. As with MW-110 and MW-115, a variety of other alkylated benzene derivatives were detected above their PQLs, but no groundwater cleanup levels exist for these analytes. The chlorinated compound cis-1,2-dichloroethene also was detected but at 2.84 µg/L, well below the Table C cleanup level of 70 µg/L.

Benzene and toluene were above their respective groundwater cleanup levels in the sample from MW-135, with benzene at 5,470 µg/L and toluene at 3,980 µg/L (Table 9). The other BTEX analytes were also present above their PQLs but below cleanup levels.

Benzene exceeded the Table C cleanup levels in samples from wells MW-125 (90.0 µg/L), MW-127 (170 µg/L), MW-130 (55.5 µg/L), and MW-139 (110 µg/L), each located in the northern area of the refinery facility (Figure 1). These samples also contained other BTEX compounds as well as other alkylated benzenes, but those analytes with groundwater cleanup levels did not exceed them. The samples from MW-125 and MW-130 also contained naphthalene and 1,1-DCE below their Table C cleanup levels, and MW-127 was found to contain the fuel oxygenate compound methyl-tert-butyl ether (MTBE) at 27 µg/L (Table 9).

As noted for the whole fuels analysis (see above), the initial groundwater sampling on May 10, 2001, at wells MW-105 and MW-105A unexpectedly indicated the presence of hydrocarbons in these wells. A sample was retrieved on this date from the deeper of the wells (MW-105, screened from 58 to 63 feet bgs) containing each BTEX analyte, though at concentrations below their respective groundwater cleanup levels (Table 9). The shallower of the wells, MW-105A (screened from 18 to 23 feet bgs), also yielded a sample on this date containing toluene, ethylbenzene, and xylenes below their cleanup levels (Table 9). Subsequent resampling of these wells for GRO/BTEX on June 13, 2001, produced samples in which GRO and BTEX compounds were not detectable above their PQLs (Table 9). We do not know the reason for the apparently anomalous detections of GRO or BTEX in these wells for the May samples, as there is no indication in the laboratory reports of laboratory- or field-caused contamination.

3.2.3.1 Volatile Organic Compounds QA/QC

RPDs could be calculated for three analytes detected above their PQLs in duplicate samples collected from MW-125 on May 10, 2001. The RPD was 23.7 percent for benzene, 18.2 percent for isopropylbenzene (cumene), and 9.67 percent for 1,1-DCE. RPDs were not calculable for the duplicate samples collected from MW-105A on June13, 2001, and analyzed for BTEX, as no analyte was detected above its PQL. Duplicates from MW-142 contained low levels of toluene (1.0 and 1.2 µg/L), allowing an RPD of 18.2 percent to be calculated for this analyte. Trip blanks for all sampling dates were found to be free of detectable hydrocarbons, and the temperature blanks indicated the samples were kept in the proper temperature range during sampling and transportation to the laboratory for analysis.

The laboratory report for MW-110 indicated that the results for n-propylbenzene, sec-butylbenzene, and n-butylbenzene are likely to be biased high. The trip blank for samples collected June 13, 2001, was biased high for 4-bromofluorobenzene, but the laboratory chemist stated the results for associated samples were not affected.

3.2.4 Semivolatile Organic Compounds

Four semivolatile organic compounds were detected in groundwater samples. Naphthalene was detected in samples from MW-110 (11 µg/L), MW-115 (33 µg/L), and MW-116 (120 µg/L) at concentrations below the Table C groundwater cleanup level of 1,460 µg/L (Table 10). The compound 2-methylnaphthalene also was detected in these samples at similar concentrations (Table 10); no groundwater cleanup level is available for this compound. The compound 2,4-dimethylphenol was detected in MW-115 and MW-116 at 15 µg/L and 22 µg/L, respectively; no groundwater cleanup level exists for these analytes. The field duplicate from MW-125 (Table 10) was found to contain di-n-octylphthalate at 12 µg/L; no ADEC cleanup level exists for this compound.

3.2.4.1 Semivolatile Organic Compound QA/QC

No RPD could be calculated for semivolatile analytes, as the only analyte (di-n-octylphthalate) detected in the samples from MW-125 was not present above the PQL in each duplicate.

The laboratory reports indicated the laboratory control spike and its duplicate were outside QC goals for 1,3-dichlorobenzene and benzoic acid for samples from MW-110, MW-115, MW-116, MW-125, MW-127 and MW-130; these compounds were not found in any samples from that extraction batch, and the results were not significantly affected. The QC RPD goal for pyridine was not met in the sample from MW-110; therefore, the result for pyridine was estimated in this sample. Pyridine was not detected in any soil or water sample at the refinery, and it is not expected this laboratory anomaly adversely affected sample results.

Surrogate recoveries were biased low for acid extractable analytes in samples from MW-125 and MW-130; results for acid extractables could be biased low for these samples. Acid extractables include benzoic acid and the phenol series of analytes. The only detected analyte in this class of compounds is 2,4-dimethylphenol, found in samples from MW-115 and MW-116. No semivolatile analytes were detected in water samples from MW-125 and MW-130.

3.2.5 Sulfolane

Following the initial observation of a "diesel range organic" analyte in MW-101 and MW-101A, further analytical efforts were undertaken as described above, and the analyte was identified as sulfolane. Samples were subsequently collected from 30 locations, and sulfolane was identified as being present in groundwater samples from eight monitoring wells, two observation wells, and one recovery well (Table 11; Figure 2). The highest concentration (32 mg/L) was found in water from well MW-138, just north of Crude Unit #2. A sample from observation well S-20 near the old bolted tanks area had the next highest sulfolane value (13 mg/L), and other wells yielded water containing sulfolane ranging from below the analytical method detection limit (either 0.2 mg/L or 2 mg/L) to 8 mg/L (Table 11).

4.0 DISCUSSION

The main reason for performing this sampling exercise was to determine the potential types of contamination present at the refinery. Therefore, the analyses were generally performed on samples from locations expected to contain environmental contaminants, or from areas anticipated to be free of contamination, either to evaluate the presence of analytes at natural "background" concentrations (metals) or demonstrate the absence of contamination. Whole fuels analyses are of somewhat limited value in this context, except that chromatographic patterns may allow for the distinction between "fresh" and "weathered" petroleum contamination. The detailed contaminant characterization provided by VOC and SVOC analyses affords a more useful evaluation of potential hydrocarbon contaminants at the refinery. The results of each of these analyses are discussed below.

4.1 Metals

The results of the metals analyses performed on soil and water samples from the refinery demonstrated the presence of several metals at a range of concentrations (Tables 3 and 7). Soil data generally appeared to exhibit less variability than the water data; soil values varied by a factor of two or three, while water values varied by as much as a factor of 10 among samples collected from various refinery locations. Of the nine metals for which soil analyses were performed, seven were detected above their PQLs, but only arsenic (As) was found to exceed the MTG pathway soil cleanup level of 2 mg/kg (Table 3). Concentrations of arsenic in soil samples from the various borings ranged from a low of 2.29 mg/kg at boring B-1 up to 5.42 mg/kg at boring B-3 (Figure 1), and each boring produced a sample containing As above the MTG cleanup level. Arsenic also was the only metal found to exceed the groundwater cleanup level of 50 μg/L in water samples collected at the refinery (Table 7); this occurred in samples from MW-110 (55.1 μg/L) and MW-116 (68.5 μg/L).

Arsenic is not a metal known to be associated with crude oil, refined petroleum product, or the process of refining, and is therefore not likely to be a soil or groundwater contaminant resulting from refinery practices. This metal is, however, known to be a common element found in soils and waters throughout the Fairbanks area, and arsenopyrite (FeAsS) is one of the most common and widespread secondary minerals in the Fairbanks district.

A study performed by the Alaska District U.S. Army Corps of Engineers (*Background Data Analysis for Arsenic, Barium, Cadmium, Chromium, & Lead on Fort Wainwright, Alaska*, March 1994) reviewed available soil and water data in the area of Fort Wainwright, and performed statistical analyses to assess the distribution of naturally occurring metals concentrations in area soils and groundwater. Soil metals data from locations north and south of the Chena River were found to be significantly different, so soil metal concentration means and 95 percent upper confidence limits (UCLs) were computed separately for each geographic data set. Groundwater data were not determined to be different with respect to location north or south of the Chena River; therefore the groundwater metals data were treated as a single data set, irrespective of location, for determining concentration means and UCLs.

Based on the analyses of data distributions and resulting mean and UCL calculations, the Corps of Engineers report generated recommended background values for Ft. Wainwright, which were based on the 95 percent UCL plus or minus one standard deviation. The UCL was used as the average concentration because of uncertainty in the data distribution average; as the sample size increases, the UCL moves closer to the "true" mean concentration. The Corps recommended that action levels be set to one standard deviation above the UCL to avoid expending resources to investigate samples within normal laboratory variation of the background value.

For soils south of the Chena River the Corps computed an As background UCL of 8.46 mg/kg using 58 sample values. The Corps data ranged from 0.135 mg/kg to 29 mg/kg, with a standard deviation of 6 mg/kg. Thus the value recommended by the Corps as background for As in soils is 14.46 mg/kg (i.e., the UCL plus the standard deviation), substantially higher than the highest soil As concentration measured (5.42 mg/kg; Table 3) in the sample from boring B-3 at the refinery (Figure 1). In our opinion, the concentrations of As seen in soil samples at the refinery represent naturally occurring background concentrations and should not be cause for any cleanup action.

For groundwater both north and south of the Chena River the Corps calculated a 95 percent UCL of 36.24 μg/L for arsenic, using 159 sample values. The data ranged from 1 μg/L to 230 μg/L, with a standard deviation of 36 µg/L. Therefore, their recommended background value was set at 72.24 µg/L (i.e., the UCL plus one standard deviation) as an action level. The two samples exceeding the Table C groundwater cleanup level for arsenic (MW-110 and MW-116) were both below this concentration. It is our opinion that these, too, represent naturally occurring background concentrations not attributable to refinery operations and should not be cause for remedial action.

4.2 Petroleum Hydrocarbons

Some whole fuels were detected above their soil or groundwater cleanup levels at several refinery locations (Table 4 and Table 8). Analyses performed on refinery soil samples indicated hydrocarbon contamination was present in soils to the water table (approximately 10 feet bgs) at a number of locations (Table 4), with Alaska MTG levels exceeded for GRO and DRO in borings B-1 and B-4 and monitoring well MW-135 (Figure 1). The chromatographic patterns associated with soil samples suggest the presence in soil of petroleum products generally in the middle distillate range. The soil sample from MW-135 exhibited a pattern consistent with a weathered middle distillate as well as a possible crude oil pattern (Table 4). As noted in the Results section, the analyst at CT&E indicated that Diesel #1 and Diesel #2, as well as gasoline range hydrocarbons, probably contributed to the observed patterns. The boring north of Crude Unit #1 (B-3; Figure 1) appeared to contain hydrocarbons in the heavier molecular weight range, though the DRO and RRO measured were below their respective cleanup levels.

Water samples exceeding the groundwater cleanup levels for whole fuels were obtained from MW-110, MW-115, MW-116, MW-130, MW-135, and MW-139 (Table 8). Except for the last two locations, these samples produced chromatograms indicative of weathered middle distillate or weathered gasoline. Laboratory reports for MW-135 and MW-139 stated the DRO/RRO chromatograms exhibited an "unknown hydrocarbon with several peaks." As with the soil sample data for MW-135, it is likely these chromatograms represent mixtures of refined fuel hydrocarbons, giving rise to patterns not specifically attributable to a single product.

As noted above, the main reason for performing this sampling exercise was to determine the potential types of contamination present at the refinery. Whole fuels analysis is of limited value in this context, though evaluation of chromatographs associated with this type of analysis does allow characterization of petroleum contaminant source material as "fresh" or "weathered." Examination of the chromatographic results indicates most of the material detected in the subsurface was weathered petroleum product. This suggests the hydrocarbon sources further characterized by VOC and SVOC analyses (discussed below) are likely generally attributable to older petroleum product releases. The VOC and SVOC data address the individual contaminant analytes of potential environmental interest at the refinery.

The hydrocarbon contaminants in soil and water that exceeded their associated cleanup levels were restricted to the BTEX compounds and naphthalene (Table 5, Table 6, and Table 9). BTEX components exceeded their cleanup level in several soil and water samples (Tables 5 and 9), but naphthalene only exceeded its cleanup level in a soil sample from boring B-1 (Tables 5 and 6) in the old bolted tanks area (Figure 1).

In the northern portion of the refinery, benzene was consistently the single petroleum contaminant exceeding either the soil or groundwater cleanup levels. Each of the BTEX analytes exceeded their soil MTG pathway cleanup levels in the samples from monitoring well MW-135 (Table 5) in the northeast area of the refinery, south of the truck loading area (Figure 1). The presence of these analytes is consistent with the high levels of GRO (7,730 mg/L) detected in the same samples (Table 4). Benzene also was found to exceed the MTG soil level (Table 5) in MW-139 (west of MW-127; Figure 1) and boring B-2 (north of MW-130; Figure 1), as well as its groundwater cleanup level in wells MW-125, MW-135, MW-130, MW-127, and MW-139 (Table 9); no other VOC or SVOC analytes were detected above their cleanup levels in these samples. Wells MW-140 and MW-142, north and west of the truck loading area, respectively (Figure 1), did not contain petroleum contamination above the soil or groundwater cleanup levels, though MW-142 yielded water samples containing measurable GRO and DRO (Table 8) and a soil sample containing DRO (Table 4). Soil collected from boring B-4, west of the rail loading area (Figure 1), contained benzene and ethylbenzene above their MTG pathway soil cleanup levels (Table 5).

The groundwater samples collected in the southern portion of the refinery (MW-110, MW-116, and MW-115; Figure 1) each contained benzene exceeding the groundwater cleanup level (Table 9). The MW-116 sample from beneath Crude Unit #1 also contained ethylbenzene above its cleanup level (Table 9).

The boring placed at the location of the old bolted tanks (B-1; Figure 1) produced soil samples exceeding the MTG pathway soil cleanup levels for BTEX and naphthalene. This location is the only one where naphthalene was found to exceed a soil or groundwater cleanup level. Naphthalene and alkyl-substituted naphthalenes are common constituents of gasoline, JP-4, and diesel fuel oils.

As noted in the Results section, the chlorinated compounds 1,1-DCE and cis-1,2-dichloroethene were detected in groundwater samples (no soil samples), but these analytes were not reported above the Table C groundwater cleanup levels. The samples containing 1,1-DCE were localized in the southern area of the refinery near Crude Units #1 and #2 (MW-116 and MW-115; Figure 1), and in the northern area just south of the truck loading area (MW-130 and MW-125; Figure 1). The compound cis-1,2-dichloroethene was detected in only a single water sample from MW-116 (2.84 μg/L), well below the Table C groundwater cleanup level of 70 μg/L. In 1986 and 1987 seven drums of spent Navy Brand solvent were emptied into the oily water sump system, which was subsequently found to be leaking. The solvent contained greater than 11.2 percent 1,1,1-trichloroethane and 35.8 percent dichloromethane. It is not known whether other chlorinated compounds may have been present as constituents of the solvent, but it is possible the chlorinated compounds detected recently were either constituents of, or decomposition products from the Navy Brand solvent. In the course of a RCRA Facility Assessment (RFA) and related cleanup activities the refinery obtained clean closure of the RFA units associated with the Navy Brand solvent contamination.

The compound MTBE was detected in a single water sample (MW-127) at a concentration of 27 µg/L. This compound is not currently considered to be a carcinogen, and it does not have an Alaska groundwater cleanup level.

4.3 Sulfolane

Sulfolane is used at the refinery to increase the aromatic compound content of some refined petroleum products. It was detected in groundwater at the highest concentration in a sample from MW-138 (32 mg/L; Table 11) near Crude Unit #2, where it is used for this purpose. Based on the results of samples from 30 locations, it is unclear whether Crude Unit #2 is the only source of this analyte. Sulfolane is also stored in Tank 194 east of Lagoon A and west of Crude Unit #1 (Figure 2). The subsurface distribution of sulfolane appears to exist as a groundwater plume (or plumes) trending generally to the northwest from Crude Unit #2 and Tank 194. Several wells north and west of MW-138 (i.e., MW-115, MW-116, S-34, S-41, S-36; Figure 2) did not produce water samples with sulfolane above the method detection limit (MDL) of 0.2 mg/L for these samples. Northwest and downgradient of S-34, sulfolane was detected in well S-20 at its second highest level observed at the refinery (13 mg/L). Further northwest from S-20 the concentration decreases with distance downgradient, and sulfolane was not detected above the MDL of 2 mg/L for samples from MW-139, MW-127, and MW-142.

Samples from MW-109, MW-110, MW-111, MW-113, MW-101, and MW-101A indicate there may be another distinct plume of sulfolane along the western portion of the refinery (Table 11; Figure 2). Given that no water sample collected between MW-138 and MW-109 contained measurable concentrations of sulfolane, it appears that another source of this analyte may be present in the area of Lagoon B (Figure 2); this source may be the area of Tank 194.

Sulfolane was not detected in samples from the refinery's eastern wells (MW-134, S-36, S-37, MW-132) or those north of the refinery (MW-125, MW-129, MW-126, MW-118, MW-140, MW-131, and MW-104). It was also not detected in MW-106, west of Lagoon B (Figure 2).

A search of the scientific literature yielded some information about the transport characteristics, environmental fate, and toxicity of this compound. Sulfolane is essentially nonvolatile, is quite soluble in water (3.79×10^5 mg/L), and has a low octanol-water partition coefficient (log K_{ow} = -0.77), indicating its migration is minimally retarded in the subsurface. It does not interact significantly with soil organic matter or with the clay mineral fraction of soil and is relatively inert. Aerobic biodegradation of sulfolane has been demonstrated in laboratory and field studies, but anaerobic sulfolane biodegradation in the subsurface environment is considered unlikely. Toxicity studies of sulfolane using mice, rats, and guinea pigs determined LD_{50} values of 1.8 to 2.5 g per kg body weight for orally administered sulfolane. It did not have toxic systemic or irritant effects when applied to guinea pig skin, and other studies demonstrated living human skin exhibits little permeability to sulfolane (0.2 g per square meter per hour). Based on these studies it is apparent sulfolane exhibits low levels of toxicity.

Sulfolane is not known to be a carcinogen, and there are no groundwater cleanup levels or risk-based concentrations for this compound.

5.0 CONCLUSIONS

Shannon & Wilson's *Draft Site Characterization and Corrective Action Plan, Williams Alaska Petroleum, Inc., North Pole Refinery*, dated December 2000, designated various analytes as contaminants of interest (COIs) at the refinery if they exceeded either the groundwater cleanup level or the soil MTG pathway cleanup level. Benzene, toluene, ethylbenzene, antimony, cadmium, and lead were potential groundwater COIs based on the most recent sample data available up to that time. Potential soil COIs were identified to be benzene, ethylbenzene, toluene, xylenes, methylene chloride, antimony, arsenic, chromium (total), and selenium. We suggested the above analytes should be considered as preliminary COIs, pending collection and analysis of the samples collected in this study.

Based on the results of the soil and groundwater sampling Shannon & Wilson performed at the refinery through August 2001, it is our opinion that the BTEX compounds should remain COIs at the facility. These compounds were detected above either the groundwater cleanup level or the soil MTG pathway cleanup level at various locations at the refinery during this sampling effort. The other analytes identified as COIs based on earlier data generally were not observed above the relevant cleanup levels. The presence of arsenic above the soil and groundwater cleanup levels appears to be due to naturally occurring levels of this metal and is not likely to be related to refinery practices. Naphthalene was only detected above the soil MTG cleanup level in boring B-1 and does not appear to be a widespread contaminant at the refinery.

Consideration of the physical properties of the hydrocarbon contaminants detected suggests that benzene remains the best analyte to measure to track petroleum contamination potentially migrating from the refinery property. Contaminant migration in aquifers is primarily controlled by two physical properties: the aqueous solubility of the compound and its tendency to sorb to the subsurface soil matrix. The latter factor can be estimated using the compound's octanol-water partition coefficient (K_{ow}), which measures the equilibrium distribution of the compound between an organic (nonpolar) and aqueous phase. As K_{ow} values commonly occur over a large range for various compounds, the log K_{ow} is typically reported. High log K_{ow} values indicate a compound has a greater tendency to sorb to the aquifer matrix, thereby increasing the probability its subsurface migration would be retarded.

The hydrocarbon analytes found to exceed either the soil or groundwater cleanup levels have the following approximate aqueous solubilities (solubility varies as a function of temperature and other solute concentrations) and log K_{ow} values:

Compound	**Aqueous Solubility (mg/L)**	**Octanol-Water Partition Coefficient (log K_{ow})**
Benzene	1780	2.13
Toluene	515	2.69
Ethylbenzene	152	3.13
p&m-Xylenes	215 and 160	3.18 and 3.20
o-Xylene	220	3.15
Naphthalene	31	3.37

As is evident from the above data, benzene is the most soluble, and its migration in the subsurface is the least likely to be retarded. Benzene also has the most stringent groundwater cleanup level. It is therefore our opinion that benzene is the most appropriate analyte to track migration of hydrocarbons in the subsurface at the refinery. Therefore, continued monitoring of the BTEX compounds appears appropriate and should be sufficient to detect subsurface movement of dissolved petroleum compounds in groundwater at the refinery.

6.0 LIMITATIONS

This report presents conclusions based on analysis of samples collected in areas of the refinery chosen to yield the greatest potential variety of contaminants. The locations sampled may not represent the highest levels of contamination present at the site, and were not generally chosen to delineate the extent of contamination at the site. It was not the intent of our exploration to detect the presence of soil or groundwater affected by contaminants other than those for which laboratory analyses were performed. No conclusions can be drawn regarding the presence or absence of other contaminants.

The data presented in this report should be considered representative of the time of our observations and sample collection. Changes due to natural forces or human activity can occur on the site. Because of such changes beyond our control, our observations and interpretations may need to be revised. In addition, there can be no assurance that a regulatory agency or its staff will reach the same conclusions as Shannon & Wilson.

We trust this information is sufficient for your needs at this time. Please contact me if you wish to discuss them further.

Sincerely,

SHANNON & WILSON, INC.

Jon Lindstrom, Ph.D.
Senior Chemist

Table 1. Soil sample locations, depths, and analyses.

Location	Description	Sample Identification	Date Collected	Depth (feet bgs)	Metals	GRO (& BTEX)[1]	DRO/RRO	VOCs	SVOCs
MW-135	Northeast area of refinery, south of truck loading rack	10833-030801-4	3/8/01	10.0 - 11.5	X	X	X	X	X
MW-135	Northeast area of refinery, south of truck loading rack	10833-030801-5[2]	3/8/01	10.0 - 11.5	X	X	X	X	X
MW-139	West of rail loading area and MW-127	1066-052901-MW139-4	5/29/01	10.0 - 11.5	X	X	X		
MW-140	North of truck loading rack.	1066-052901-MW140-3	5/29/01	7.5 - 9.0	X	X	X		
MW-142	West of rail loading area and MW-139	1066-001-01-SL	8/10/01	7.5-9.0		X	X[3]		
B1	Central portion of refinery, in old bolted tanks area	1066-053001-B1-3	5/30/01	7.5 - 9.0	X	X	X	X	X
B1	Central portion of refinery, in old bolted tanks area	1066-053001-B1-4[4]	5/30/01	7.5 - 9.0	X	X	X	X	X
B2	Near asphalt tanks, north of MW-130	1066-053001-B2-4	5/30/01	10.0 - 11.5	X	X	X	X	X
B3	North of crude unit #1	1066-053001-B3-4	5/30/01	10.0 - 11.5	X	X	X	X	X

Table 1. Soil sample locations, depths, and analyses.

Location	Description	Sample Identification	Date Collected	Depth (feet bgs)	Metals	GRO (& BTEX) [1]	DRO/RRO	VOCs	SVOCs
B4	West of rail loading area, near MW-113	1066-053001-B4-3	5/30/01	7.5 - 9.0	X	X	X	X	X
--		Trip Blank	3/8/01	--		X		X	
--		Trip Blank	5/30/01	--		X		X	
--		Trip Blank	8/10/01	--		X			

[1] BTEX analytes were determined in those samples not also analyzed for other VOCs

[2] Duplicate of sample 10833-030801-4

[3] Sample analyzed for DRO only

[4] Duplicate of sample 1066-053001-B1-3

Table 2. Groundwater sample locations, depths, and analyses.

Location	Sample Identification	Date Collected	Screen Depth (feet bgs)	Metals	GRO (& BTEX) [1]	DRO/RRO	VOCs	SVOCs
MW101	1066-051001-MW101	5/10/01	56-61	X	X	X		
MW101	1066-072601-MW101	7/26/01	56-61			X [3]		
MW101	1066-072601-MW201 [2]	7/26/01	56-61			X [3]		
MW101A	1066-051001-MW101A	5/10/01	18-23		X	X		
MW101A	1066-072601-MW101A	7/26/01	18-23			X [3]		
MW105	1066-051001-MW105	5/10/01	58-63	X	X	X		
MW105	1066-061301-MW1005	6/13/01	58-63		X			
MW105A	1066-051001-MW105A	5/10/01	18-23	X	X	X		
MW105A	1066-061301-MW105A	6/13/01	18-23		X			
MW105A	1066-061301-MW105B [4]	6/13/01	18-23		X			
MW106	1066-051001-MW106	5/10/01	18.5-23		X	X		
MW110	1066-061301-MW110	6/13/01	13.5-18	X	X	X	X	X
MW115	1066-051001-MW115	5/10/01	12.5-17	X	X	X	X	X
MW116	1066-051001-MW116	5/10/01	12-17	X	X	X	X	X
MW125	1066-051001-MW125	5/10/01	19.5-24	X	X	X	X	X
MW125	1066-051001-MW225 [5]	5/10/01	19.5-24	X	X	X	X	X
MW127	1066-051001-MW127	5/10/01	20-24.5	X	X	X	X	X
MW130	1066-051001-MW130	5/10/01	19-23	X	X	X	X	X
MW133	1066-051001-MW133	5/10/01	17.5-22		X	X		
MW135	1066-071901-MW135	7/19/01	10.57-19.49		X	X		
MW139	1066-071901-MW139	7/19/01	5.7-25.2		X	X		
MW140	1066-071901-MW140	7/19/01	4.2-23.5		X	X		
MW142	1066-081301-MW142	8/13/01	5.35-19.35		X	X		

Table 2. Groundwater sample locations, depths, and analyses.

Location	Sample Identification	Date Collected	Screen Depth (feet bgs)	Metals	GRO (& BTEX) [1]	DRO/RRO	VOCs	SVOCs
MW142	1066-081301-MW242 [6]	8/13/01	5.35-19.35		X	X		
--	Trip blank	7/19/01	--		X		X	
--	Trip blank	8/13/01	--		X		X	
--	Trip blank	6/13/01	--		X		X	
--	Trip blank	5/10/01	--		X		X	

[1] BTEX analytes were determined in those samples not also analyzed for other VOCs (VOC analysis includes BTEX)

[2] Sample is duplicate of 1066-061301-MW105A

[3] Sample is duplicate of 1066-051001-MW125

[4] Sample is duplicate of 1066-072601-MW101

[5] Sample analyzed for DRO only

[6] Sample is duplicate of 1066-081301-MW142

Table 3. Concentrations of metals in Williams North Pole refinery soil boring samples.

Location	Date	Depth (feet bgs)	Antimony (mg/kg)	Arsenic (mg/kg)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)
Soil Cleanup Level [1] →			3.6	2	1,100	5	26	1,000 [2]	1.4	3.5	21
MW135	3/8/01	10.0 - 11.5	<0.893	**3.51**	50.6	<0.0447	14.3	<5.58	<0.0418	<0.447	<0.179
MW135 [3]	3/8/01	10.0 - 11.5	<0.957	**4.10**	91.7	<0.0478	21.1	<5.98	<0.0391	<0.478	<0.191
MW139	5/29/01	10.0 - 11.5	0.342	**4.86**	61.8	0.257	13.8	4.58	<0.0386	<1.14	<0.114
B-1	5/30/01	7.5 - 9.0	0.324	**2.41**	60.0	<0.206	10.6	3.79	<0.0355	<1.03	<0.103
B-1 [4]	5/30/01	7.5 - 9.0	<0.285	**2.29**	61.3	<0.190	21.1	3.78	<0.0357	<0.952	<0.0952
B-2	5/30/01	10.0 - 11.5	<0.299	**2.63**	52.0	0.279	13.3	3.70	<0.0349	<0.998	<0.0998
B-3	5/30/01	10.0 - 11.5	0.366	**5.42**	103	0.469	21.9	7.48	<0.0415	<1.01	0.107
B-4	5/30/01	7.5 - 9.0	<0.328	**3.88**	59.7	0.219	15.3	4.03	<0.0378	<1.09	<0.109
MW140	5/29/01	7.5 - 9.0	<0.314	**2.66**	60.6	<0.209	8.17	3.43	<0.0357	<1.05	<0.105

Notes:

Bold face type values are greater than soil cleanup levels.

[1] 18AAC75.341 Table B Method Two soil cleanup levels for migration to groundwater (< 40 inches of annual precipitation zone).

[2] Industrial land use soil cleanup level.

[3] Duplicate sample

[4] Duplicate sample

Table 4. Whole fuels concentrations in samples from soil borings.

Location	Date	Depth (feet bgs)	GRO (mg/kg)	DRO (mg/kg)	RRO (mg/kg)	Remarks
Soil Cleanup Level[1] ⟶			300	250	11,000	
MW135	3/8/01	10.0 - 11.5	**7,570**	**1,630**	<1050	DRO: Pattern consistent with weathered middle distillate. DRO/RRO: Possible crude oil pattern.
MW135[2]	3/8/01	10.0 - 11.5	**7,730**	**1,080**	127	DRO: Pattern consistent with weathered middle distillate. DRO/RRO: Possible crude oil pattern.
MW139	5/29/01	10.0 - 11.5	2.23	<11.8	<23.6	
MW140	5/29/01	7.5 - 9.0	<1.77	<10.6	<21.3	
MW142	8/10/01	7.5 - 9.0	<3.96	17.3	NA	DRO: Pattern consistent with highly weathered middle distillate.
B-1	5/30/01	7.5 - 9.0	**938**	**1,220**	<213	DRO: Pattern consistent with middle distillate.
B-1[3]	5/30/01	7.5 - 9.0	**1,980**	**3,460**	<217	DRO: Pattern consistent with weathered middle distillate.
B-2	5/30/01	10.0 - 11.5	4.69	<10.7	<21.5	
B-3	5/30/01	10.0 - 11.5	<23.8	79.1	82.4	DRO: Heavier hydrocarbons contributing to diesel range quantitation. DRO/RRO: Possible lube oil pattern.
B-4	5/30/01	7.5 - 9.0	**381**	**331**	<22.7	DRO/RRO: Pattern consistent with weathered middle distillate.
Trip blank	3/8/01	--	<2.51	NA	NA	
Trip blank	5/30/01	--	<2.50	NA	NA	
Trip blank	8/10/01	--	<2.49	NA	NA	

Notes:

Bold face type values are greater than soil cleanup levels.

NA = Not analyzed (analyte not measured)

[1] 18AAC75.341 Table B Method Two soil cleanup levels for migration to groundwater (<40 inches of annual precipitation zone).

[2] Duplicate sample

[3] Duplicate sample

Table 5. Concentrations of volatile organic compounds in Williams North Pole refinery soil boring samples.

Location	Date	Depth (feet bgs)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	p&m-Xylenes (mg/kg)	o-Xylene (mg/kg)	Isopropylbenzene (Cumene) (mg/kg)	n-Propylbenzene (mg/kg)	1,3,5-Trimethylbenzene (mg/kg)	tert-Butylbenzene (mg/kg)	1,2,4-Trimethylbenzene (mg/kg)	sec-Butylbenzene (mg/kg)	4-Isopropyltoluene (p-cymene) (mg/kg)	n-Butylbenzene (mg/kg)	Naphthalene (mg/kg)	Trichlorofluoromethane (mg/kg)
Soil Cleanup Level[1]		⟶	0.02	5.4	5.5	78 (Total xylenes)		229	1.4 to 28 MTG	25	3100(R) to 82000 (I)	95	3100 (R) to 82000 (I)	?	3100(R) to 82,000(I)	43	1.1 to 23 (MTG)
MW135	3/8/01	10.0-11.5	**74.9**	**392**	**96.0**	**348**	**134**	19.8	40.7	42.4	<10.8	115	<10.8	<10.8	<10.8	<10.8	18.8
MW135[2]	3/8/01	10.0-11.5	**82.0**	**398**	**95.4**	**345**	**132**	19.8	40.5	43.5	<12.8	113	<12.8	<12.8	<12.8	<12.8	22.7
MW139	5/29/01	10.0-11.5	**0.0587**	<0.0375	<0.0375	0.378	0.137	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B-1	5/30/01	7.5-9.0	**1.39**	<0.835	**44.2**	**170**	**74.9**	17.2	34.5	34.8	<0.835	102	10.7	8.42	12.4	**47.7**	<0.835
B-1[3]	5/30/01	7.5-9.0	**1.61**	<0.815	**49.1**	**202**	**87.7**	19.1	38.8	38.3	<0.815	115	12.0	9.12	13.0	**53.7**	<0.815
B-2	5/30/01	10.0-11.5	**0.0719**	0.372	0.106	0.327	0.117	<0.0113	0.0145	0.0180	<0.0113	0.0567	<0.0113	<0.0113	<0.0113	0.0570	<0.0113
B-3	5/30/01	10.0-11.5	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124
B-4	5/30/01	7.5-9.0	**3.08**	3.73	**5.58**	16.7	5.87	3.55	3.80	5.60	0.0812	14.8	1.55	1.39	<2.25	6.64	<0.0225
MW140	5/29/01	7.5-9.0	<0.00885	<0.0354	<0.0354	<0.0354	<0.0354	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW142	8/10/01	7.5-9.0	<0.0198	<0.0793	<0.0793	<0.0793	<0.0793	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trip blank	3/8/01	--	<0.0131	<0.0131	<0.0131	0.0146	<0.0131	<0.0131	<0.0131	<0.0131	<0.0131	<0.0131	<0.0131	<0.0131	<0.0131	<0.0131	0.0259
Trip blank	5/30/01	--	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130	<0.0130
Trip blank	8/10/01	--	<0.0125	<0.0498	<0.0498	<0.0498	<0.0498	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

Bold face type values are greater than soil cleanup levels.

NA = Not analyzed (analyte not measured)

Not all analytes tested shown; only those analytes with results greater than the laboratory PQL are presented. See laboratory reports for all analytes determined.

[1] Benzene, toluene, ethylbenzene, xylenes and naphthalene cleanup levels are 18AAC75.341 Table B Method Two soil cleanup levels for migration to groundwater in the under 40 inches of annual precipitation zone.

[2] Duplicate sample

[3] Duplicate sample

Table 6. Concentrations of semi-volatile organic compounds in Williams North Pole refinery soil boring samples.

Location	Date	Depth (feet bgs)	Naphthalene (mg/kg)	2-Methylnaphthalene (mg/kg)	Dibenzofuran (mg/kg)	Fluorene (mg/kg)	Phenanthrene (mg/kg)
Soil Cleanup Level[1] →			43				
MW135	3/8/01	10.0 - 11.5	5.94	9.04	0.524	0.483	1.37
MW135 [2]	3/8/01	10.0 - 11.5	2.64	4.47	<0.342	<0.342	0.644
B-1	5/30/01	7.5 - 9.0	<35.2	50.1	<35.2	<35.2	<35.2
B-1 [3]	5/30/01	7.5 - 9.0	**47.4**	80.8	<35.9	<35.9	<35.9
B-2	5/30/01	10.0 - 11.5	<0.358	<0.358	<0.358	<0.358	<0.358
B-3	5/30/01	10.0 - 11.5	<0.741	<0.741	<0.741	<0.741	<0.741
B-4	5/30/01	7.5 - 9.0	0.485	1.30	<0.368	<0.368	<0.368

Notes:

Bold face type values are greater than soil cleanup levels.

Not all analytes tested shown; only those analytes with results greater than the laboratory PQL are presented. See laboratory reports for all analytes determined.

[1] The naphthalene value is the 18AAC75.341 Table B Method Two soil cleanup level for migration to groundwater in the less than 40 inches annual precipitation zone.

[2] Duplicate sample

[3] Duplicate sample

Table 7. Concentrations of metals in Williams North Pole refinery groundwater samples.

Location	Date	Screen Depth (feet bgs)	Antimony (µg/L)	Arsenic (µg/L)	Barium (µg/L)	Cadmium (µg/L)	Chromium (µg/L)	Lead (µg/L)	Mercury (µg/L)	Selenium (µg/L)	Silver (µg/L)
	MCL [1]	→	6	50	2000	5	100	15	0.2	50	180
MW101	5/10/01	56-61	<1.11	10.9	71.2	3.74	<4.44	<2.22	<0.200	<5.56	4.92
MW105	5/10/01	58-63	<1.11	<5.56	80.0	3.90	<4.44	<2.22	<0.200	<5.56	4.92
MW105A	5/10/01	18-23	<1.11	5.69	134	3.71	<4.44	<2.22	<0.200	<5.56	4.99
MW110	6/13/01	13.5-18	1.32	**55.1**	523	<2.00	29.7	8.80	<0.200	<5.00	<2.00
MW115	5/10/01	12.5-17	<1.11	32.4	601	3.86	8.67	3.24	<0.200	5.66	5.02
MW116	5/10/01	12-17	<1.11	**68.5**	243	3.82	6.19	<2.22	<0.200	<5.56	5.00
MW125	5/10/01	19.5-24	<1.11	19.4	152	3.75	<4.44	<2.22	<0.200	<5.56	4.87
MW-125 [2]	5/10/01	19.5-24	<1.11	18.2	155	3.75	<4.44	<2.22	<0.200	<5.56	4.88
MW-127	5/10/01	20-24.5	<1.11	15.6	215	3.77	<4.44	<2.22	<0.200	<5.56	4.90
MW130	5/10/01	19-23	<1.11	23.8	229	4.09	4.99	<2.22	<0.200	<5.56	4.93

Notes:

Bold face type = concentration greater than groundwater cleanup level

[1] 18 AAC 75.350 Table C groundwater cleanup levels.

[2] Duplicate sample

Table 8. Concentrations of whole fuels in Williams North Pole refinery groundwater samples.

Location	Date	Screen Depth (feet bgs)	GRO (mg/L)	DRO (mg/L)	RRO (mg/L)	Remarks
	MCL [1]	→	1.3	1.5	1.1	
MW101	5/10/01	56-61	<0.0900	0.818	<0.990	DRO/RRO - Unknown hydrocarbon peak between C_{12}-C_{13} alkane range.
MW101	7/26/01	56-61	NA	0.946	NA	DRO - Unknown single hydrocarbon at C_{12}-C_{13} alkane range.
MW101 [2]	7/26/01	56-61	NA	0.845	NA	DRO - Unknown single hydrocarbon at C_{12}-C_{13} alkane range.
MW101A	5/10/01	18-23	<0.0900	1.20	<0.990	DRO/RRO - Unknown hydrocarbon peak between C_{12}-C_{13} alkane range.
MW101A	7/26/01	18-23	NA	1.43	NA	DRO - Unknown single hydrocarbon at C_{12}-C_{13} alkane range.
MW105	5/10/01	58-63	0.153	<0.495	<0.990	
MW105A	5/10/01	18-23	<0.0900	<0.495	<0.990	
MW105A	6/13/01	18-23	<0.0900	NA	NA	
MW105A [3]	6/13/01	18-23	<0.0900	NA	NA	
MW105	6/13/01	58-63	<0.0900	NA	NA	
MW106	5/10/01	18.5-23	<0.0900	<0.495	<0.990	
MW110	6/13/01	13.5-18	**8.69**	**2.87**	<1.00	DRO - Pattern consistent with weathered middle distillate or highly weathered gasoline.
MW115	5/10/01	12.5-17	**5.62**	**2.44**	<0.990	DRO - Pattern consistent with weathered gasoline. DRO/RRO - Pattern consistent with weathered middle distillate.
MW116	5/10/01	12-17	**36.8**	**4.57**	<1.02	DRO - Pattern consistent with weathered gasoline.
MW125	5/10/01	19.5-24	0.184	<0.495	<0.990	
MW-125 [4]	5/10/01	19.5-24	0.214	<0.495	<0.990	
MW-127	5/10/01	20-24.5	1.01	<0.495	<0.990	
MW130	5/10/01	19-23	0.678	**1.66**	<1.00	DRO - Pattern consistent with weathered gasoline. DRO/RRO - Pattern consistent with weathered middle distillate.
MW133	5/10/01	17.5-22	<0.0900	<0.495	<0.990	
MW135	7/19/01	10.6-19.5	**32.9**	**3.38**	<1.05	DRO/RRO - Unknown hydrocarbon with several peaks.
MW139	7/19/01	5.7-25.2	**2.98**	**1.59**	<1.00	DRO - Unknown hydrocarbon with several peaks.
MW140	7/19/01	4.2-23.5	<0.0900	<0.505	<1.01	

Location	Date	Screen Depth (feet bgs)	GRO (mg/L)	DRO (mg/L)	RRO (mg/L)	Remarks
	MCL[1]	→	1.3	1.5	1.1	
MW142	8/13/01	5.4-19.4	0.085	0.568	NA	GRO - Gasoline pattern observed. DRO - Unknown hydrocarbon pattern present.
MW142[5]	8/13/01	5.4-19.4	0.084	0.523	NA	GRO - Gasoline pattern observed. DRO - Unknown hydrocarbon pattern present.
Trip blank	5/10/01	--	<0.0900	NA	NA	
Trip blank	6/13/01	--	<0.0900	NA	NA	
Trip blank	7/19/01	--	<0.0900	NA	NA	
Trip blank	8/13/01	--	<0.040	NA	NA	

Notes:

Bold face type values are greater than cleanup level.

NA = Not analyzed (analyte not measured).

[1] 18 AAC 75.350 Table C groundwater cleanup levels

[2] Duplicate sample

[3] Duplicate sample

[4] Duplicate sample

[5] Duplicate sample

Table 9. Concentrations of volatile organic compounds detected in Williams North Pole refinery groundwater samples.

Location	Date	Screen Depth (feet bgs)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p&m-Xylenes (µg/L)	o-Xylene (µg/L)	1,2,4-Trimethylbenzene (µg/L)	1,3,5-Trimethylbenzene (µg/L)	n-Propylbenzene (µg/L)	Isopropylbenzene (cumene) (µg/L)	4-Isopropyltoluene cymene (µg/L)	methylpropylbenzene n-Butylbenzene (µg/L)	sec- Butylbenzene (µg/L)	Naphthalene (µg/L)	1,1-Dichloroethene (µg/L)	cis-1,2-Dichloroethene (µg/L)
		MCL →	5 [1]	1,000 [1]	700 [1]	10,000 (total xylenes) [1]		70	1850	240 Tap	3650	?	240 Tap	240 Tap	1,460 [1]	7 [1]	70 [1]
MW101	5/10/01	56-61	<0.500	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW101A	5/10/01	18-23	<0.500	<2.00	<2.00	3.89	<2.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW105	5/10/01	58-63	1.64	9.46	6.46	33.9	10.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW105	6/13/01	58-63	<0.500	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW105A	5/10/01	18-23	<0.500	2.37	2.21	6.92	2.12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW105A	6/13/01	18-23	<0.500	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW105A [2]	6/13/01	18-23	<0.500	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW106	5/10/01	18.5-23	0.698	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW110	6/13/01	13.5-18	**3,080**	372	51.0	283	97.0	30.9	8.62	5.71	6.15	1.38	1.58	1.21	20.4	<1.00	<1.00
MW115	5/10/01	12.5-17	**966**	<1.00	44.0	914	2.70	281	87.3	48.8	37.4	6.99	4.03	6.56	76.1	1.57	<1.00
MW116	5/10/01	12-17	**3,960**	3.14	**753**	1,140	1,770	621	203	162	106	18.3	14.3	18.6	316	<2.00	2.84
MW125	5/10/01	19.5-24	**70.9**	<1.00	1.68	1.77	<1.00	<1.00	<1.00	<1.00	1.62	<1.00	<1.00	<1.00	2.83	4.77	<1.00
MW125 [2]	5/10/01	19.5-24	**90.0**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	1.35	<1.00	<1.00	<1.00	<1.00	4.33	<1.00
MW127 [3]	5/10/01	20-24.5	**170**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	1.38	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
MW130	5/10/01	19-23	**55.5**	15.3	5.78	16.5	8.67	7.58	1.74	2.31	1.78	<1.00	<1.00	<1.00	16.2	1.70	<1.00
MW133	5/10/01	17.5-22	<0.500	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW135	7/19/01	10.6-19.5	**5470**	**3,980**	332	964	442	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW139	7/19/01	5.7-25.2	**110**	<2.00	97.7	638	196	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW140	7/19/01	4.2-23.5	<0.500	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW142	8/13/01	5.4-19.4	<1.0	1.2	<1.0	<2.0	<1.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW142 [2]	8/13/01	5.4-19.4	<1.0	1.0	<1.0	<2.0	<1.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trip blank	5/10/01	--	<0.500	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Trip blank	6/13/01	--	<0.500	<1.00	<1.00	<2.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<2.00	<1.00	<1.00
Trip blank	7/19/01	--	<0.500	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trip blank	8/13/01	--	<1.0	<1.0	<1.0	<2.0	<1.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: **Bold face type** values are greater than groundwater cleanup level.
NA = Not analyzed (analyte not measured).
Not all analytes tested shown; only those analytes with results greater than the laboratory PQL are presented. See laboratory reports for all analytes determined.

[1] 18 AAC 75.345 Table C groundwater cleanup levels.

[2] Duplicate sample

[3] Sample from MW-127 also contained methyl-tert-butyl ether at 0.027 mg/L.

Table 10. Concentrations of semi-volatile organic compounds detected in Williams North Pole refinery groundwater samples.

Location	Date	Screen Depth (feet bgs)	Naphthalene (µg/L)	2-Methylnaphthalene (µg/L)	2,4-Dimethylphenol (µg/L)	di-n-Octylphthalate (µg/L)
	MCL	→	1460 [1]			
MW110	6/13/01	13.5-18	11	13	<9.9	<9.9
MW115	5/10/01	12.5-17	33	15	15	<9.9
MW116	5/10/01	12-17	120	70	22	<10
MW125	5/10/01	19.5-24	<9.9	<9.9	<9.9	<9.9
MW-125 [2]	5/10/01	19.5-24	<9.9	<9.9	<9.9	12
MW-127	5/10/01	20-24.5	<9.9	<9.9	<9.9	<9.9
MW130	5/10/01	19-23	<9.9	<9.9	<9.9	<9.9

Notes:

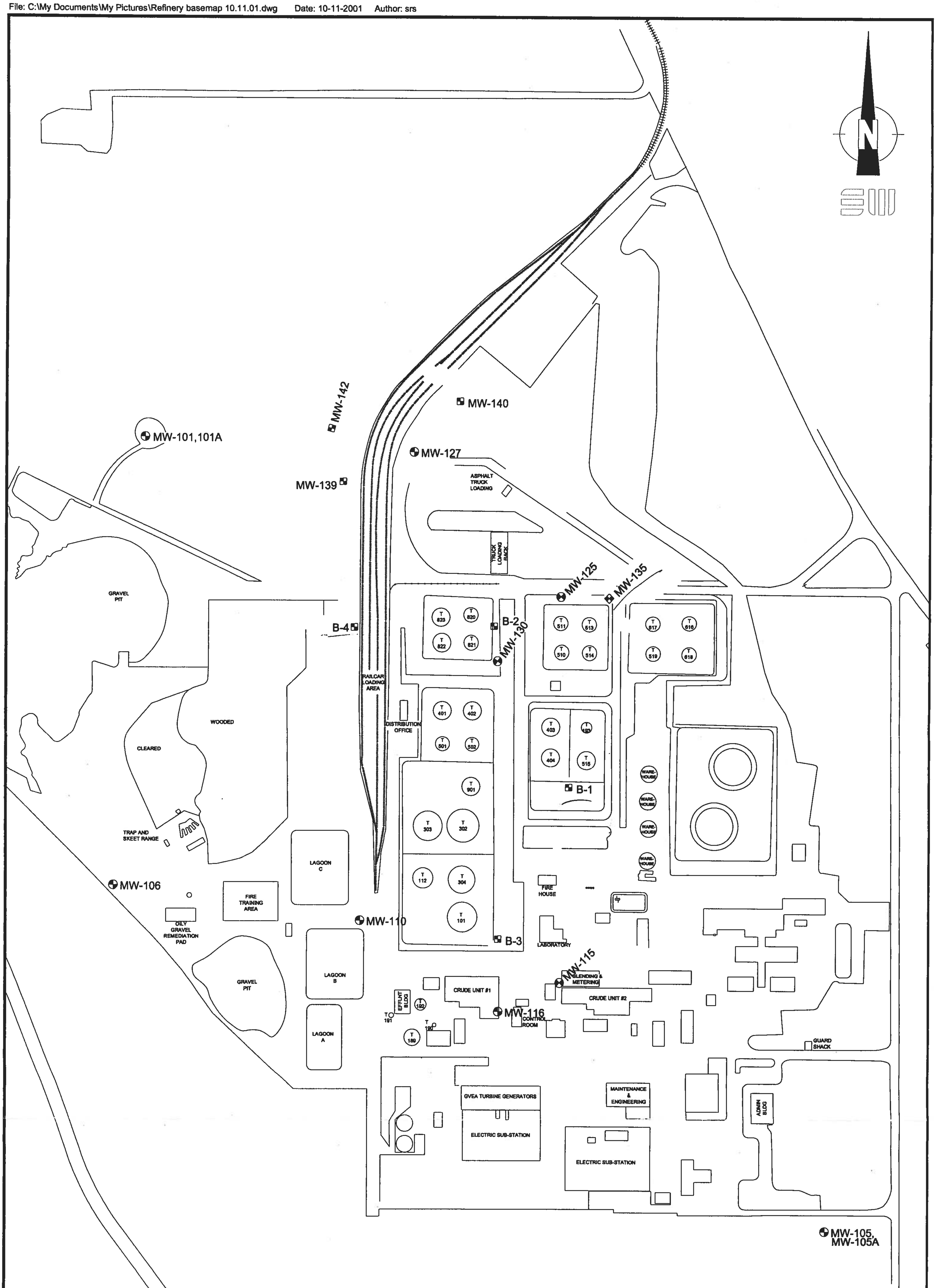
[1] 18 AAC 75.350 Table C groundwater cleanup levels.

[2] Duplicate sample

Table 11. Concentrations of sulfolane detected in Williams North Pole refinery groundwater samples from monitoring and observation wells.

Refinery Lab Sample #	Location	Date Sampled	MDL (mg/L)	Sulfolane (mg/L)	Screen Depth (feet bgs)
E-071701-356	MW 101	7/17/01	2	4	56-61
E-072601-381	MW 101	7/26/01	2	4	56-61
E-071701-357	MW 101A	7/17/01	2	5	18-23
E-072601-382	MW 101A	7/26/01	2	7	18-23
E-071701-353	MW 104	7/17/01	2	<2	63-67
E092401-480	MW 106	9/24/01	0.2	<0.2	18.5-23
E-072501-369	MW 109	7/25/01	2	3	9.5-14
E-072501-370	MW 110	7/25/01	2	8	13.5-18
E-072501-371	MW 111	7/25/01	2	2	14.5-19.5
E-071701-355	MW 113	7/17/01	2	2	11.5-16
E092401-481	MW 115	9/24/01	0.2	<0.2	12.5-17
E092401-482	MW 116	9/24/01	0.2	<0.2	12-17
E-071701-354	MW 118	7/17/01	2	<2	38.5-43
E092401-483	MW 125	9/24/01	0.2	<0.2	19.5-24
E-072501-374	MW 126	7/25/01	2	<2	20-24.5
E-072501-372	MW 127	7/25/01	2	<2	20-24.5
E-072501-375	MW 129	7/25/01	2	<2	37-41.5
E092401-484	MW 130	9/24/01	0.2	8	19-23
E-071701-358	MW 131	7/17/01	2	<2	20-24.5
E092401-485	MW 132	9/24/01	0.2	<0.2	17.5-22
E092401-486	MW 134	9/24/01	0.2	<0.2	17-21.5
E092401-487	MW 138	9/24/01	0.2	32	3.9-18
E-072501-373	MW 139	7/25/01	2	<2	5.7-25.2
E-072501-376	MW 140	7/25/01	2	<2	4.2-23.5
E092401-494	MW 142	9/24/01	0.2	<0.2	5.35-19.35
E092401-479	R 14	9/24/01	0.2	3	6' (total depth)
E092401-488	S 20	9/24/01	0.2	13	12' (total depth)
E092401-489	S 34	9/24/01	0.2	<0.2	
E092401-490	S 36	9/24/01	0.2	<0.2	
E092401-491	S 37	9/24/01	0.2	<0.2	
E092401-492	S 41	9/24/01	0.2	<0.2	
E092401-493	S 51	9/24/01	0.2	4	14.5' (total depth)

File: C:\My Documents\My Pictures\Refinery basemap 10.11.01.dwg Date: 10-11-2001 Author: srs



NOTE:
LOCATIONS OF WELLS WERE ESTABLISHED BY SURVEY DATA FROM SHANNON & WILSON INC. AND HISTORICAL DATA FROM DESIGN ALASKA INC.
LOCATIONS OF OTHER FEATURES WERE DIGITIZED FROM AERIAL PHOTOGRAPHS SUPPLIED BY WILLIAMS ALASKA INC.
NO BOUNDARY SURVEY WAS PERFORMED.

LEGEND
- ▣ NEW WELL / SOIL BORING FOR THIS STUDY
- ● PREVIOUSLY EXISTING MONITORING WELL

0 300 600
Scale in Feet

WILLIAMS ALASKA INC.
NORTH POLE REFINERY
NORTH POLE, ALASKA

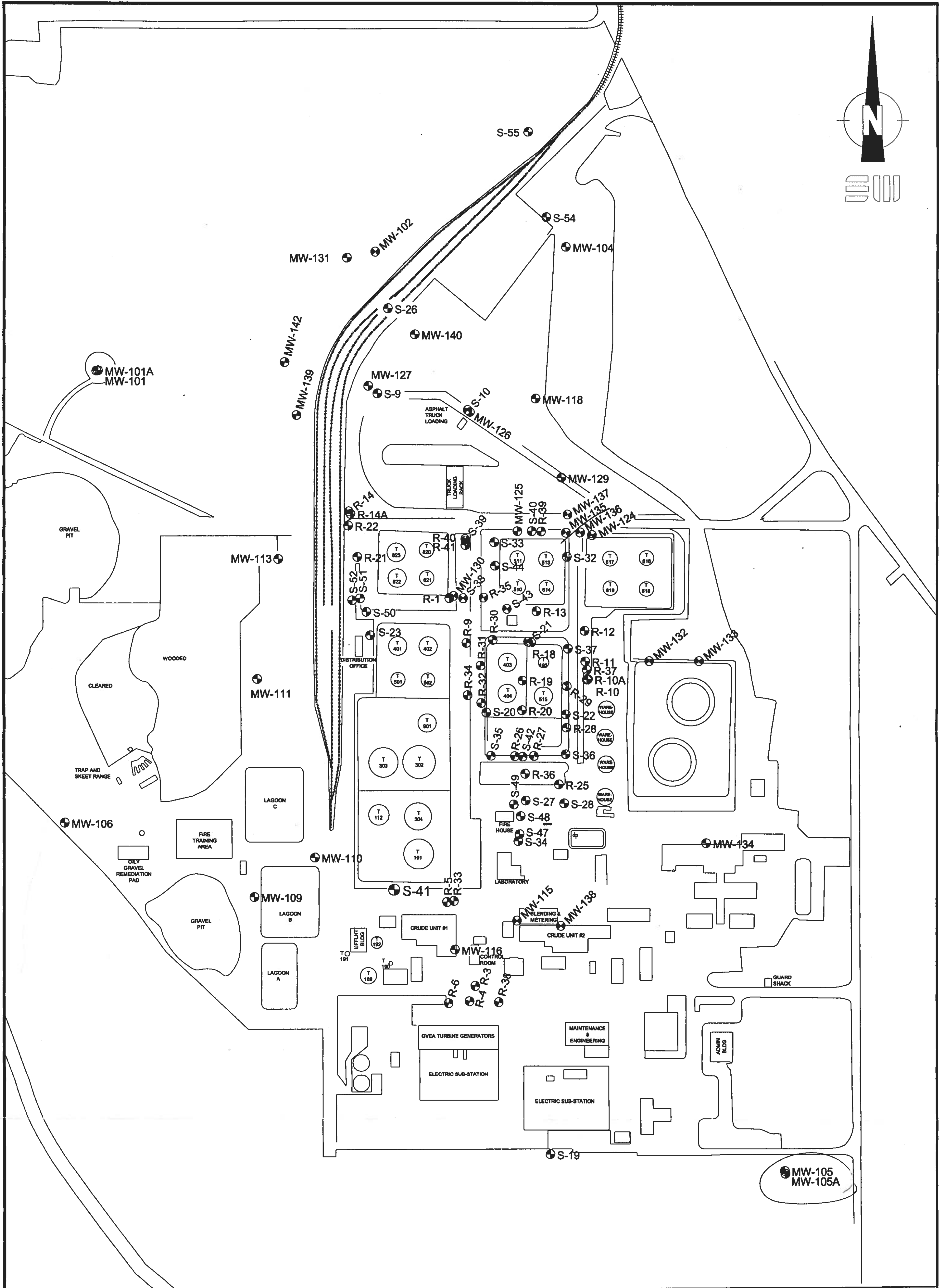
LOCATIONS OF SAMPLED BORINGS AND WELLS

October 2001 31-1-11006-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Figure 1

File: C:\My Documents\My Pictures\Refinery basemap 10.11.01.dwg Date: 10-11-2001 Author: srs



NOTE:
LOCATIONS OF WELLS WERE ESTABLISHED BY SURVEY DATA FROM SHANNON & WILSON INC. AND HISTORICAL DATA FROM DESIGN ALASKA INC.
LOCATIONS OF OTHER FEATURES WERE DIGITIZED FROM AERIAL PHOTOGRAPHS SUPPLIED BY WILLIAMS ALASKA INC.
NO BOUNDARY SURVEY WAS PERFORMED.

WILLIAMS ALASKA INC.
NORTH POLE REFINERY
NORTH POLE, ALASKA

SITE MAP

October 2001 31-1-11006-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Figure 2

SOIL DESCRIPTION

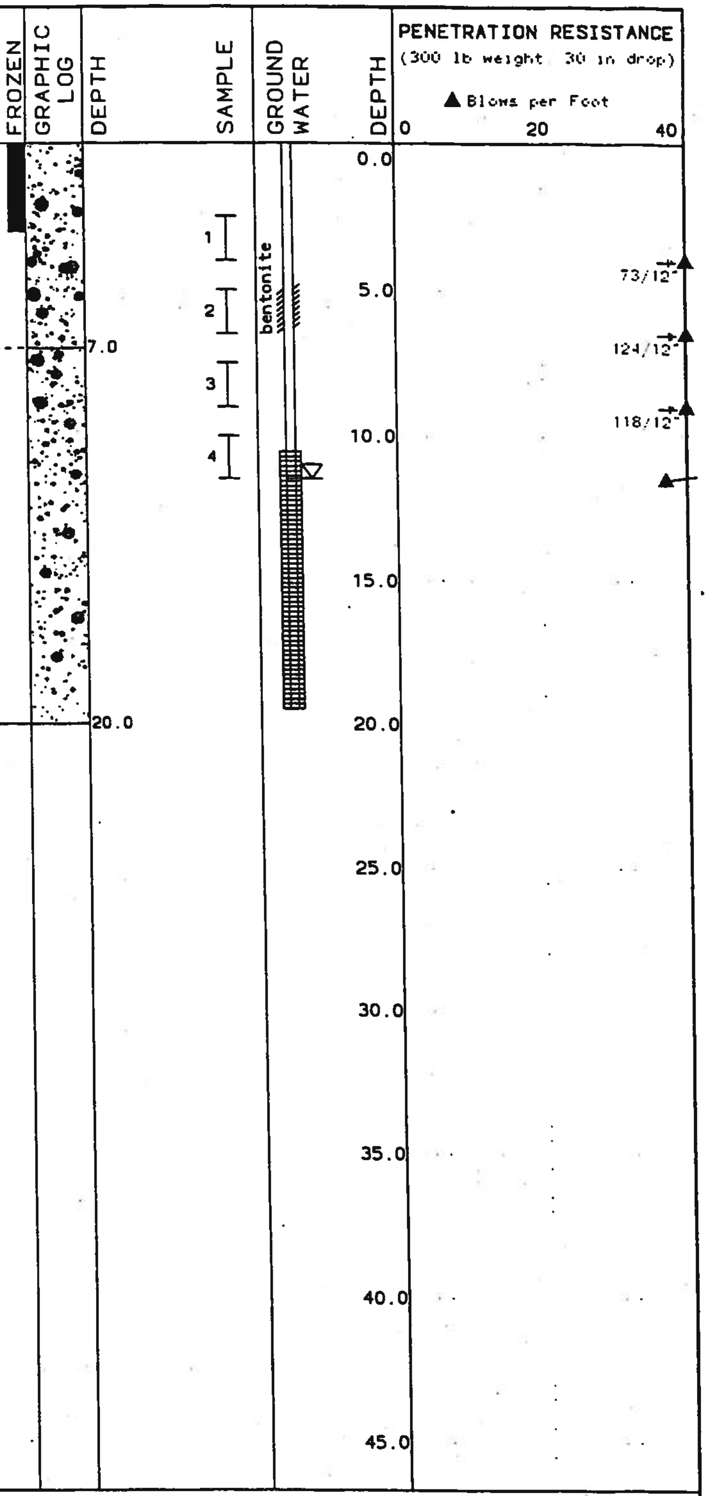
Surface Elevation: unknown

brown gravely SAND

brown SAND with trace gravel, hydrocarbon and glycol odor

Bottom of Boring
Boring Completed 3/8/01

Well Construction Details
2-inch PVC pipe
0.020 machined slots
Slotted depth 10.57 to 19.49 feet
Sand pack 6.5 to 20 feet
Bentonite seal 5 to 6.5 feet
Above grade monument
Well stick-up 3.0 feet



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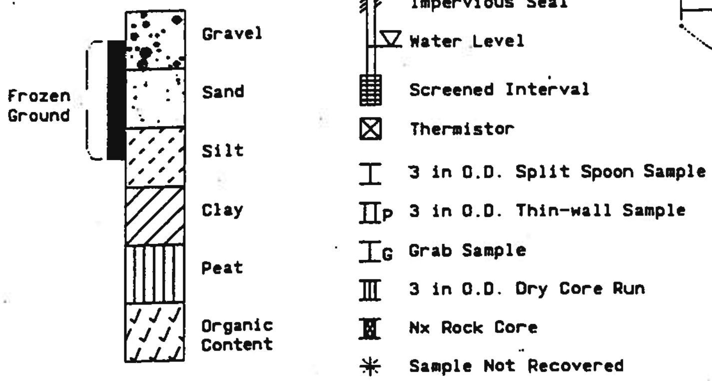

Note: Stratification lines represent approximate boundaries between soil types and transition may be gradual.

Williams Refinery
North Pole, Alaska

LOG OF MONITORING WELL MW-135

April 2001

31-1-10833

SHANNON & WILSON, INC.
Geotechnical Consultants

Sheet 1 of 1

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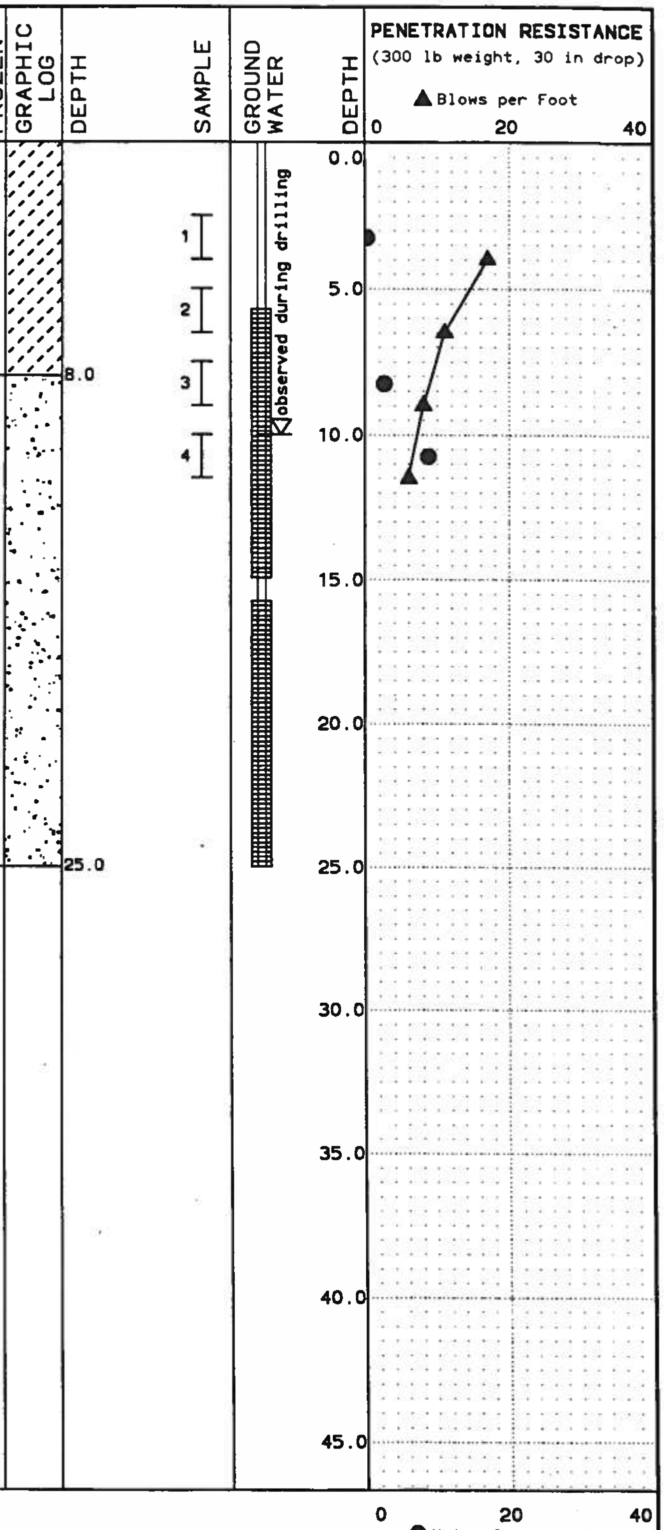
SOIL DESCRIPTION

Surface Elevation: unknown

brown to brownish red SILT, trace gravel, 4 inches of hard, dark brown silt with organics at 5.5 feet

brown SAND



Bottom of Boring
Boring Completed 5/29/01

Well Construction Details:
2-inch PVC casing
0.020-inch machined slots
slotted depth 5.70 to 14.94 and
15.77 to 25.02 feet
well stickup 1.79 feet

LEGEND

Frozen Ground

- Gravel
- Sand
- Silt
- Clay
- Peat
- Organic Content

- Impervious Seal
- ▽ Water Level
- ▦ Screened Interval
- ☒ Thermistor
- I 3 in O.D. Split Spoon Sample
- IIp 3 in O.D. Thin-wall Sample
- IG Grab Sample
- III 3 in O.D. Dry Core Run
- Nx Rock Core
- ✳ Sample Not Recovered

ATTERBERG LIMITS

- Liquid Limit
- Water Content
- Plastic Limit

Note: Stratification lines represent approximate boundaries between soil types and transition may be gradual.

Williams Refinery
Corrective Measures Study
North Pole, Alaska

LOG OF MONITORING WELL MW-139

September 2001

31-1-11066

SHANNON & WILSON, INC.
Geotechnical Consultants

Sheet 1 of 1

SOIL DESCRIPTION

Surface Elevation: unknown

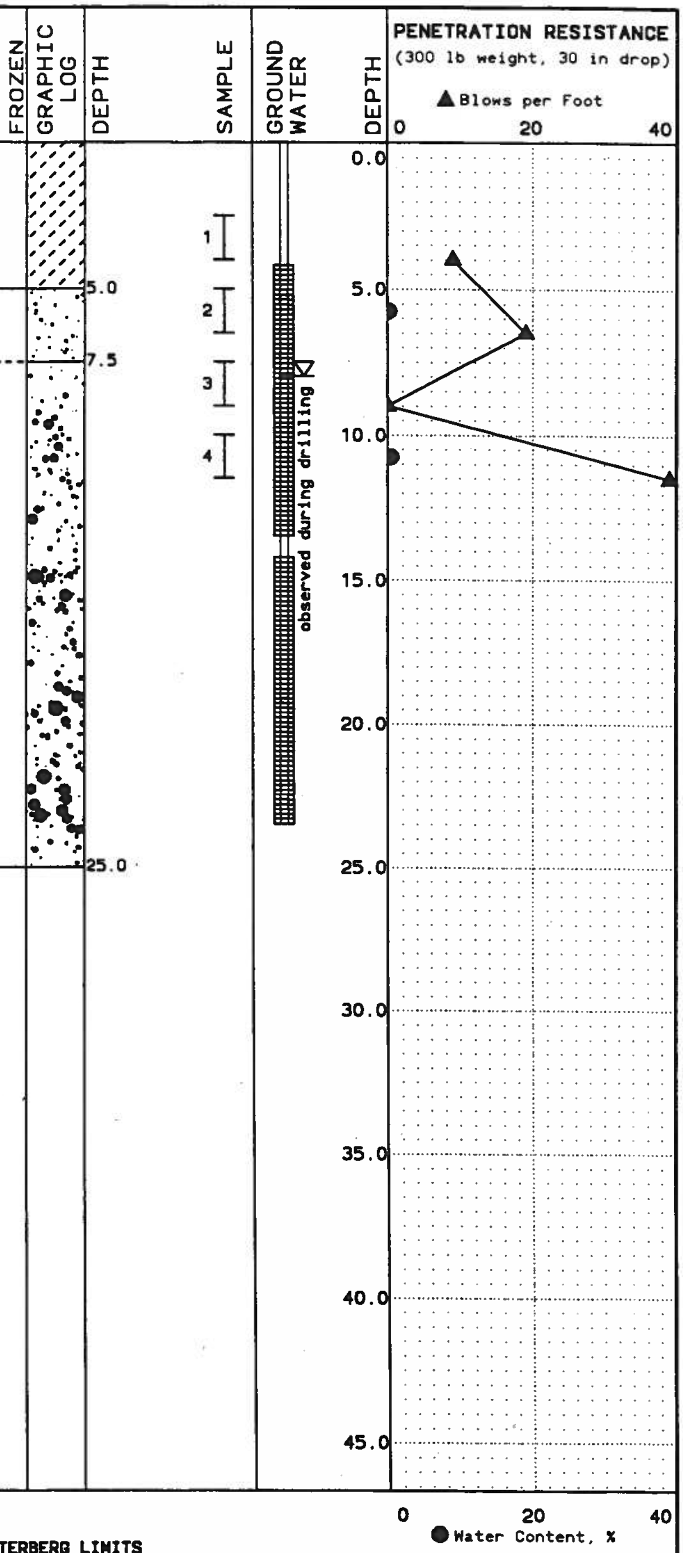
brown sandy SILT, trace organics at top

brown SAND

brown sandy GRAVEL

Bottom of Boring
Boring Completed 5/30/01

Well Construction Details:
2-inch PVC casing
0.020-inch machined slots
slotted depth 4.20 to 13.48 and 14.25 to 23.50 feet
well stickup 2.48 feet



LEGEND

- Gravel
- Sand
- Silt
- Clay
- Peat
- Organic Content
- Frozen Ground
- Impervious Seal
- ▽ Water Level
- Screened Interval
- ☒ Thermistor
- I 3 in O.D. Split Spoon Sample
- IIp 3 in O.D. Thin-wall Sample
- IG Grab Sample
- III 3 in O.D. Dry Core Run
- Nx Rock Core
- ✳ Sample Not Recovered

ATTERBERG LIMITS

- Liquid Limit
- Water Content
- Plastic Limit

Note: Stratification lines represent approximate boundaries between soil types and transition may be gradual.

Williams Refinery
Corrective Measures Study
North Pole, Alaska

LOG OF MONITORING WELL MW-140

September 2001

31-1-11066

SHANNON & WILSON, INC.
Geotechnical Consultants

Sheet 1 of 1

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SOIL DESCRIPTION

Surface Elevation:

Brown/gray, gravelly SILT.

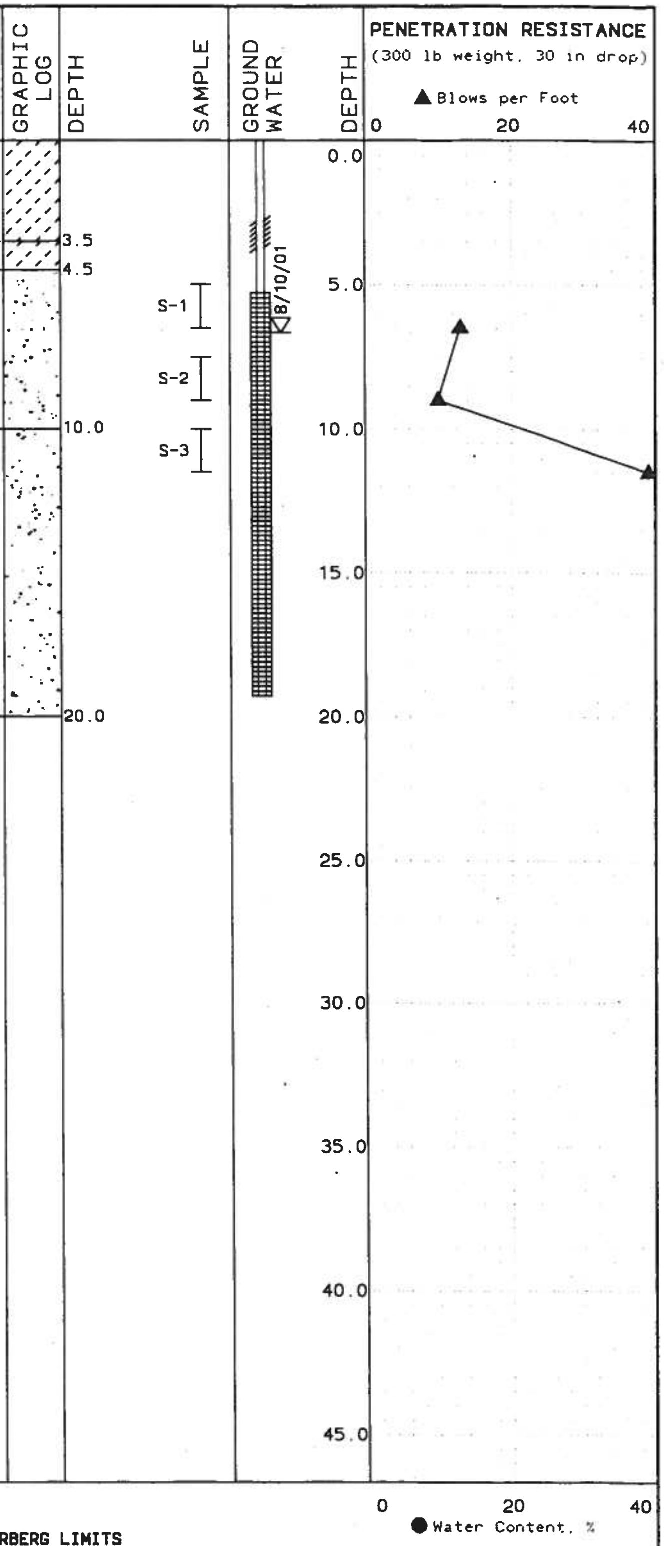
Brown SILT

Brown and gray, silty fine SAND, with lenses of silt.

Gray, gravelly SAND.

Bottom of Boring
Boring Completed 8/10/01

Well Construction Details
2-inch PVC pipe
0.010-inch machined slots
Slotted depth 5.35 to 19.35 feet
Sand pack 3.9 feet to 20 feet
Bentonite seal 2.8 to 3.9 feet
Well stick-up 3.15 feet
Above-grade monument



LEGEND

▨	Gravel
▨	Sand
▨	Silt
▨	Clay
▨	Peat
▨	Organic Content

Frozen Ground

╫	Impervious Seal
▽	Water Level
▦	Screened Interval
☒	Thermistor
I	3 in O.D. Split Spoon Sample
IIp	3 in O.D. Thin-wall Sample
IG	Grab Sample
III	3 in O.D. Dry Core Run
▣	Nx Rock Core
✳	Sample Not Recovered

ATTERBERG LIMITS

Liquid Limit
Water Content
Plastic Limit

Note: Stratification lines represent approximate boundaries between soil types and transition may be gradual.

Williams Alaska Petroleum, Inc. Refinery
North Pole, Alaska

Log of Boring MW-142

August 2001

31-1-11066

SHANNON & WILSON, INC.
Geotechnical Consultants

Sheet 1 of 1

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SOIL DESCRIPTION

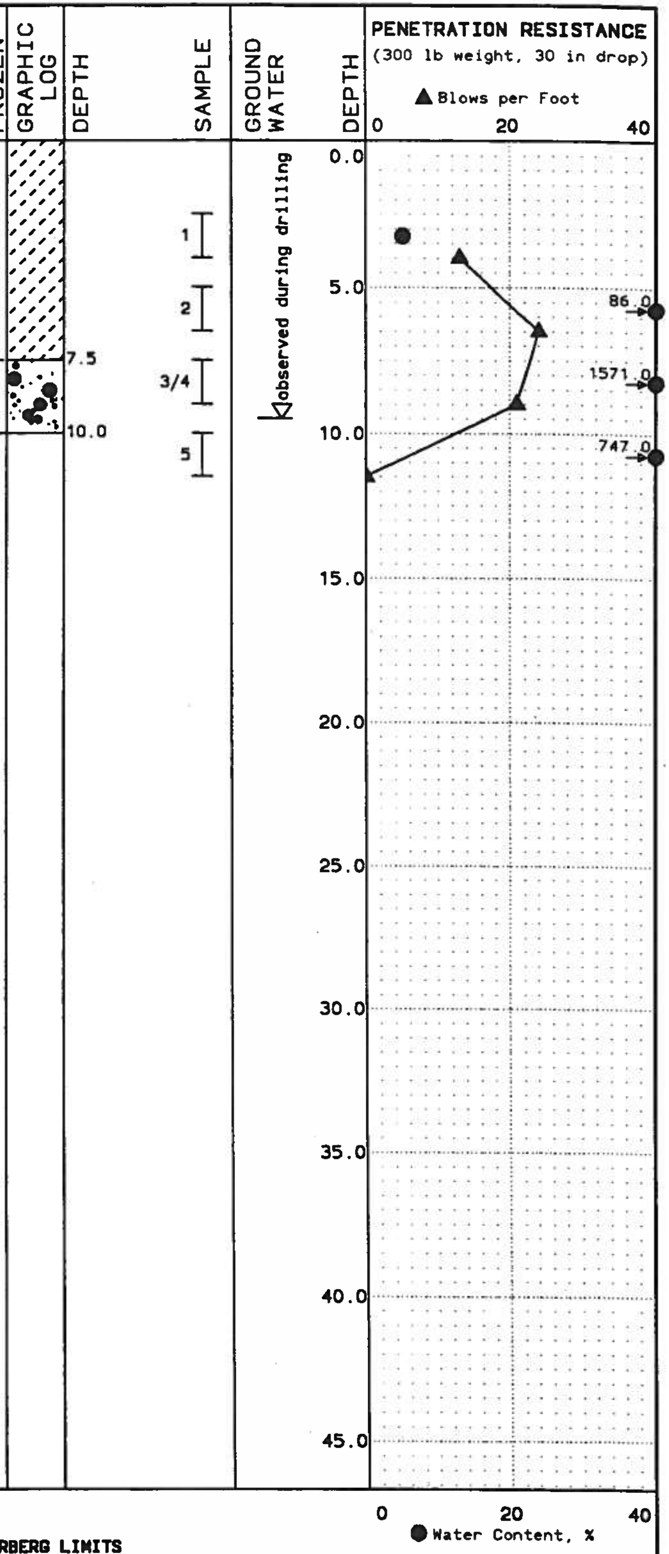
Surface Elevation: unknown

brown to gray SILT, trace gravel

gray sandy GRAVEL

Bottom of Boring
Boring Completed 5/30/01

Boring located south of Tanks 515 and 404



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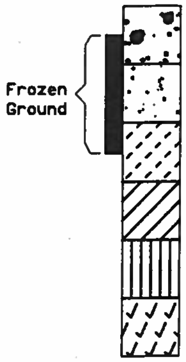

Impervious Seal

▽ Water Level

Screened Interval

☒ Thermistor

I 3 in O.D. Split Spoon Sample

IP 3 in O.D. Thin-wall Sample

IG Grab Sample

Ⅲ 3 in O.D. Dry Core Run

Nx Rock Core

✳ Sample Not Recovered

ATTERBERG LIMITS

Note: Stratification lines represent approximate boundaries between soil types and transition may be gradual.

Williams Refinery
Corrective Measures Study
North Pole, Alaska

LOG OF BORING 2001 B-1

September 2001 | 31-1-11066

SHANNON & WILSON, INC.
Geotechnical Consultants

Sheet 1 of 1

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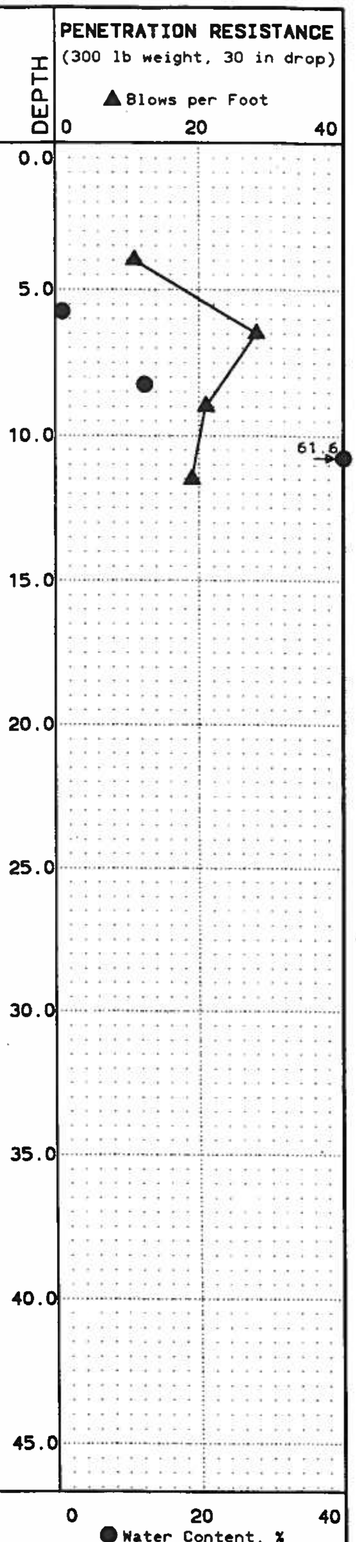
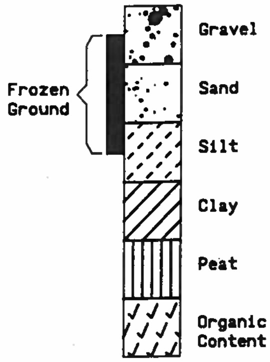
SOIL DESCRIPTION Surface Elevation: unknown	FROZEN	GRAPHIC LOG	DEPTH	SAMPLE	GROUND WATER
brown sandy GRAVEL			5.0	1	
brown to gray sandy SILT			7.0	2	
brown to gray SAND			8.0		
gray sandy GRAVEL			10.0	3 4	▽ observed during drilling

Bottom of Boring
Boring Completed 5/30/01

Boring located east of Tank 820



LEGEND



Impervious Seal
▽ Water Level
Screened Interval
☒ Thermistor
I 3 in O.D. Split Spoon Sample
IIp 3 in O.D. Thin-wall Sample
IG Grab Sample
III 3 in O.D. Dry Core Run
Nx Rock Core
✳ Sample Not Recovered

ATTERBERG LIMITS

Liquid Limit
Water Content
Plastic Limit

Note: Stratification lines represent approximate boundaries between soil types and transition may be gradual.

Williams Refinery
Corrective Measures Study
North Pole, Alaska

LOG OF BORING 2001 B-2

September 2001 31-1-11066

SHANNON & WILSON, INC.
Geotechnical Consultants

Sheet 1 of 1

C:\DOSBORNG\10668B3.LOG 09-04-2001 14:50:04

SOIL DESCRIPTION

Surface Elevation: unknown

FROZEN | GRAPHIC LOG | DEPTH | SAMPLE | GROUND WATER | DEPTH

brown to gray silty GRAVEL

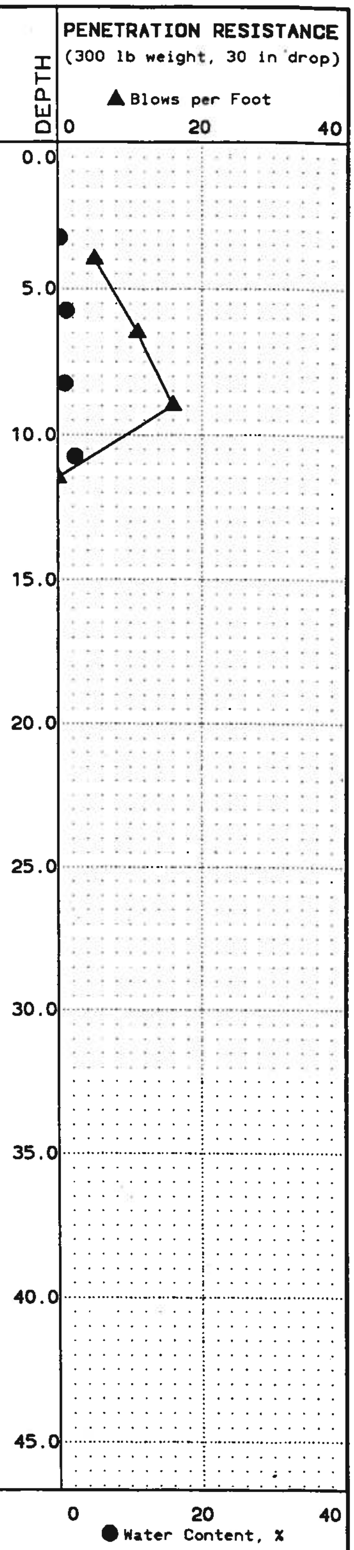
brown to gray SILT with trace gravel

Samples: 1, 2, 3, 4

Ground water: ▽ observed during drilling

Bottom of Boring
Boring Completed 5/30/01

Boring located south east of Tank 101



LEGEND

Frozen Ground

- Gravel
- Sand
- Silt
- Clay
- Peat
- Organic Content

- Impervious Seal
- ▽ Water Level
- Screened Interval
- ☒ Thermistor
- I 3 in O.D. Split Spoon Sample
- Ip 3 in O.D. Thin-wall Sample
- IG Grab Sample
- III 3 in O.D. Dry Core Run
- Nx Rock Core
- ✳ Sample Not Recovered

ATTERBERG LIMITS

- Liquid Limit
- Water Content
- Plastic Limit

Note: Stratification lines represent approximate boundaries between soil types and transition may be gradual.

Williams Refinery
Corrective Measures Study
North Pole, Alaska

LOG OF BORING 2001 B-3

September 2001 | 31-1-11066

SHANNON & WILSON, INC.
Geotechnical Consultants

Sheet 1 of 1

C:\00SBORNG\106684 LOG 09-04-2001 14:55:14

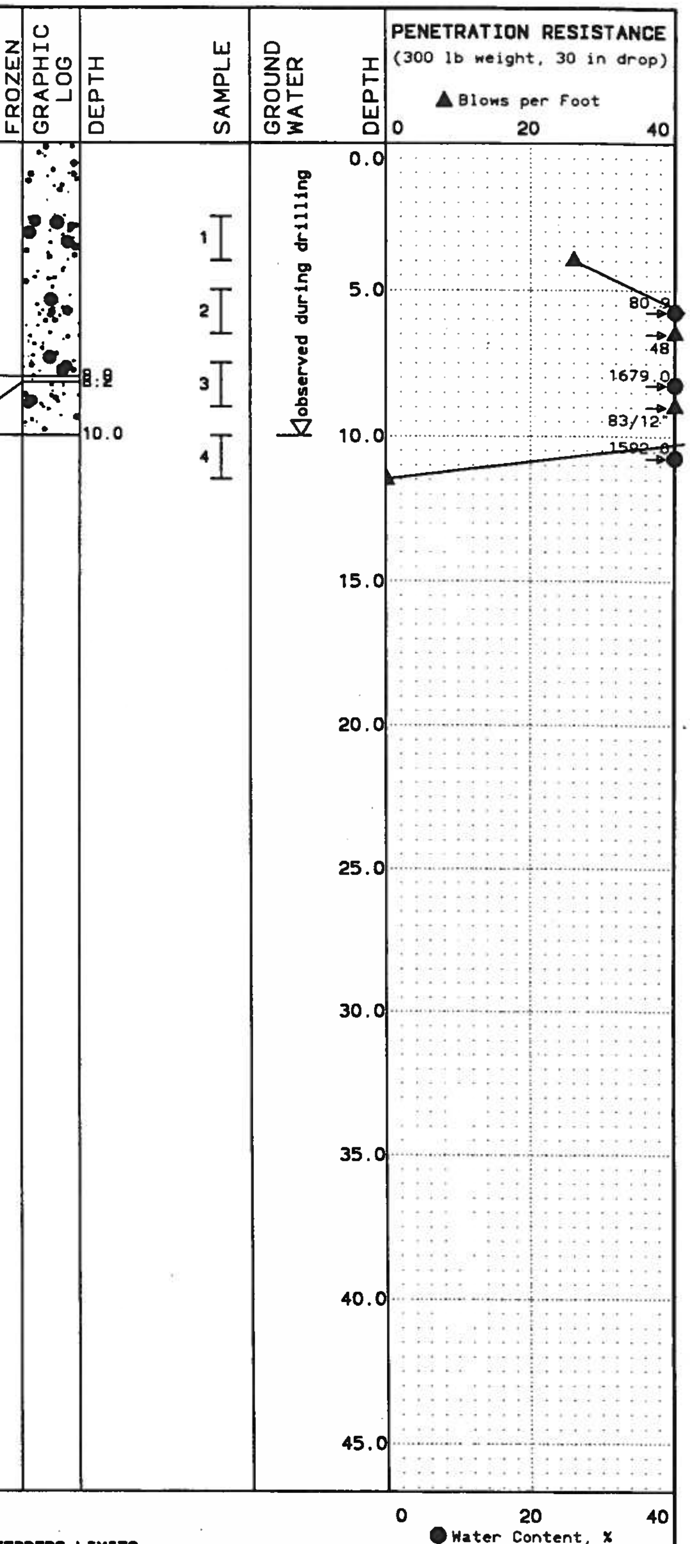
SOIL DESCRIPTION

Surface Elevation: unknown

brown to gray sandy GRAVEL

hard gray SAND

gray sandy GRAVEL



Bottom of Boring
Boring Completed 5/30/01

Boring located at rail loading area
between tracks 3 and 4

LEGEND

Gravel
Sand
Silt
Clay
Peat
Organic Content

Frozen Ground

Impervious Seal
▽ Water Level
Screened Interval
☒ Thermistor
I 3 in O.D. Split Spoon Sample
IIP 3 in O.D. Thin-wall Sample
IG Grab Sample
III 3 in O.D. Dry Core Run
Nx Rock Core
✳ Sample Not Recovered

ATTERBERG LIMITS

Liquid Limit
Water Content
Plastic Limit

Note: Stratification lines represent approximate boundaries between soil types and transition may be gradual.

Williams Refinery
Corrective Measures Study
North Pole, Alaska

LOG OF BORING 2001 B-4

September 2001 31-1-11066

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Sheet 1 of 1