
FINAL REPORT

MN-044

SITE ASSESSMENT REPORT
WERNECKE CAMP
KENO HILL, YUKON

PUBLIC WORKS & GOVERNMENT SERVICES

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 **NORECOL, DAMES & MOORE**

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1.0 INTRODUCTION AND BACKGROUND

In 1993, an assessment of abandoned mine exploration and development sites in the Yukon was performed by DIAND Technical Services under the Arctic Environmental Strategy Action on Waste. The assessments provided a general overview of the level of environmental impacts associated with the sites. Conditions identified ranged from no environmental or safety concerns from mine workings, to significant occurrence of off-site transport of contaminants (by water and, in some cases, fugitive air emissions). The key area of concerns identified included:

- accessible adits and portals;
- deteriorating buildings and other structures;
- abandoned fuel in drums and tanks;
- potentially acid generating tailings and waste rock; and
- metals leaching in mine water.

No samples were collected or analyzed during the performance of these assessment studies.

Subsequent to the completion of the 1993 study, Indian and Northern Affairs Canada determined that additional investigation would be warranted. Norecol, Dames & Moore, Inc. (NDM) was requested to perform a site assessment on four selected mine sites to identify specific environmental and human safety risks associated with the specific abandoned mine sites and to provide recommendations and Class "D" cost estimates for mitigation or remediation of the identified risks. The site inspection and data collection phase of the work program was performed during the period of August 26, 1996 through September 1, 1996. The four mine sites assessed by NDM on behalf of PWGSC included:

- Kalzas Twins
- Paddy Camp
- Wernecke
- Past Wernecke

A brief discussion of the program's scope of work, approach and methodology have been presented in Section 2.0 of this report.

1.1 LOCATION & SITE ACCESS

The "Wernecke" site is located some 4 km north of the town of Keno City along the Gambler Gulch trail. The site is accessible from the town of Keno City by 4-wheel drive vehicle, persons on foot, and/or an all-terrain-vehicle (ATV). A site location map has been presented in Figure 1. A site layout plan, identifying sampling locations, has been presented in Figure 2. Photographs identifying current site conditions have been presented in Appendix C.

1.2 OVERVIEW OF SITE DEVELOPMENT

The Ladue and Sadie mines, located at the site called "Wernecke", operated from 1923 to 1932. Facilities included the mine, mill, shops, townsite and community facilities. The equipment was powered by steam, generated in a wood-fired boiler (still on site).

The Ladue mine was serviced by two shafts (#1 and #2), which are now covered with rubble. Some 40 m to the south of the #2 shaft (shown on Figure 2), there is an area where the workings have caved to surface. Presumably, the caving occurred in an old stope. Some 60 m further to the east, there is an area where there has been some open pit mining on surface. The site, in and around the #2 shaft and openings, has been levelled by a bulldozer, and rock has been used to at least partially fill both the caved area and open pit.

There is also an adit, located to the northwest of the Ladue mine shafts at the 4,500' elevation, which intersects the bottom of the Ladue workings.

The mill was located immediately to the northwest of the #2 shaft. Tailings from the mill were discharged and allowed to flow downhill into a small lake.

The Sadie mine, located immediately to the southwest of, and connected underground to, the Ladue mine, was also serviced by two shafts, which are now covered with rubble. There is nothing left at the Sadie site.

2.0 PURPOSE AND SCOPE OF WORK

The NDM assessment of the four mine properties included the following primary elements as requested by PWGSC in their standing offer of August 9, 1996. Work program components were streamlined and tailored as appropriate to the specific mine sites:

- Inspect mine openings and workings, buildings and infrastructure, and waste disposal areas (tailings, waste rock dumps).
- Photo document, survey (as appropriate) and map relevant site features.
- Sample stained soils, surface water (including any flows from adits, diamond drill holes, etc.), and petroleum storage containers.
- Identify and map mineralization which may be prone to acid rock drainage (ARD) (where available, existing deposit/mine geology reports will be used to supplement information collected on site for this project).
- Sample tailings and waste rock dumps as required to identify potential or existing ARD conditions. Samples will be collected for acid base accounting (ABA). As well, pH of leachate (if available) and representative paste pH determinations will be made on site.
- Sample landfills and other solid waste disposal facilities for leachate quality and to identify other environmental problems such as proximity to water bodies, stability hazards, etc.
- Identify available, site-specific, mitigation measures, where required.
- Identify and inventory (quantify) hazardous (such as petroleum products) and non hazardous materials (such as materials stockpiles) (explosives will be identified but not disturbed).
- Identify potential and actual environmental pathways and receptors for site contaminants (and quantified where possible through sampling previously discussed).
- Assess human safety hazards and potential for accidental or deliberate access to hazardous areas.
- Develop preliminary cost estimates (class D [+/-25%]) for the following:
 - physical and chemical stabilization of waste rock and tailings disposal areas;
 - sealing all mine openings;
 - consolidation and land filling of non hazardous, non combustible solid wastes;

- closure of existing landfills and dumps containing non hazardous wastes;
- remediation of contaminated soils to CCME industrial standards (or removal if remediation is not feasible);
- removal and disposal of hazardous solid wastes;
- on site flaring of uncontaminated petroleum products or removal and off site disposal of petroleum and other hazardous liquids;
- demolition of buildings and other structures to foundation level and burning of combustible nonhazardous materials in approved locations.

Optionally, at the discretion of DIAND, revegetation cost estimates could also be provided.

Access roads were not included as a general work program requirement; however, areas affected directly by mine development were reviewed where applicable. As directed by PWGSC, only areas identified as associated with the former exploration activities, or adjacent areas reportedly affected by these activities, were evaluated by the NDM project team during the review program.

3.0 SITE ASSESSMENT METHODOLOGY

3.1 ASSUMPTIONS

At each mine site, the assessment was limited to the area specifically developed or occupied for mine exploration or mining purposes and immediately-adjacent areas within applicable claim boundaries, as well as off-site environmental resources believed to be affected by mine exploration or development activities. Access roadways to mine sites were not included in the assessments.

3.2 ASSESSMENT CRITERIA

In 1991, the Canadian Council of Ministers of the Environment (CCME) initiated the National Contaminated Sites Remediation Program (NCSRP) for remediation of high priority sites in Canada. In order to provide consistent standards against which the remediation of these sites could be completed, the CCME requested the development of the Canadian Environmental Quality Criteria for Contaminated Sites.

The interim environmental quality criteria produced in September, 1991, were adopted from existing guidelines and criteria used throughout Canada on federal lands. The CCME noted at the time of their creation that the CCME criteria did not constitute values for uniform environmental quality at all contaminated sites and their use would require consideration of local conditions (CCME, 1991).

For the purposes of evaluating environmental conditions consistently throughout the four specified mine sites, the CCME interim criteria was applied. Soil and groundwater analytical results were assessed according to CCME criteria, where available. Due to the lack of appropriate CCME criteria for mine sites, the commercial/industrial criteria have been applied as an interim measure for evaluating soil conditions. As no CCME criteria currently exist for VPH and LEPH/HEPH parameters, these analyses were performed for characterization purposes only of suspected petroleum hydrocarbons noted at certain sites in surface soils. To provide a reference for comparison, appropriate BC Criteria for Managing Contaminated Sites (CMCS, July, 1995) and the New Petroleum Hydrocarbon Criteria (August, 1995) have been provided. The characterization information resulting from the application of these analyses has provided information concerning the identification of the suspected petroleum hydrocarbon(s) observed.

Surface water samples have been evaluated against the CCME aquatic life criteria.

3.3 METHODS

3.3.1 Program Methodology

During the performance of the site inspection, site specific information was reviewed to identify the potential contaminants of concern (PCOC's). Information was collected from the Yukon Chamber of Mines, Department of Indian and Northern Affairs, Whitehorse Mining District Mining Recorder, United Keno Hill Mines Ltd., Department of Energy, Mines and Resources, Environment Canada Atmospheric Environment Service, Yukon Tourism, Keno City Hotel, the Keno City Mining Museum, and Mr. Mike Mancini (Keno City Snack Bar). A full list of references is presented at the end of this report.

Waste rock disposal areas were inspected, measured, characterized and sampled by a professional geologist. Non-hazardous debris was characterized and documented. Mine openings, associated mine workings, and building structures were inspected and assessed by a professional mining engineer for stability and the presence of hazardous materials. Areas of visible contamination were characterized, measured and sampled. Hazardous materials were identified, characterized where possible, and sampled where possible for laboratory analysis. Samples were collected and preserved in anticipation of the finalization of the analytical program to maximize the characterization of the site. Upon completion of the sampling program and data collection phase, NDM consulted DIAND to finalize the analytical program and discuss the identified concerns.

The methodology for assessment of mine openings was based on findings from the field inspection, as well as a review of available reports and other available information. Some records were available on the sites in the DIAND files. Information was also available, in particular of the underground workings, for the "Wernecke" and "Past Wernecke" sites from United Keno Hill Mines Ltd (UKHM).

3.3.2 Sampling Methods and Quality Assurance

Samples of waste rock, surface water, barrel contents, and/or visibly stained soils were collected by a trained environmental scientist for further characterization and laboratory analysis. A sample parameter summary chart has been presented in Table 1.

Surface Water Sampling

Water samples were collected from surface streams upstream and downstream of identified mine workings/exploration activities as well as from representative seeps originating from waste rock stockpiles, pits, tailings or adit areas.

Surface water samples were collected into pre-cleaned plastic bottles supplied by the project laboratory according to the analysis selected. The location of the sample with respect to mine workings, other surface water features, etc. was noted in the field. pH readings were collected in the field for each surface water sample and recorded. Visual observations,

including colouration, clarity, odour, etc., was noted and recorded for each sample. Each sample container was clearly labelled with the site name, sample location and sample interval number, and the project scientist's initials. Filled sample containers were stored in ice-packed coolers at the site and during transport to the laboratory. Samples were maintained in a refrigerated state until analysis. Surface water samples were analyzed by CanTest Laboratories, Vancouver, B.C.

Soil Sampling

Soil samples were collected from any areas associated with historical barrel/hazardous materials storage, areas of visible surface staining, garbage dump areas, and boiler houses.

Soil samples were collected by the field scientist using a shovel and/or trowel and were placed into pre-cleaned 250 ml glass jars with Teflon-lined lids, supplied by the project laboratory. The sampling instrument was cleaned between the collection of different samples. Coolers were repacked for shipment with fresh ice packs at the end of the field inspection program, and were immediately delivered to the project laboratory with chain of custody records. All samples were stored under refrigeration at the project laboratory until analysis. Samples were analyzed by CanTest Laboratories, Vancouver, B.C. Soil and Laboratory Quality Assurance/Quality Control information has been presented in Appendix D.

Each sample container was clearly labelled with the site name, sample location and sample interval number, and the project scientist's initials. Visual observations, including size of stained area, presence/absence of odour, particle size, location, etc., were recorded on the field sample sheets. Filled sample containers were stored in ice-packed coolers at the site to minimize dissipation of volatile compounds. Samples were maintained in a refrigerated state prior to analysis.

Waste Rock

Waste rock samples were representatively sampled by the field scientist from as many waste rock piles as could be identified in the field. Field observations such as waste rock pile rock-type composition, colour, presence/absence of visible carbonate/sulphide mineralization, primary and secondary mineralization, etc. were recorded during the site visit. Each waste rock pile was mapped and its dimensions measured.

Each sample was collected by hand and placed into heavy gage plastic bags, sealed tightly, and placed in coolers for shipping. Waste rock samples were analyzed for ABA (Acid Base Accounting) by CESL Laboratories, Vancouver, B.C.

Analytical Parameters

Samples of soil and water were analyzed for compounds of environmental concern that could potentially be present based on existing information and the results of the site inspection. Samples were analyzed to detect the parameters of concern (PCOC's) identified during the

performance of the work program. The following parameters were analyzed in soils collected from the Wernecke camp: Benzene/Toluene/Ethylbenzene/and Xylene (BTEX), Volatile Petroleum Hydrocarbons (VPH), Total Metals and Polyaromatic Hydrocarbons (PAHs). Surface water samples collected at the Wernecke camp were analyzed for conventional parameters (pH, Total Suspended Solids, and sulphate) and total metals. Modified Sobek Method Acid-Base Accounting (ABA) analyses were performed on waste rock samples collected by the project team. ABA analysis included total sulphur, sulphurous sulphate, modified sobek neutralization potential and paste pH. Sulphur content used for calculation of acid potential (AP) was total sulphur content minus sulphate content yielding AP in terms of sulphide content.

4.0 ENVIRONMENTAL SETTING

4.1 MINERALIZATION

The Wernecke camp is located within the Keno Hill Camp. According to the GSC, deposit is characterized by the presence of silver/lead/zinc (Ag-Pb-Zn) mineralization (Roots & Murphy, 1992). The local geological setting of the Wernecke camp includes the presence of Mississippian Keno Hill quartzite, Upper Devonian and Mississippian sedimentary and felsic meta-volcanic rocks. Principle ore minerals include argentiferous (silver-containing) galena, freibergite ("grey copper"), and pyrargyrite ("ruby silver") (UKHM, Report No. UKH/96/01, Site Characterization). Minor ore minerals include polybasite, stephanite, argentite, greenockite and native silver. The primary gangue mineral is siderite, often associated with quartz. Sulphosalts, sphalerite, pyrite, calcite, pyrrhotite, siderite, and arsenopyrite have also been reported..

According to a review of site conditions prepared by Access Mining Consultants (6/1/96), the following major rock types are commonly encountered in the study area:

- schists and phyllite with variable carbon content;
- chloritic phyllite and schists;
- quartzites and phyllitic quartzites;
- sericite-quartz phyllite; and,
- greenstones.

The Wernecke camp is located within an area of anomalously elevated values for certain mineral constituents. The presence of sphalerite, galena, and sulphantimonites associated with this type of deposit may be related to elevated levels of cadmium and antimony (Economic Mineral Deposits, 1956). Zinc smelters commonly recover cadmium as a by-product of the processing of the ore. According to the UKHM report UKH/96/01 (Site Characterization), the following minerals known to occur in the Keno Hill camp contain antimony: Freibergite, pyrargyrite, polybasite, stephanite, and jamesonite. The same report also records the occurrence of greenockite/hawleyite, which is cadmium-containing. The presence of sulphide mineralization and/or carbonate minerals at the site is significant in interpreting Acid Base Accounting data as discussed in Section 5.5.

4.2 SURFACE HYDROLOGY

The site is located on the northwest flank of Keno Hill, several kilometres upgradient of Gambler and Hansen Lakes. Regional drainage appears to flow towards these two lakes and associated connecting stream systems, including the Keno Ladue River. A small tributary of Gambler Lake is located greater than 1 km from the site. According to the Department of Fisheries and Oceans (DFO, Yukon, Habitat Enhancement Branch, 02/05/97), Hansen Lake was the site of a government Toxithene treatment program in the 1960's. Toxithene is an organochloride which was added to the lake to exterminate native fish species prior to the

introduction of a non-native rainbow trout. Subsequent to this program, the rainbow trout were unable to survive in the lake. The only species since identified by DFO is Northern Pike. No adverse impacts to nearby surface water features and/or fisheries habitat were noted by DFO due to the historical activities at the Wernecke camp.

A small pond of water was noted in the most northern trench and appeared to contain seasonal surface water runoff produced by precipitation. No stream or seeps were observed at the site.

4.3 CLIMATE

A total of four climate stations exist within the study area and include:

- Atmospheric Environment Services (AES) station at the Elsa Townsite;
- Atmospheric Environment Services (AES) station on the southern flank of Keno Hill;
- Seasonal station operated by DIAND at the Flat Creek Catchment; and,
- Principal climatological station at the Mayo Airport, operated by the AES.

Climate records for Keno Hill from July 1974 to February 1982 show average temperatures ranging from -16.7°C in January, the coldest month, to 10.4°C in June, the warmest month of the year. The record low temperature during this period was -44.4°C on January 5, 1975, and the record high was on August 1, 1976 and was 27.2°C. Average monthly precipitation ranges from 25.3 mm in February to 79.6 mm in July. The mean annual precipitation for Keno Hill is 597.4 mm.

4.4 VEGETATION

The study area is located within the Mayo Lake - Ross River Ecoregion (Oswald and Senyk, 1977) just below the treeline. The site is typical of boreal forest and is heavily vegetated with alder (*Alnus crispa*), willow (*Salix* spp.), and black spruce (*Picea mariana*) representing the primary species. Vegetation typical of an alpine environment is visible upgradient of the site.

4.5 FISH AND WILDLIFE RESOURCES

4.5.1 Fisheries

Due to the distance of the site from any significant surface water feature, no fisheries issues were identified at the site. As described in Section 4.2, Northern Pike have been reported in Hansen Lake. No adverse effects on nearby surface water features or fish habitat have been identified as a result of historical mining activities at the Wernecke site.

4.5.2 Wildlife

The Elsa-Keno Hill area supports a wide variety of wildlife, including waterfowl, upland game birds, fur-bearers, small mammals, and ungulates. Caribou have been occasionally harvested in the area; however, no recent occurrences have been recorded. Moose, marten, wolverine and lynx are also known to inhabit the study area. Historically, thin-horn sheep inhabited the area but disappeared in the 1920's because of over hunting. Small mammals common to the study area include muskrat, ground squirrel, beaver, red squirrel, varying hare, fox, mink, weasel, vole, shrew, porcupine, river otter, and chipmunks. Large carnivorous mammals include grizzly bear, black bear, and timber wolf (Access Mining Consultants, 1996).

4.6 SITE TOPOGRAPHY AND SOILS

The study area is located on the northwestern flank of Keno Hill, immediately below the treeline at an approximate elevation of 1250 m above sea level. The existing site reflects the effects of long-term historical human interference through the presence of trenches and the widespread levelling of the steeply-sloping site with waste rock. This is most evident in the area of the former mine workings. Numerous trenches, waste rock piles, access roads and one large open pit are present at the site. A site layout plan has been presented in Figure 2.

Site soils, visible in the undisturbed areas surrounding the camp, are sparse and consist primarily of residual soils formed by the weathering of the underlying bedrock and from the decomposition of glacial till. In vegetated areas, minor amounts of organic material were present in site soils overlying bedrock.

A fine-grained material was noted downgradient of the former mine workings along an access road at the northwest end of the camp. Samples of this silt-sand material were collected during the site inspection for analysis. It is believed that this material may represent residual tailings deposited during the processing of ore at the camp.

4.7 PERMAFROST

The region is characterized by the presence of discontinuous permafrost. According to a previous study by Access Mining Consultants Ltd. (6/1/96), permafrost is irregularly distributed and its character is influenced by several factors including elevation, hillside exposure, depth of overburden, amount of vegetative cover, and the presence of surface and/or ground water. According to Access, mine workings on the north slope of Keno Hill intersected permafrost at 400 feet below ground surface. Mine workings located on the south slope of Keno Hill showed little evidence of permafrost due to the southern hillside exposure and lower elevation. No surface signs of underlying permafrost were noted during the site visit; however, it is highly likely due to location that permafrost conditions would be encountered in the study area at depth.

5.0 SITE DESCRIPTION AND FINDINGS

5.1 BUILDINGS, INFRASTRUCTURE, EQUIPMENT

The buildings at the Wernecke camp are generally in poor condition with the exception of the former mine manager's house, subsequently used as an office. Several of the wooden structures have collapsed, either partially or totally. In addition to the former mine manager's house, several other structures were still intact and could be identified at the site including the following:

- 3 x 4 m wood frame sauna
- 4 x 5 m wood frame shed
- outhouse (metal clad)
- 6 X 10 m wood frame structure apparently used as a residence
- 11 X 24 m collapsed log and wood frame structure with arched roof
- boiler with metal exhaust stack

Other than the outhouse, which is a more recent construction, the buildings have been vandalized and are close to a state of collapse. The wooden structures were built on wood crib foundations. The wood and timber on site does not appear to have been treated using chemicals. Photographs of some onsite collapsed building structures are presented in Photographs #3 and #4.

According to a report produced by DIAND Technical Services in 1994, the Wernecke site is considered to be a historical site. Discussions with the Keno City Mining Museum staff and local businessmen (Mr. Mike Mancini, September, 1997) have indicated that the abandoned mining community of Wernecke is a popular hiking destination and historical marker.

The area is extensively trenched and is accessible by vehicle via the Gambler Gulch trail. What appeared to be an historical access road extended from the centre of camp downhill in a northwesterly direction. This road was covered with a tailings-like surface material for approximately 300 m which is further discussed in Section 5.5.

The surface exploration and trenching covers an area at least 800 x 600 m with an open pit situated in the centre of the site. An open hole, measuring 5 x 3 m was noted to the southeast of the main pit and is interpreted to have been caving of old underground workings. The open hole, flagged by NDM staff at the time of the site visit, is shown in Photograph #1.

5.2 NON-HAZARDOUS MATERIALS

A waste dump area was observed down gradient of the camp area on the west side of a northwest-trending access road to the site. Empty drums, scrap metal and other non-hazardous debris were dumped on the vegetated slope. The surface area appeared darkened and stained. One soil sample (WS4) was collected from this area and submitted for total

metals, BTEX, VPH, and LEPH/HEPH analyses. As no CCME criteria is available VPH and LEPH/HEPH, these analyses were performed as a screening process and have been referenced to BC CMCS and New Petroleum Hydrocarbon criteria (July and August, 1995) for commercial/industrial sites. According to the results of the analytical program, WS4 was within CCME criteria for BTEX. As no CCME criteria is currently available for VPH and LEPH/HEPH, these analyses were performed as a screening process and to characterize and confirm, if present, the identity of the petroleum hydrocarbon suspected. According to the results for these analyses, VPH and LEPH/HEPH levels at the waste dump were within criteria and were less than the detection limit. The waste dump is shown in Photograph #6.

WS4 did exceed CCME commercial/ industrial criteria for silver, antimony, cadmium, lead, and zinc. These results are consistent with the mineralogy of the Wernecke deposit. The Wernecke camp is located within an area of anomalously elevated values for certain mineral constituents. The presence of sphalerite, galena, and sulphantimonites associated with this type of deposit is related to elevated levels of cadmium and antimony (Economic Mineral Deposits, 1956). The recorded occurrence of greenockite/hawleyite, a cadmium-containing mineral, and a pribramitic sphalerite (cadmium-containing), may have also contributed to the elevated levels of this element in analysed samples. The presence of sulphide mineralization and/or carbonate minerals at the site is significant in interpreting Acid Base Accounting data as discussed in Section 5.5.

No landfills or borrow areas were identified during the field inspection. Soil sample results have been presented in Tables 3 through 6.

5.3 HAZARDOUS MATERIALS

One surface sample (WS1) was collected from the helicopter pad and analyzed for BTEX, VPH, LEPH and HEPH due to the storage of approximately 12 fuel drums at this location. According to the labelling on the fuel drums, they appeared to be owned by Archer Catharo and Transnorth Helicopters and contained Jet B fuel. The drums were in good condition and were dated "August 1996". As no CCME criteria is available VPH and LEPH/HEPH, these analyses were performed as a screening process and have been referenced to BC CMCS and New Petroleum Hydrocarbon criteria (July and August, 1995) for commercial/industrial sites. According to the results of the analytical program, the surface material did not exceed either the CMCS, New Petroleum Hydrocarbon Criteria, or CCME criteria for any of the parameters analyzed.

One sample (WS3) was collected from the ashy residue observed by the project team at the base of the boiler. This sample was submitted for total metals and PAH analyses. According to the results of the analytical program, sample WS3 exceeded CCME criteria for cadmium, lead, zinc, and benzo(b+k)fluoranthene and indeno(1,2,3-c,d)pyrene. The approximate volume of the ashy material is estimated to be equal to 3 - 205 L barrels. The boiler is shown in Photograph #5.

Analytical results have been presented in Tables 3 through 6.

5.4 SURFACE WATER QUALITY

One surface water sample was collected from the Wernecke site (Figure 2 and Photograph #7) and was analyzed for pH, total suspended solids (TSS), sulphate, and total metal concentrations (Table 7). The surface water pH was within the CCME Criteria for Freshwater Aquatic Life (CCME). Total metal concentrations in the sample were slightly above the CCME criterion for zinc. Sulphate concentrations were elevated in the sample (433 mg/L). TSS concentrations were low (<10 mg/L) and within an acceptable range. There are no CCME for sulphate and TSS.

5.5 WASTE ROCK DISPOSAL AREAS

At the time of the site visit, visual observations were made as to the condition of the waste rock piles, characterization of rock type, visible presence of carbonate/sulphides, visible evidence of acid generation, etc. No visible evidence of acid generation was noted at the time of the site visit. Several views of the onsite waste rock piles are presented in Photographs #2, #4, and #8.

Seven samples of rock were selected at the Wernecke site. The samples were all waste rock from the site area (Figure 2). The waste rock samples consisted of Quartzite (WWR1 and WWR2), Greystone (WWR3), Argillite (WWR4 and WWR5) and Graphitic Schist (WWR6 and WWR7). The samples were submitted for ABA which provide paste pH, total sulphur, total sulphate, calculated acid and neutralization potential and NP/AP ratio (Table 2).

The samples were all non-acidic (paste pH varying from 7.1 to 7.9) with low total sulphur concentrations (0.25 to 1.1%). Sulphate-sulphur concentrations ranged from <0.13 to 0.3%. The corresponding acid potential (AP) ranged from 3.4 to 29 kg CaCO₃/t. The neutralization potential (NP) ranged from 49 to 165 kg CaCO₃/t. Due to the low sulphur content and NP/SAP of 3 to 22, the material was classified as potentially acid consuming.

5.6 TAILINGS

A fine to medium grained material was observed by the project team at the northwest edge of the camp area along a north-trending access route. This material showed flow patterns and appeared to have been deposited in a saturated state. Due to the location of this material down gradient of the mine workings and the grain-size of the material, it was assumed that it represented historical mine tailings.

One sample of this material (WS2) was collected and analyzed for total metals analyses. The analytical results have been presented in Table 6. According to the analytical results, the sample exceeded CCME commercial/industrial criteria for silver, cadmium, lead, and zinc. These results are consistent with the mineralogy of the deposit at Wernecke camp.

5.7 MINE OPENINGS

The Ladue mine, located at Wernecke, was serviced by two shafts, which are now covered with rubble. The location of the # 2 shaft can be identified on site (Figure 2), but not the #1 shaft. Some 40 m to the south of the #2 shaft, there is an area where the workings have caved to surface. Presumably, the caving occurred in an old stope. Some 60 m further to the east, there is an area where there has been some open pit mining on surface. The site, in and around the #2 shaft and openings, has been levelled by a bulldozer, and rock has been used to at least partially fill both the caved area and open pit.

There is also an adit, located to the northwest of the Ladue mine shafts at the 1,370 m (4,500') elevation, which intersects the bottom of the Ladue workings. The Ladue adit is partially collapsed, and full of ice most of the year. It would have to be sealed with waste rock as part of reclamation.

The Sadie mine, located to the southwest of, and connected underground to, the Ladue mine, was also serviced by two shafts, which are now covered with rubble. There is nothing left at the Sadie site.

A view of the old mine workings at the centre of the site are presented in Photograph #4.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 HEALTH AND SAFETY

The presence of collapsed building structures along the steeply sided main camp area present a concern, particularly as the area is a popular hiking trail for visitors to the Keno Hill area. Fencing and visual notification may be used as warnings to the site; however, the structures themselves should be modified to reduce the risk to health & safety. According to a report produced by DIAND Technical Services in 1994, the Wernecke site is considered to be a historical site. Discussions with the Keno City Mining Museum staff and local businessmen (Mr. Mike Mancini, September, 1997) have indicated that the abandoned mining community of Wernecke is a popular hiking destination and historical marker. A review of the site by a cultural resources expert may be advisable to identify the site's historical value.

A public health and safety issue is the presence of the open pit and caved area at the centre of the site. The caved area was flagged around its perimeter by the project team during the field inspection to increase its visibility. This area should be filled by dozing waste rock from around the area into the hole. Should PWGSC have on-going concerns regarding the potential for additional caving, an assessment of existing mine plans may be performed. A 2 m high berm should be constructed around the open pit to reduce the risk of inadvertent access by hikers or snowmobilers.

6.2 ENVIRONMENTAL RISKS

Elevated PAHs exceeding CCME commercial/industrial criteria were identified in the ashy residue located at the base of the boiler. The ashy residue should be collected by an appropriate contractor and placed in sealed containers, labelled, manifested, and transported off-site to a secure landfill facility, such as the Swan Hills facility in Alberta. Several licensed hazardous materials contractors in Whitehorse are available to perform this task. Costs for this task have been presented in Section 7.0.

The storage of fuel barrels at the helicopter pad appears to be temporary; however, the owners of the barrels should provide some form of spill containment during periods of barrel storage, such as rudimentary berms and a polythene liner.

6.3 AESTHETIC CONCERNS

Non-hazardous scrap material identified at the waste dump can be left on-site as is, consolidated, or buried under waste rock. A review of the site by a cultural resources expert and further discussions with the local tourism board may be advisable to identify the site's historical value. It is recommended that the extensive piles of waste rock be used to fill in the trenches and as burial cover for incinerated materials.

7.0 LIMITATIONS

The findings and conclusions documented in this report have been prepared for specific application to this project and have been developed in a manner consistent with that level of care and skill normally exercised by members of the environmental science profession currently practising under similar conditions in the area, and in accordance with the terms and conditions set forth in our proposal. No other warranty, expressed or implied, is made. This report is for the exclusive use of Public Works & Government Services Canada and their representatives. The scope of services performed in execution of this investigation may not be appropriate to satisfy the needs of other users, and any use or re-use of this document or the findings, conclusions, or recommendations presented herein is at the sole risk of said user.

Testing conducted on the site was in locations and for parameters consistent with former site uses. However, as conditions between sampling locations may vary, a potential always remains for the presence of unknown, unidentified, or unforeseen surface and subsurface contamination. Given that the scope of service for this assessment included limited soil and groundwater sampling and analytical testing, it is possible that currently unrecognized contamination may exist at the site and, if present, that the levels of contamination may vary across the site. Further evidence against such potential site contamination would require additional surface and subsurface exploration and chemical analytical testing.

Opinions, conclusions and recommendations in this report apply to site conditions existing at the time of our assessment and are based on comparison of chemical analytical results to the Canadian Council of Ministers of the Environment (1991), B.C. Environment, Lands and Parks "Criteria For Managing Contaminated Sites In B.C.", (July 1995) and the New Petroleum Hydrocarbon Criteria (August, 1995). In the event these criteria are changed, new criteria are introduced, or new information is developed in future site work, Norecol, Dames & Moore, Inc. should be provided the opportunity to reevaluate the conclusions of this report, and to amend our opinions, as appropriate.

Norecol, Dames & Moore, Inc.'s objective is to perform our work in a professional manner and with the best interests of our clients in mind. It is important to recognize that even the most comprehensive scope of services may fail to detect environmental liability on a particular site. Therefore, Norecol, Dames & Moore, Inc. cannot act as insurers and cannot "certify" or "underwrite" that a site is free of environmental contamination, and no expressed or implied representation or warranty is included or intended in our reports except that our

work was performed, within the limits prescribed by our client, with the customary thoroughness and competence of our profession.

NORECOL, DAMES & MOORE, INC.

per:



Linda Wrong, B.Sc.
Environmental Geologist



David P. Harpley, P.Geo.
Senior Consultant
Senior Review

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TABLES

TABLE 1
WERNECKE SITE
SAMPLE PARAMETERS SUMMARY CHART
PUBLIC WORKS AND GOVERNMENT SERVICES
YUKON ABANDONED MINE SITES - WERNECKE
20749-013-310

Sample Identification	Sample Type	Parameters Analysed						
		PCB	Total Metals	ABA	BTEX/VPH	LEPH/HEPH	Conventional Parameters	PAH
WWR1	waste rock			X				
WWR2	waste rock			X				
WWR3	waste rock			X				
WWR4	waste rock			X				
WWR5	waste rock			X				
WWR6	waste rock			X				
WWR7	waste rock			X				
WS1	soil				X	X		
WS2	soil		X					
WS3	soil		X					X
WS4	soil		X		X	X		
WW1	surface water		X				X	

PCB - polychlorinated biphenyls

ABA - acid-base accounting

BTEX/VPH - benzene, toluene, ethylbenzene, xylenes, volatile petroleum hydrocarbons

LEPH/HEPH - light extractable petroleum hydrocarbons / heavy extractable petroleum hydrocarbons

Conventional Parameters - pH, sulphate, total suspended solids

PAH - polycyclic aromatic hydrocarbons

TABLE 2
 MODIFIED SOBEK METHOD ACID-BASE ACCOUNTING
 PUBLIC WORKS AND GOVERNMENT SERVICES
 YUKON ABANDONED MINE SITES - WERNECKE
 20749-013-310

Sample No.	Rock Type	Paste pH	S(T) %	S(SO4) %	AP	NP	NET NP	NP/AP
WWR1	Quartzite, grey; massive, <1% pyrite finely disseminated (5-10%)	7.45	0.51	0.18	10.3	90.0	79.7	8.7
WWR2	Quartzite, finely disseminated pyrite (1%); abundant fine calcium carbonate veining, partly oxidized	7.09	0.42	0.16	8.1	49.3	41.1	6.1
WWR3	Greenstone, dark green, <1% pyrite, 1% carbonate, massive	7.68	1.09	0.15	29.4	81.3	51.9	2.8
WWR4	Argillite, abundant quartz veining, iron staining associated with quartz veining, grey, slightly slate fabric	7.70	0.25	0.14	3.4	75.3	71.8	21.9
WWR5	Argillite to phyllite, abundant quartz veining, iron staining associated with quartz veining, grey, slightly slate fabric, slightly silky sheen	7.86	0.25	0.13	3.8	73.8	70.0	19.7
WWR6	Graphitic Schist, 20% carbonaceous material (graphite); medium to dark grey, silky sheen, platy texture, boudinage quartz veining, finely disseminated cubes of pyrite <1%	7.94	0.52	0.20	10.0	164.5	154.5	16.5
WWR7	Graphitic Schist, 20% carbonaceous material (graphite); medium to dark grey, silky sheen, platy texture, boudinage quartz veining, finely disseminated cubes of pyrite <1%	7.88	0.71	0.30	12.8	112.8	99.9	8.8

AP = Acid Potential in Tonnes CaCO₃ Equivalent per 1000 Tonnes of material.

NP = Neutralization Potential in Tonnes CaCO₃ Equivalent per 1000 Tonnes of Material.

NET NP = Net Neutralization Potential = Tonnes CaCO₃ Equivalent per 1000 Tonnes of Material.

TABLE 3
CONCENTRATION OF BTEX AND VOLATILE PETROLEUM HYDROCARBONS IN SOIL SAMPLES
PUBLIC WORKS AND GOVERNMENT SERVICES
YUKON ABANDONED MINE SITES - WERNECKE SITE
20749-013-310
ug/g (ppm)

			Benzene	Ethylbenzene	Toluene	Xylenes	Volatile Petroleum Hydrocarbons
CCME	Commercial/Industrial		5.	50.	30.	50 (a)	NC
CMCS PHC	Commercial/Industrial						200.
Sample No.	Location	Depth (m)					
WS1	Helicopter Pad	0 - 0.15	<0.5	<0.5	<0.5	<0.5	<10.
WS4	Scrap Metal/Garbage Dump	0 - 0.15	<0.5	<0.5	<0.5	<0.5	<10.
Method Detection Limit			0.5	0.5	0.5	0.5	10.

CCME - Canadian Council of Ministers of the Environment Interim Canadian Environmental Quality Criteria for Contaminated Sites

CMCS PHC - Criteria for Managing Contaminated Sites, British Columbia, July, 1995 and New Petroleum Hydrocarbon Criteria, August, 1995

< - less than the detection limit indicated

NC - no criteria established

(a) - Criteria for total of m, p and o xylenes.

- Greater than CCME criteria for commercial/industrial land use

- Greater than CMCS PHC criteria for commercial/industrial land use

TABLE 4
CONCENTRATIONS OF LEPH & HEPH IN SOIL SAMPLES
PUBLIC WORKS AND GOVERNMENT SERVICES
YUKON ABANDONED MINE SITES - WERNECKE SITE
 20749-013-310
 ug/g (ppm)

			LEPH	HEPH
CMCS - PHC	Commercial/Industrial		2000.	5000.
Sample No.	Location	Depth (m)		
WS1	Helicopter Pad	0 - 0.15	<250.	<250.
WS4	Scrap Metal/Garbage Dump	0 - 0.15	<250.	<250.
Method Detection Limit			250.	250.

Page 1 of 1

CMCS PHC - Criteria for Managing Contaminated Sites, British Columbia, July, 1995
 and New Petroleum Hydrocarbon Criteria, August, 1995

< - less than the detection limit indicated

NC - no criterion established

- Greater than CMCS PHC criteria for commercial/industrial land use

TABLE 5
 CONCENTRATION OF METALS IN SOIL SAMPLES
 PUBLIC WORKS AND GOVERNMENT SERVICES
 YUKON ABANDONED MINE SITES - WERNECKE SITE
 20749-013-310
 ug/g (ppm)

CCME	Commercial/Industrial		Silver	Arsenic	Boron	Barium	Beryllium	Cadmium	Cobalt	Chromium*	Copper	Mercury	Manganese	Molybdenum	Nickel	Lead	Antimony	Selenium	Tin	Vanadium	Zinc
Sample No.	Location	Depth (m)																			
WS2	Suspected Tailings	0 - 0.15	35.	0.2	55.	49.8	<1.	242.	2.	35.	79.	1.5	23400.	<4.	12.	2730.	37.	<0.5	<5.	21.	16700.
WS3	Boiler Ash	0 - 0.15	33.	0.14	84.	123.	<1.	35.4	12.	18.	91.	0.06	2000.	<4.	33.	2350.	59.	<0.5	16.	24.	1910.
WS4	Garbage Dump/Scrap Metal	0 - 0.15	51.	0.18	46.	63.2	<1.	222.	<1.	7.	61.	1.4	40400.	<4.	10.	2720.	110.	<0.5	<5.	12.	17200.
Method Detection Limit			2.	0.05	0.5	0.1	1.	0.25	1.	2.	1.	0.001	0.2	4.	2.	1.	10.	0.5	5.	0.5	1.

CCME - Canadian Council of Ministers of the Environment Interim Canadian Environmental Quality Criteria for Contaminated Sites

< - less than the detection limit indicated

NC - no criteria established

☐ - Greater than CCME criteria for commercial/industrial land use

* - Total Chromium

TABLE 6
 CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) IN SOIL SAMPLES
 PUBLIC WORKS AND GOVERNMENT SERVICES
 YUKON ABANDONED MINE SITES - WERNECKE SITE
 20749-013-310
 ug/g (ppm)

CCME	Commercial/Industrial		Benz(a)anthracene	Dibenz(a,h)anthracene	Chrysene	Benzo(b+k)fluoranthene*	Benzo(ghi)perylene	Pyrene	Benzo(a)pyrene	Indeno(1,2,3-c,d)pyrene	Acenaphthene	Acenaphthylene	Anthracene	Fluoranthene	Fluorene	Naphthalene	Phenanthrene	Total PAHs (a)	Total Low MW PAHs	Total High MW PAHs
Sample No.	Location	Depth (m)	10.	10.	NC	10.	NC	100.	10.	10.	NC	NC	NC	NC	NC	50.	50.	NC	NC	NC
WS3	Boiler Ash	0 - 0.15	4.2	1.6	8.3	17.	18.	6.	7.2	15.	<0.05	0.12	0.35	5.2	<0.05	0.07	1.8	84.8	2.34	82.5
Method Detection Limit			0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05			

CCME - Canadian Council of Ministers of the Environment Interim Canadian Environmental Quality Criteria for Contaminated Sites

< - less than the detection limit indicated

NC - no criterion established

(a) Total PAH concentration calculated using value of one half the detection limit where reported as "less than".

* - Criterion for each of benzo (b) and (k) fluoranthene.

- Greater than CCME criteria for commercial/industrial land use

TABLE 7
CONCENTRATIONS OF CONVENTIONAL PARAMETERS AND TOTAL METALS IN SURFACE WATER
PUBLIC WORKS AND GOVERNMENT SERVICES
YUKON ABANDONED MINE SITES - WERNECKE SITE
 20749-013-310
 ug/L (ppb)

CCME	Freshwater Aquatic Life	pH	Total Suspended Solids (mg/L)	Sulphate SO4 (mg/L)	Silver	Aluminum*	Arsenic	Boron	Barium	Beryllium	Cadmium	Cobalt	Chromium	Copper	Iron	Mercury	Manganese	Molybdenum	Nickel	Lead	Selenium	Tin	Vanadium	Zinc
Sample	Location	6.5-9.0	NC	NC	0.1	5 - 100	50	NC	NC	NC	0.2 - 1.8	NC	2 - 20	2 - 4	300	0.1	100	NC	25 - 150	1 - 7	1	NC	NC	30
WW1	Northernmost Trench - Pond	7.93	3.	433.	<0.1	<200.	<1.	<10.	8.	<3.	0.2	<1.	<1.	<1.	50.	<0.05	29.	3.	2.	<1.	<1.	<1.	<10.	47.
Method Detection Limit					0.1	200.	1.	10.	1.	3.	0.2	1.	1.	1.	30.	50.	3.	1.	1.	1.	1.	1.	10.	5.

CCME - Canadian Council of Ministers of the Environment Interim Canadian Environmental Quality Criteria for Contaminated Sites

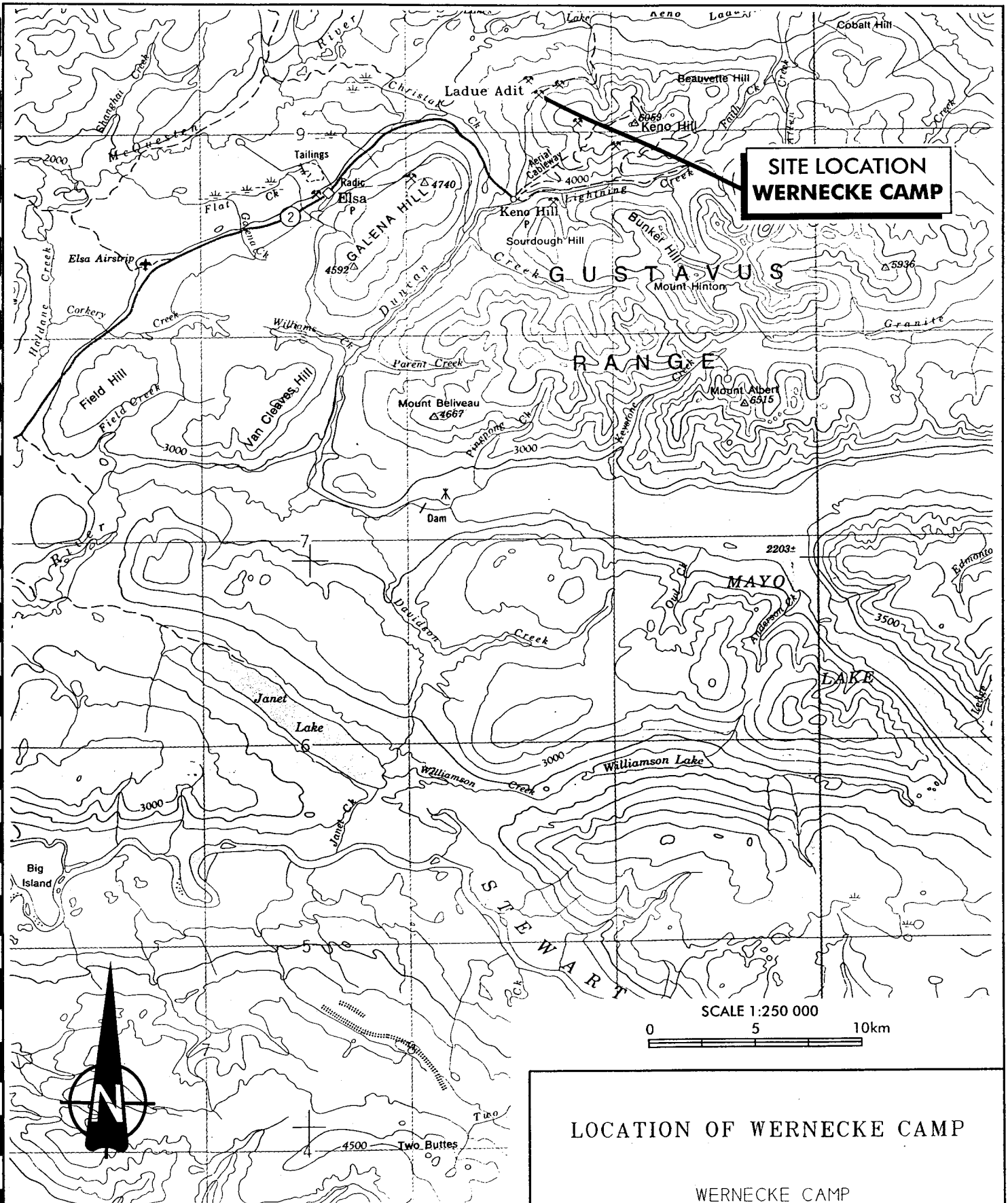
< - less than the detection limit indicated

NC - no criteria established

☐ - Greater than CCME criteria for aquatic life (AW)

* - Criteria depend on pH or hardness of sample

FIGURES



**SITE LOCATION
WERNECKE CAMP**

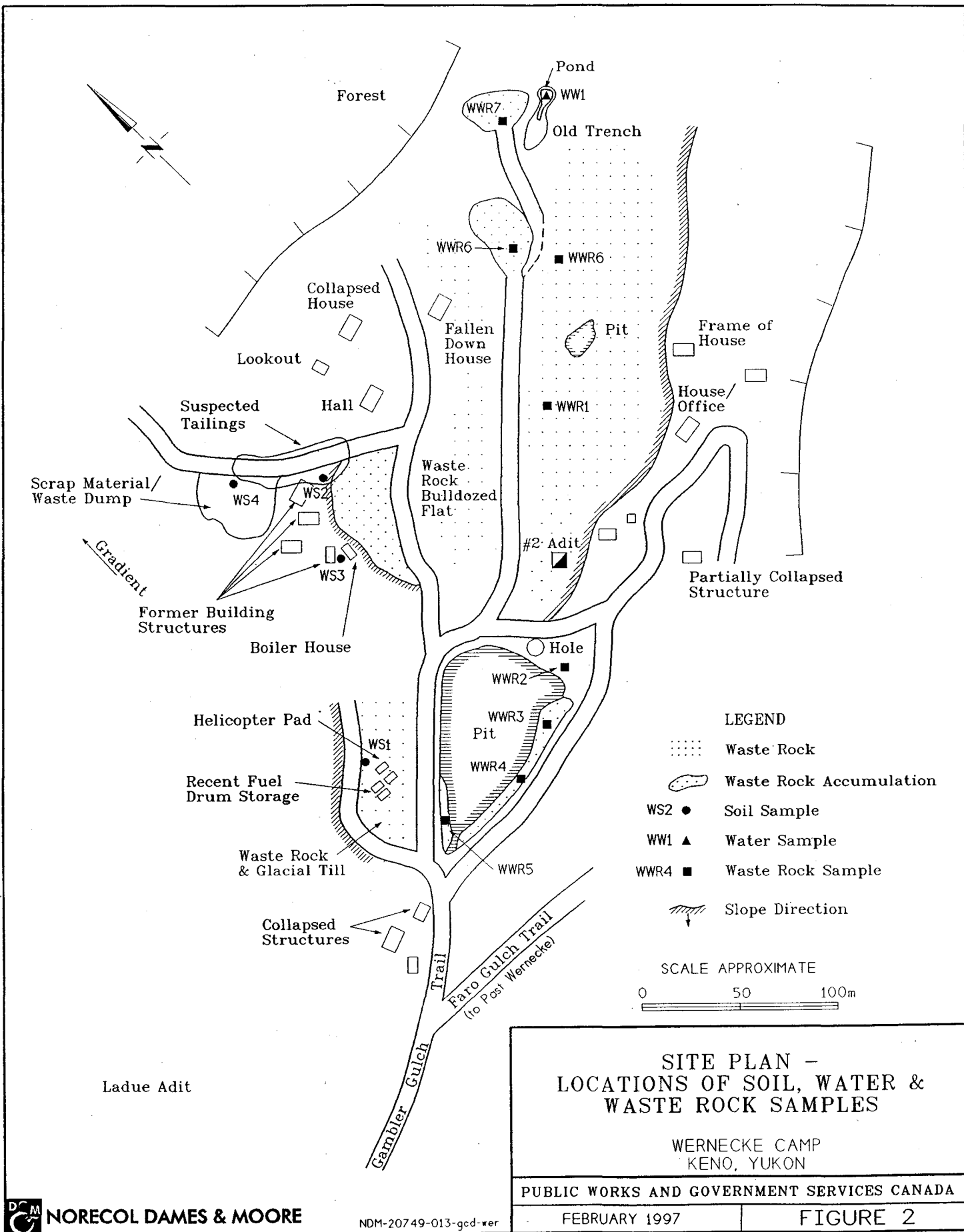
LOCATION OF WERNECKE CAMP

WERNECKE CAMP
KENO HILL, YUKON

PUBLIC WORKS AND GOVERNMENT SERVICES CANADA

OCTOBER 1996

FIGURE 1



APPENDIX A
FIELD DATA COLLECTION SHEETS

WATER SAMPLING

PROJECT NAME: Yukon Mine Site Review NAME OF SAMPLER: LAW/JD
 Location: Wenatchee Date: 08/29/96

SAMPLE #:	<u>WW1</u>		pH:	<u>7.0</u>
Location description:	<u>North end of camp - Pond in northernmost trench</u>			
Analysis:	<u>metals</u>	<u>water chem</u>	Eh	<u>TSS</u> total sulphur

SAMPLE #:			pH:	
Location description:				
Analysis:	metals	water chem	Eh	total sulphur

SAMPLE #:			pH:	
Location description:				
Analysis:	metals	water chem	Eh	total sulphur

SAMPLE #:			pH:	
Location description:				
Analysis:	metals	water chem	Eh	total sulphur

SAMPLE #:			pH:	
Location description:				
Analysis:	metals	water chem	Eh	total sulphur

Comments: _____

Sample # Format

site name - W number
 eg. Tintina - W1

BL = barrel
 W = water
 S = soil
 WR = waste rock

APPENDIX B
LABORATORY ANALYTICAL REPORTS

Analysis Report

CANTEST

CanTest Ltd

Professional
Analytical
Services

1523 West 3rd Ave
Vancouver, BC
V6J 1J8

Fax: 604 731 2386

Tel: 604 734 7276

1 800 665 8566

REPORT ON: Analysis of Soil and Water Samples

REPORTED TO: Norecol, Dames & Moore, Inc.
Suite 1900
650 West Georgia Street
Vancouver, B.C.
V6B 4N7

Att'n: Ms. Linda Wrong

CHAIN OF CUSTODY: 19028, 19024, 19025, 19027

PROJECT NAME: PWASC

PROJECT NUMBER: 20749-013

NUMBER OF SAMPLES: 25

REPORT DATE: September 24, 1996

DATE SUBMITTED: September 3, 1996

GROUP NUMBER: 6090406

SAMPLE TYPE: Water and Soil

TEST METHODS:

Volatile Petroleum Hydrocarbons in Soil (VPH-GNS) - analysis was performed using a draft methanol extraction-purge and trap-GC/FID procedure specified by the B.C. MOELP. The VPH compounds elute between n-pentane (n-C5) and n-undecane (n-C11). BTEX compounds are not included in the VPH result. VPH results produced by this method can be compared to Generic Numerical Standard (GNS) criteria.

Volatile Organic Compounds in Soil - analysis was performed using procedures based on U.S. EPA Methods 624/8240, involving methanol extraction, sparging/collection with a Purge and Trap apparatus and analysis using GC/MS.

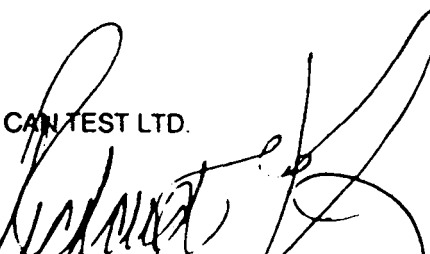
Conventional Parameters - analyses were performed using procedures based on those described in "British Columbia Environmental Laboratory Manual For the Analysis of Water, Wastewater, Sediment and Biological Materials" (1994 Edition), Province of British Columbia and "Standard Methods for the Examination of Water and Wastewater" 17th Edition, (1989) and 16th Edition (1985), published by the American Public Health Association.

Extractable Petroleum Hydrocarbons in Water/Soil (LEPH/HEPH-GNS) - analysis was performed using a draft DCM extraction-GC/FID procedure specified by the B.C. MOELP. Compounds eluting between n-decane (n-C10) and n-nonadecane (n-C19) are defined as Light Extractable Petroleum Hydrocarbons (LEPH). Compounds eluting between n-nonadecane and n-dotriacontane (n-C32) are defined as Heavy Extractable Petroleum Hydrocarbons (HEPH). These results can be compared to Generic Numerical Standard (GNS) criteria. The results may or may not be corrected for specified PAH's, as noted on the report.

Mercury in Water - analysis was performed using procedures based on Standard Methods for the Examination of Water and Wastewater section 3112 B, acid permanganate digestion, analysis using Cold Vapour Atomic Absorption.

(Continued)

CANTEST LTD.


Richard S. Jornitz
Supervisor, Inorganic Testing

REPORTED TO: Norecol, Dames & Moore, Inc.

CANTEST

REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Metals in Water - analysis was performed using Inductively Coupled Plasma Spectroscopy (ICP) or Graphite Furnace Atomic Absorption.

Metals in Water - analysis was performed using procedures based on U.S. EPA Method 200.8, Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma-Mass Spectroscopy (ICP/MS).

Polynuclear Aromatic Hydrocarbons - analysis was performed using procedures based on U.S. EPA Methods 625/8270, involving extraction, clean-up steps, and analysis using GC/MS.

Arsenic in Soil - analysis was performed using Zeeman background-corrected Graphite Furnace Atomic Absorption Spectrophotometry.

Cadmium in Soil - analysis was performed using background-corrected Flame Atomic Absorption Spectrophotometry.

Mercury in Soil - analysis was performed using Cold Vapour Atomic Absorption Spectrophotometry.

Lead in Soil - analysis was performed using background-corrected Flame Atomic Absorption Spectrophotometry.

Metals in Soil - Undried representative samples were digested with a mixture of nitric acid and hydrochloric acid-"Aqua Regia". Analysis was performed using Inductively Coupled Argon Plasma Spectroscopy (ICAP) or by specific techniques as described. Moisture was determined gravimetrically at 105 on a separate sample portion.

Selenium in Soil - analysis was performed using Zeeman background-corrected Graphite Furnace Atomic Absorption Spectrophotometry.

TEST RESULTS:

(See following pages)

REPORTED TO: Norecol, Dames & Moore, Inc.

CANTEST

REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Conventional Parameters in Water

CLIENT SAMPLE IDENTIFICATION:	SAMPLE DATE	CAN TEST ID	pH	Total Suspended Solids	Sulphate SO4
WW1	Aug 29/96	609040027	7.93	3	433
PWW1	Aug 29/96	609040028	6.08	<	4.6
PWW2	Aug 29/96	609040029	7.18	10	4.8
PWW3	Aug 29/96	609040030	7.83	< 5	3.5
PWW4	Aug 29/96	609040031	7.11	<	5.0
PWW5	Aug 29/96	609040032	7.81	< 5	5.3
KW1	Aug 28/96	609040033	5.62	7	9.1
KW2	Aug 28/96	609040034	5.51	<	8.8
PW1	Aug 28/96	609040035	8.05	7	178
PW2a	Aug 28/96	609040036	7.72	< 0.2	502
PW2b	Aug 28/96	609040037	8.00	5	179
PW3	Aug 28/96	609040038	8.11	4	181
DETECTION LIMIT UNITS			pH units	1 mg/L	1 mg/L

mg/L = milligrams per liter
< = Less than detection limit

REPORTED TO: Norecol, Dames & Moore, Inc.



REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Metals Analysis in Water

CLIENT SAMPLE IDENTIFICATION:		WW1	PWW1	PWW2	PWW3		
SAMPLE PREPARATION:		TOTAL	TOTAL	TOTAL	TOTAL		
DATE SAMPLED:		Aug 29/96	Aug 29/96	Aug 29/96	Aug 29/96		
CAN TEST ID:		609040027	609040028	609040029	609040030	DETECTION LIMIT	UNITS
Aluminum	Al	<	<	<	<	0.2	mg/L
Antimony	Sb	<	<	<	<	0.2	mg/L
Arsenic	As	<	<	<	<	0.001	mg/L
Barium	Ba	0.008	0.017	0.019	0.018	0.001	mg/L
Beryllium	Be	<	<	<	<	0.003	mg/L
Boron	B	<	0.01	<	<	0.01	mg/L
Cadmium	Cd	0.0002	0.0012	0.0014	0.0008	0.0002	mg/L
Calcium	Ca	167	1.78	1.81	1.18	0.01	mg/L
Chromium	Cr	<	<	<	<	0.001	mg/L
Cobalt	Co	<	<	<	<	0.001	mg/L
Copper	Cu	<	0.002	<	<	0.001	mg/L
Iron	Fe	0.05	<	<	<	0.03	mg/L
Lead	Pb	<	0.32	0.19	0.11	0.001	mg/L
Magnesium	Mg	39.7	0.56	0.55	0.30	0.05	mg/L
Manganese	Mn	0.029	0.055	0.042	0.010	0.003	mg/L
Mercury	Hg	<	<	<	<	0.05	µg/L
Molybdenum	Mo	0.003	<	<	<	0.001	mg/L
Nickel	Ni	0.002	0.002	0.002	<	0.001	mg/L
Phosphorus	PO4	<	<	<	<	0.4	mg/L
Potassium	K	1.07	0.14	0.12	0.10	0.01	mg/L
Selenium	Se	<	<	0.001	<	0.001	mg/L
Silicon	SiO2	2.2	3.2	2.8	2.9	0.1	mg/L
Silver	Ag	<	0.0029	0.0018	0.0037	0.0001	mg/L
Sodium	Na	1.2	0.7	0.6	0.6	0.1	mg/L
Strontium	Sr	0.50	0.009	0.008	0.007	0.001	mg/L
Tin	Sn	<	<	<	<	0.001	mg/L
Titanium	Ti	<	<	<	<	0.006	mg/L
Vanadium	V	<	<	<	<	0.01	mg/L
Zinc	Zn	0.047	0.065	0.075	0.035	0.005	mg/L
Zirconium	Zr	<	<	<	<	0.02	mg/L

mg/L = milligrams per liter
 < = Less than detection limit

µg/L = micrograms per liter

REPORTED TO: Norecol, Dames & Moore, Inc.

CANTEST

REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Metals Analysis in Water

CLIENT SAMPLE IDENTIFICATION:	PWW4	PWW5	KW1	KW2		
SAMPLE PREPARATION:	TOTAL	TOTAL	TOTAL	TOTAL		
DATE SAMPLED:	Aug 29/96	Aug 29/96	Aug 28/96	Aug 28/96		
AN TEST ID:	609040031	609040032	609040033	609040034	DETECTION LIMIT	UNITS
Aluminum Al	<	<	<	<	0.2	mg/L
Antimony Sb	<	<	<	<	0.2	mg/L
Arsenic As	<	<	<	<	0.001	mg/L
Barium Ba	0.011	0.009	0.063	0.069	0.001	mg/L
Beryllium Be	<	<	<	<	0.003	mg/L
Boron B	<	<	<	0.01	0.01	mg/L
Cadmium Cd	0.0004	0.0002	<	<	0.0002	mg/L
Calcium Ca	1.51	1.50	2.42	2.35	0.01	mg/L
Chromium Cr	<	<	<	<	0.001	mg/L
Cobalt Co	<	<	<	<	0.001	mg/L
Copper Cu	<	<	0.003	0.003	0.001	mg/L
Iron Fe	<	<	<	0.06	0.03	mg/L
Lead Pb	0.027	0.016	<	<	0.001	mg/L
Magnesium Mg	0.37	0.37	0.71	0.68	0.05	mg/L
Manganese Mn	0.085	0.075	0.029	0.013	0.003	mg/L
Mercury Hg	<	<	<	<	0.05	µg/L
Molybdenum Mo	<	<	<	<	0.001	mg/L
Nickel Ni	0.002	0.001	0.001	0.002	0.001	mg/L
Phosphorus PO4	<	<	<	<	0.4	mg/L
Potassium K	0.11	0.094	0.59	0.45	0.01	mg/L
Selenium Se	<	<	<	<	0.001	mg/L
Silicon SiO2	3.0	3.0	6.0	6.2	0.1	mg/L
Silver Ag	0.0002	<	<	<	0.0001	mg/L
Sodium Na	0.6	0.6	0.9	0.9	0.1	mg/L
Strontium Sr	0.007	0.007	0.017	0.017	0.001	mg/L
Tin Sn	<	<	<	<	0.001	mg/L
Tantalum Ti	<	<	<	<	0.006	mg/L
Vanadium V	<	<	<	<	0.01	mg/L
Zinc Zn	0.018	0.012	0.007	0.009	0.005	mg/L
Zirconium Zr	<	<	<	<	0.02	mg/L

mg/L = milligrams per liter
 < = Less than detection limit

µg/L = micrograms per liter

REPORTED TO: Norecol, Dames & Moore, Inc.



REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Metals Analysis in Water

CLIENT SAMPLE IDENTIFICATION:		PW1	PW2a	PW2b	PW3		
SAMPLE PREPARATION:		TOTAL	TOTAL	TOTAL	TOTAL		
DATE SAMPLED:		Aug 28/96	Aug 28/96	Aug 28/96	Aug 28/96		
CAN TEST ID:		609040035	609040036	609040037	609040038	DETECTION LIMIT	UNITS
Aluminum	Al	<	<	<	<	0.2	mg/L
Antimony	Sb	<	<	<	<	0.2	mg/L
Arsenic	As	0.002	0.008	0.002	0.002	0.001	mg/L
Barium	Ba	0.044	0.027	0.043	0.042	0.001	mg/L
Beryllium	Be	<	<	<	<	0.003	mg/L
Boron	B	0.02	<	0.02	0.03	0.01	mg/L
Cadmium	Cd	0.0023	0.0016	0.0023	0.0022	0.0002	mg/L
Calcium	Ca	90.7	192	90.7	92.3	0.01	mg/L
Chromium	Cr	<	<	<	<	0.001	mg/L
Cobalt	Co	<	<	<	<	0.001	mg/L
Copper	Cu	0.001	0.003	0.001	0.001	0.001	mg/L
Iron	Fe	0.38	<	0.29	0.22	0.03	mg/L
Lead	Pb	0.002	0.002	0.001	0.001	0.001	mg/L
Magnesium	Mg	16.8	58.1	17.2	17.7	0.05	mg/L
Manganese	Mn	0.095	0.004	0.088	0.084	0.003	mg/L
Mercury	Hg	<	<	<	<	0.05	µg/L
Molybdenum	Mo	<	<	<	<	0.001	mg/L
Nickel	Ni	0.002	0.004	0.002	0.001	0.001	mg/L
Phosphorus	PO4	<	<	<	<	0.4	mg/L
Potassium	K	0.43	1.10	0.40	0.36	0.01	mg/L
Selenium	Se	0.002	0.001	0.003	0.002	0.001	mg/L
Silicon	SiO2	5.5	4.6	5.2	5.3	0.1	mg/L
Silver	Ag	<	<	<	<	0.0001	mg/L
Sodium	Na	1.2	3.1	1.2	1.3	0.1	mg/L
Strontium	Sr	0.20	0.38	0.20	0.20	0.001	mg/L
Tin	Sn	<	<	<	<	0.001	mg/L
Titanium	Ti	<	<	<	<	0.006	mg/L
Vanadium	V	<	<	<	<	0.01	mg/L
Zinc	Zn	0.28	0.12	0.27	0.25	0.005	mg/L
Zirconium	Zr	<	<	<	<	0.02	mg/L

mg/L = milligrams per liter
 < = Less than detection limit

µg/L = micrograms per liter

REPORTED TO: Norecol, Dames & Moore, Inc.

CANTEST

REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Polycyclic Aromatic Hydrocarbons in Soil

CLIENT SAMPLE IDENTIFICATION:	WS3	
DATE SAMPLED:	Aug 29/96	
CAN TEST ID:	609040051	
ANALYSIS DATE:	Sep 7/96	DETECTION LIMIT
Low Molecular Weight PAH's		
Naphthalene	0.07	0.05
Acenaphthylene	0.12	0.05
Acenaphthene	<	0.05
Fluorene	<	0.05
Phenanthrene	1.8	0.05
Anthracene	0.35	0.05
Total LMW-PAH's	2.34	
High Molecular Weight PAH's		
Fluoranthene	5.2	0.05
Pyrene	6.0	0.05
Benzo(a)anthracene	4.2	0.05
Chrysene	8.3	0.05
Benzo(b)fluoranthene	17	0.05
Benzo(k)fluoranthene		0.05
Benzo(a)pyrene	7.2	0.05
Indeno(1,2,3-c,d)pyrene	15	0.05
Dibenz(a,h)anthracene	1.6	0.05
Benzo(g,h,i)perylene	18	0.05
Total HMW-PAH's	82.5	
Total PAH's	84.8	

Results expressed as micrograms per gram, on a dry weight basis. ($\mu\text{g/g}$)

< = Less than detection limit

NOTE: Benzo(b)fluoranthene and Benzo(k)fluoranthene reported as total.

REPORTED TO: Norecol, Dames & Moore, Inc.



REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Monocyclic Aromatic Hydrocarbons in Soil

CLIENT SAMPLE IDENTIFICATION:	KS1	KS2	KS3	KS4	
DATE SAMPLED:	Aug 28/96	Aug 28/96	Aug 28/96	Aug 28/96	
CAN TEST ID:	609040041	609040042	609040043	609040044	
ANALYSIS DATE:	Sep 8/96	Sep 8/96	Sep 8/96	Sep 8/96	DETECTION LIMIT
Volatile Pet. Hydrocarbons	<	<	<	<	10
Benzene	<	<	<	<	0.5
Ethylbenzene	<	<	<	<	0.5
Toluene	<	<	<	<	0.5
Xylenes	<	<	<	<	0.5
Surrogate Recovery					
Toluene-d8	101	103	104	104	-
Bromofluorobenzene	86	93	91	89	-

Results expressed as micrograms per gram, on a dry weight basis. ($\mu\text{g/g}$)

Surrogate recoveries expressed as percent (%)

< = Less than detection limit

REPORTED TO: Norecol, Dames & Moore, Inc.



REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Monocyclic Aromatic Hydrocarbons in Soil

CLIENT SAMPLE IDENTIFICATION:	KS5	PS1	PS2	PS3	
DATE SAMPLED:	Aug 28/96	Aug 28/96	Aug 28/96	Aug 28/96	
CAN TEST ID:	609040045	609040046	609040047	609040048	
ANALYSIS DATE:	Sep 8/96	Sep 8/96	Sep 8/96	Sep 4/96	DETECTION LIMIT
Volatile Pet. Hydrocarbons	<	<	<	<	10
Benzene	<	<	<	<	0.5
Ethylbenzene	<	<	<	<	0.5
Toluene	<	<	<	<	0.5
Xylenes	<	<	<	<	0.5
Surrogate Recovery					
Toluene-d8	86	87	88	91	-
Bromofluorobenzene	83	84	83	83	-

Results expressed as micrograms per gram, on a dry weight basis. ($\mu\text{g/g}$)

Surrogate recoveries expressed as percent (%)

< = Less than detection limit

REPORTED TO: Norecol, Dames & Moore, Inc.



REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Monocyclic Aromatic Hydrocarbons in Soil

CLIENT SAMPLE IDENTIFICATION:	WS1	WS4	PWS1	
DATE SAMPLED:	Aug 29/96	Aug 29/96	Aug 29/96	
CAN TEST ID:	609040049	609040053	609040054	
ANALYSIS DATE:	Sep 8/96	Sep 8/96	Sep 8/96	DETECTION LIMIT
Volatile Pet. Hydrocarbons	<	<	10	10
Benzene	<	<	<	0.5
Ethylbenzene	<	<	<	0.5
Toluene	<	<	<	0.5
Xylenes	<	<	<	0.5
Surrogate Recovery				
Toluene-d8	91	92	94	-
Bromofluorobenzene	84	79	92	-

Results expressed as micrograms per gram, on a dry weight basis. ($\mu\text{g/g}$)

Surrogate recoveries expressed as percent (%)

< = Less than detection limit

REPORTED TO: Norecol, Dames & Moore, Inc.

CANTEST

REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Extractable Petroleum Hydrocarbons in Soil

CLIENT SAMPLE IDENTIFICATION:	SAMPLE DATE	CAN TEST ID	LEPH-uncorrected for PAH's	HEPH-uncorrected for PAH's
KS1	Aug 28/96	609040041	940	49000
KS2	Aug 28/96	609040042	620	1700
KS3	Aug 28/96	609040043	<	<
KS4	Aug 28/96	609040044	<	<
KS5	Aug 28/96	609040045	<	<
PS1	Aug 28/96	609040046	<	1100
PS2	Aug 28/96	609040047	<	<
PS3	Aug 28/96	609040048	<	<
WS1	Aug 29/96	609040049	<	<
WS4	Aug 29/96	609040053	<	<
PWS1	Aug 29/96	609040054	<	19000
DETECTION LIMIT UNITS			250 $\mu\text{g/g}$	250 $\mu\text{g/g}$

$\mu\text{g/g}$ = micrograms per gram, on a dry weight basis.

< = Less than detection limit .

Sample# 609040041 , 609040042 , 609040046 , 609040054 - The presence of hydrocarbon components with boiling points greater than that of C30 were detected.

REPORTED TO: Norecol, Dames & Moore, Inc.



REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Metals Analysis in Soil

CLIENT SAMPLE IDENTIFICATION:	KS1	KS2	KS3	KS4		
DATE SAMPLED:	Aug 28/96	Aug 28/96	Aug 28/96	Aug 28/96		
CAN TEST ID:	609040041	609040042	609040043	609040044	DETECTION LIMIT	UNITS

Metals Analysis		KS1	KS2	KS3	KS4	DETECTION LIMIT	UNITS
Moisture		26.8	55.2	42.8	33.5	0.01	%
Antimony	Sb	<	<	<	<	10	µg/g
Arsenic	As	0.17	0.21	0.34	0.20	0.05	µg/g
Barium	Ba	12.3	139	326	176	0.1	µg/g
Beryllium	Be	<	<	<	<	1	µg/g
Cadmium	Cd	0.36	0.52	<	1.61	0.25	µg/g
Chromium	Cr	12	18	39	29	2	µg/g
Cobalt	Co	2	<	16	8	1	µg/g
Copper	Cu	25	22	99	48	1	µg/g
Lead	Pb	31	71	27	147	1	µg/g
Mercury	Hg	0.03	0.13	0.07	0.10	0.001	µg/g
Molybdenum	Mo	<	<	<	<	4	µg/g
Nickel	Ni	5	5	34	20	2	µg/g
Selenium	Se	<	<	<	<	0.5	µg/g
Silver	Ag	<	<	<	<	2	µg/g
Tin	Sn	<	<	<	11	5	µg/g
Vanadium	V	24	9	61	44	0.5	µg/g
Zinc	Zn	425	51	95	132	1	µg/g
Aluminum	Al	5320	3630	29000	20200	10	µg/g
Boron	B	8	6	23	16	0.5	µg/g
Calcium	Ca	1100	2340	2100	3420	1	µg/g
Iron	Fe	15300	8270	45100	33000	2	µg/g
Magnesium	Mg	876	526	5380	4000	0.1	µg/g
Manganese	Mn	125	226	441	296	0.2	µg/g
Phosphorus	PO4	1530	2700	3500	3520	20	µg/g
Sodium	Na	77	49	140	198	5	µg/g
Strontium	Sr	9	16.7	26.0	50.9	0.1	µg/g
Titanium	Ti	101	66	200	191	0.3	µg/g

% = percent

< = Less than detection limit

µg/g = micrograms per gram, on a dry weight basis.

REPORTED TO: Norecol, Dames & Moore, Inc.



REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Metals Analysis in Soil

CLIENT SAMPLE IDENTIFICATION:	KS5	PS1	PS2	PS3		
DATE SAMPLED:	Aug 28/96	Aug 28/96	Aug 28/96	Aug 28/96		
CAN TEST ID:	609040045	609040046	609040047	609040048	DETECTION LIMIT	UNITS

Metals Analysis		KS5	PS1	PS2	PS3	DETECTION LIMIT	UNITS
Moisture		19.9	14.1	35.2	36.8	0.01	%
Antimony	Sb	<	<	<	<	10	µg/g
Arsenic	As	0.19	0.47	0.57	0.41	0.05	µg/g
Barium	Ba	202	25.4	224	194	0.1	µg/g
Beryllium	Be	<	<	<	<	1	µg/g
Cadmium	Cd	0.28	1.73	0.87	0.84	0.25	µg/g
Chromium	Cr	23	18	20	18	2	µg/g
Cobalt	Co	9	14	9	9	1	µg/g
Copper	Cu	35	96	42	42	1	µg/g
Lead	Pb	23	113	19	19	1	µg/g
Mercury	Hg	0.02	0.02	0.04	0.04	0.001	µg/g
Molybdenum	Mo	<	<	<	<	4	µg/g
Nickel	Ni	23	29	25	25	2	µg/g
Selenium	Se	<	<	<	<	0.5	µg/g
Silver	Ag	<	<	<	<	2	µg/g
Tin	Sn	<	38	<	<	5	µg/g
Vanadium	V	29	18	35	31	0.5	µg/g
Zinc	Zn	65	216	131	122	1	µg/g
Aluminum	Al	10800	6420	11100	9330	10	µg/g
Boron	B	13	18	12	11	0.5	µg/g
Calcium	Ca	2110	34800	15400	15800	1	µg/g
Iron	Fe	26500	52600	25200	24400	2	µg/g
Magnesium	Mg	3710	10000	7030	6940	0.1	µg/g
Manganese	Mn	385	654	514	502	0.2	µg/g
Phosphorus	PO4	1490	4210	25200	3000	20	µg/g
Sodium	Na	102	87	165	120	5	µg/g
Strontium	Sr	20	50.5	37.8	36.7	0.1	µg/g
Titanium	Ti	168	19	243	211	0.3	µg/g

% = percent
 < = Less than detection limit

µg/g = micrograms per gram, on a dry weight basis.

REPORTED TO: Norecol, Dames & Moore, Inc.



REPORT DATE: September 24, 1996

GROUP NUMBER: 6090406

Metals Analysis in Soil

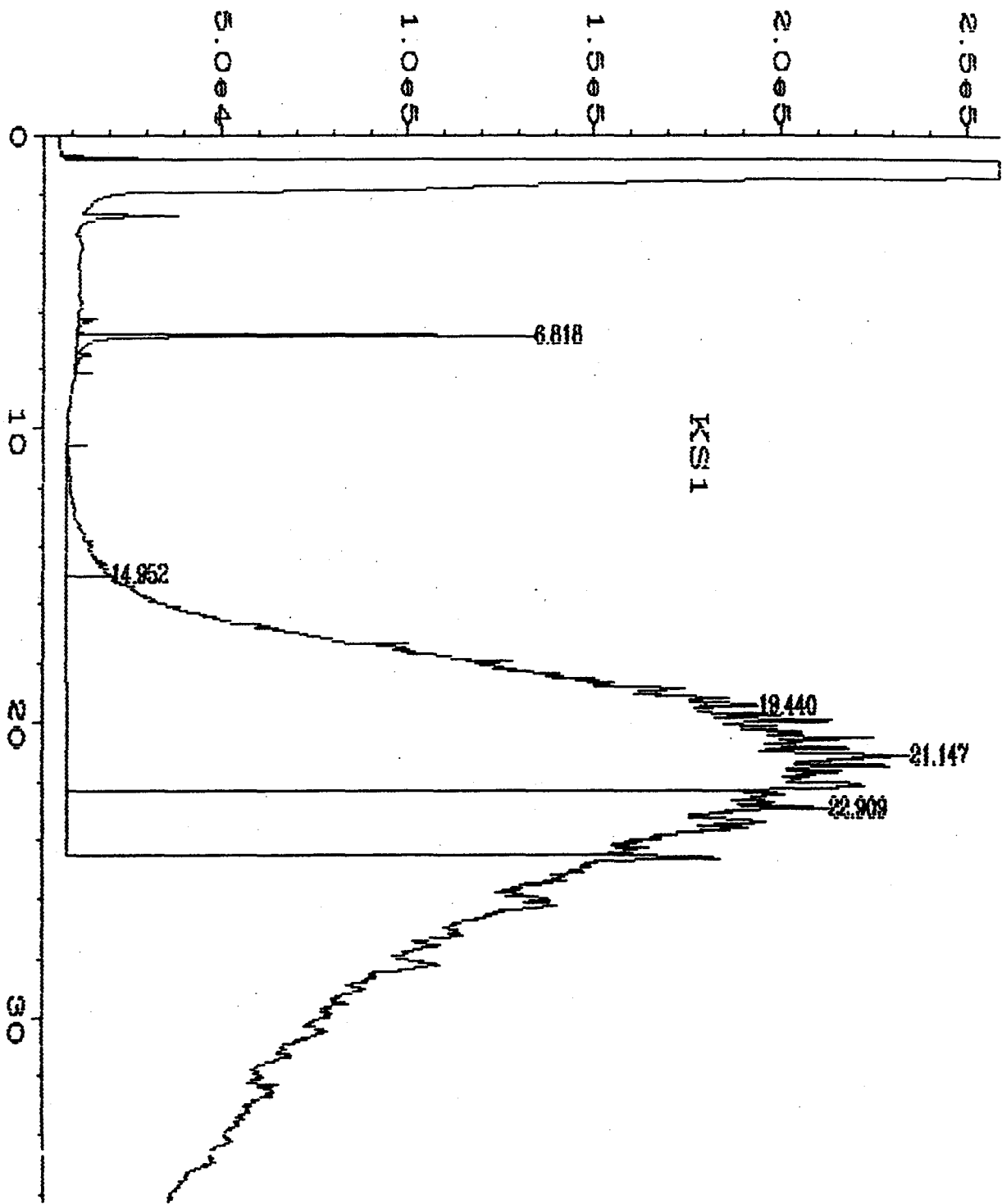
CLIENT SAMPLE IDENTIFICATION:	WS2	WS3	WS4	PWS1		
DATE SAMPLED:	Aug 29/96	Aug 29/96	Aug 29/96	Aug 29/96		
CAN TEST ID:	609040050	609040051	609040053	609040054	DETECTION LIMIT	UNITS

Metals Analysis		WS2	WS3	WS4	PWS1	DETECTION LIMIT	UNITS
Moisture		16.6	20.5	29.8	9.8	0.01	%
Antimony	Sb	37	59	110	<	10	µg/g
Arsenic	As	0.20	0.14	0.18	0.47	0.05	µg/g
Barium	Ba	49.8	123	63.2	46	0.1	µg/g
Beryllium	Be	<	<	<	<	1	µg/g
Cadmium	Cd	242	35.4	222	18.2	0.25	µg/g
Chromium	Cr	35	18	7	8	2	µg/g
Cobalt	Co	2	12	<	4	1	µg/g
Copper	Cu	79	91	61	110	1	µg/g
Lead	Pb	2730	2350	2720	1720	1	µg/g
Mercury	Hg	1.5	0.06	1.4	0.19	0.001	µg/g
Molybdenum	Mo	<	<	<	<	4	µg/g
Nickel	Ni	12	33	10	14	2	µg/g
Selenium	Se	<	<	<	<	0.5	µg/g
Silver	Ag	35	33	51	<	2	µg/g
Tin	Sn	<	16	<	<	5	µg/g
Vanadium	V	21	24	12	11	0.5	µg/g
Zinc	Zn	16700	1910	17200	1480	1	µg/g
Aluminum	Al	2680	25400	1830	43900	10	µg/g
Boron	B	55	84	46	12	0.5	µg/g
Calcium	Ca	12100	29400	4420	6630	1	µg/g
Iron	Fe	161000	103000	112000	24200	2	µg/g
Magnesium	Mg	16600	2880	9120	2520	0.1	µg/g
Manganese	Mn	23400	2000	40400	2290	0.2	µg/g
Phosphorus	PO4	3020	2740	1760	1700	20	µg/g
Sodium	Na	49	421	116	40	5	µg/g
Strontium	Sr	15.6	182	6.8	12	0.1	µg/g
Titanium	Ti	21.8	18.8	7.9	27	0.3	µg/g

% = percent

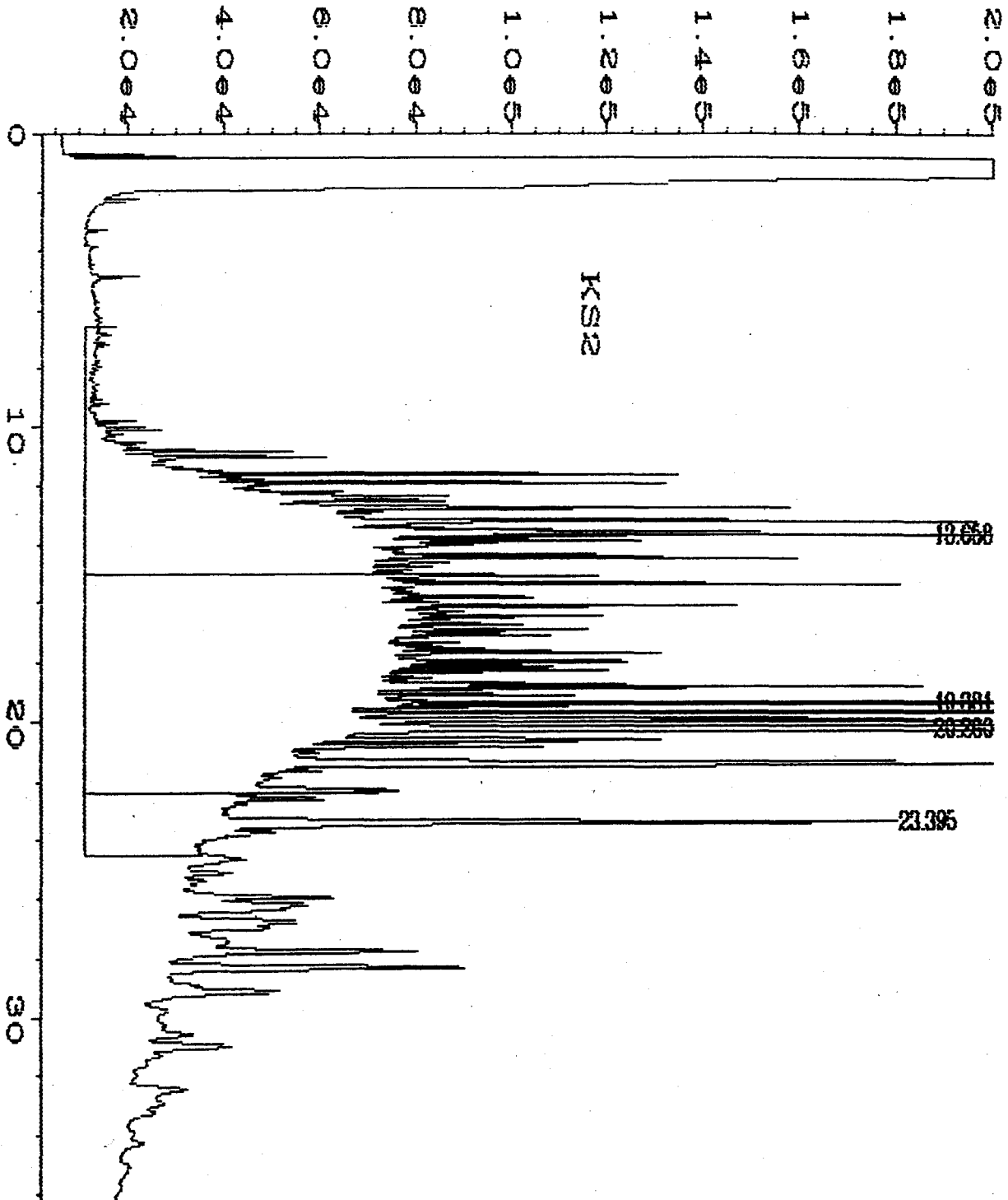
< = Less than detection limit

µg/g = micrograms per gram, on a dry weight basis.



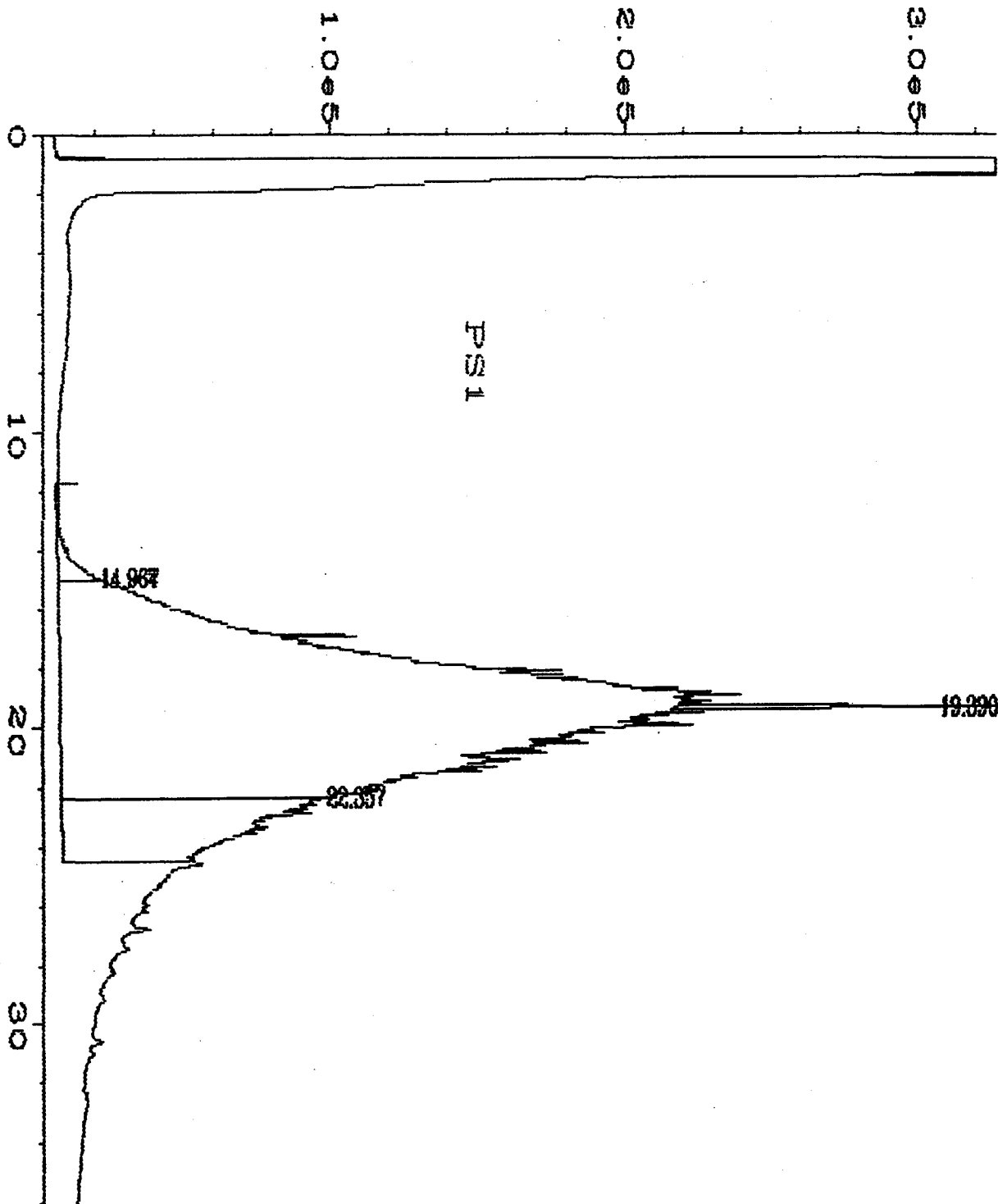
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Operator	: MK	Vial Number	: 59
Instrument	: FID	Injection Number	: 1
Sample Name	: 609040041-60ML	Sequence Line	: 11
Run Time Bar Code:		Instrument Method:	TEHBAKE.MTH
Acquired on	: 07 Sep 96 06:28 AM	Analysis Method	: !TEH.MTH
Report Created on:	11 Sep 96 11:01 AM		



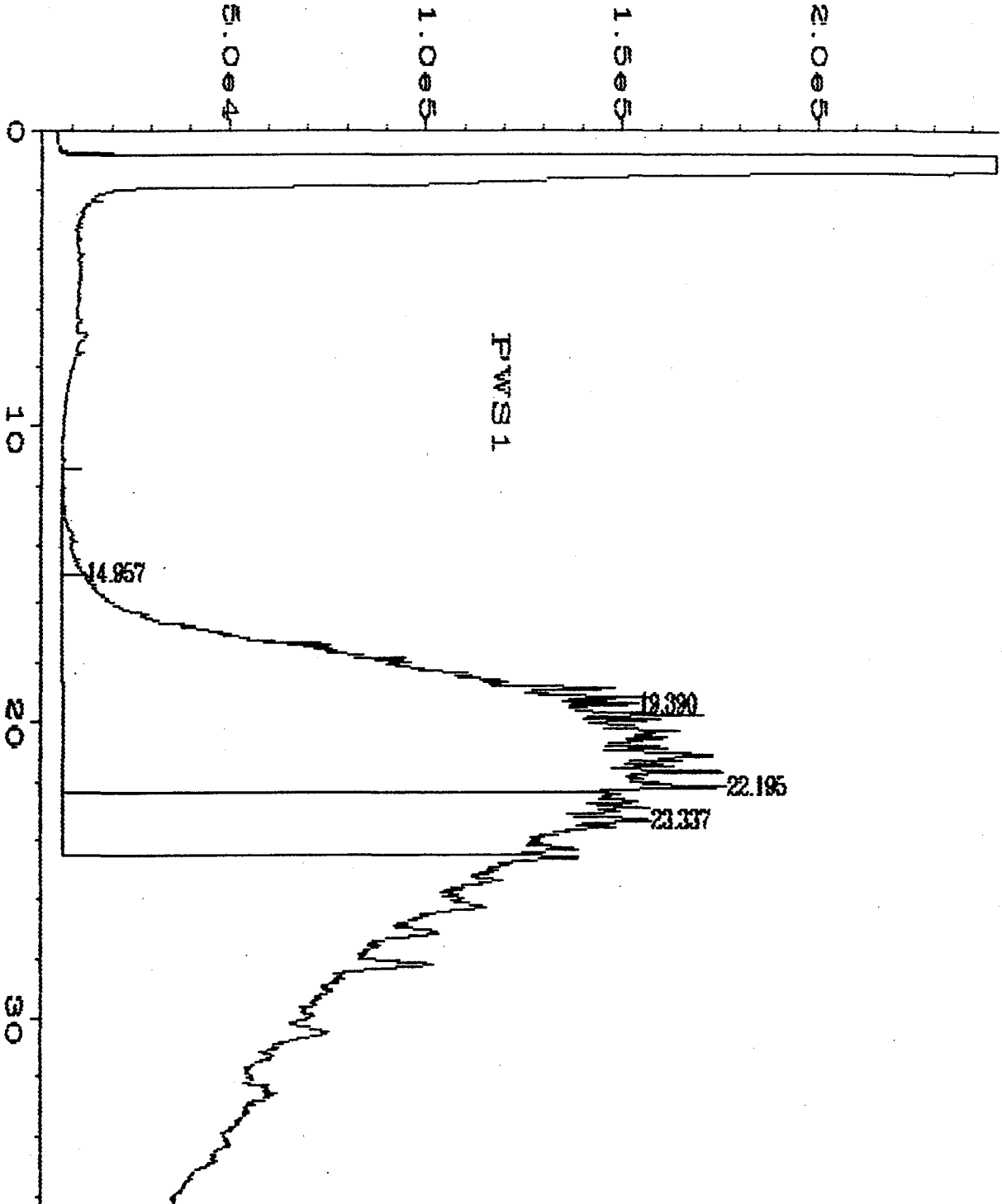
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 Instrument : FID
 Sample Name : 609040042
 Run Time Bar Code:
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 Report Created on: 10 Sep 96 06:19 PM
 Page Number : 1
 Vial Number : 60
 Injection Number : 1
 Sequence Line : 11
 Instrument Method: TEHBAKE.MTH
 Analysis Method : !TEH.MTH



user modified

Data File Name : C:\HPCHEM\FID\DATA\090696\065F1301.D
 Operator : MK
 Instrument : FID
 Sample Name : 609040046
 Run Time Bar Code :
 Acquired on : 07 Sep 96 11:35 AM
 Report Created on: 10 Sep 96 06:36 PM
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 Vial Number : 65
 Injection Number : 1
 Sequence Line : 13
 Instrument Method: TEHBAKE.MTH
 Analysis Method : !TEH.MTH



user modified

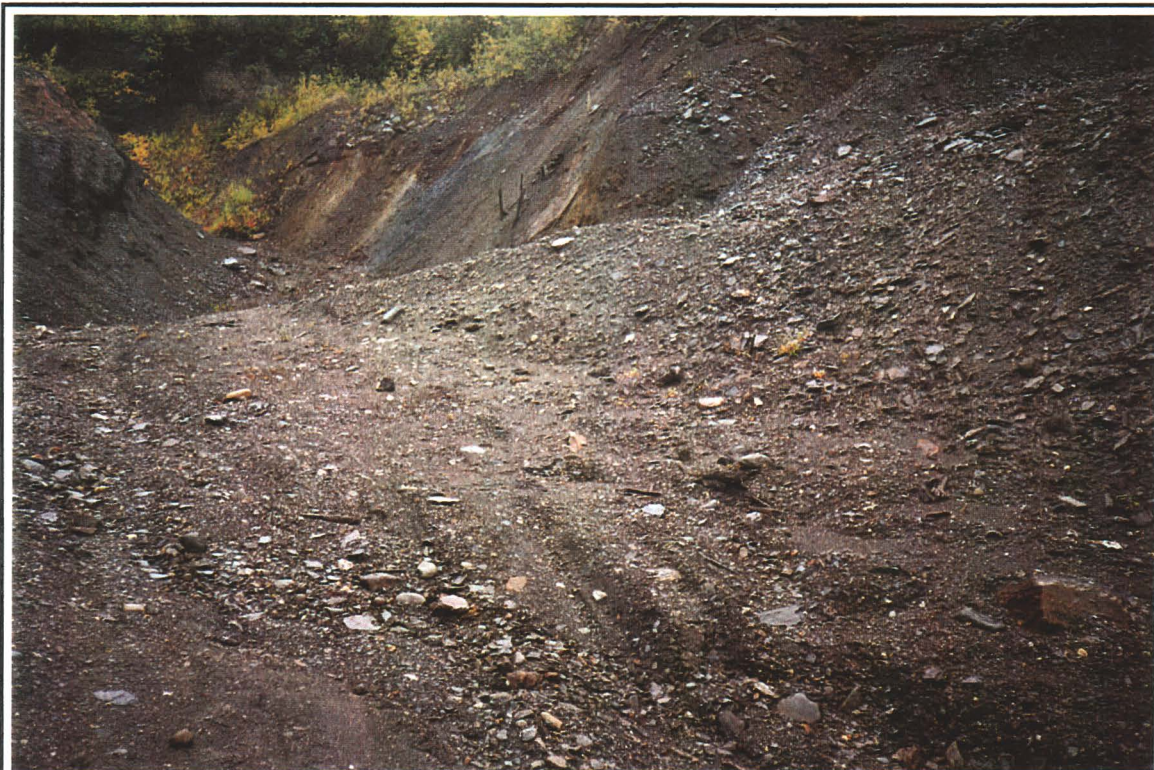
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Instrument	: FID	Injection Number	: 1
Sample Name	: 609040054-40ML	Sequence Line	: 15
Run Time Bar Code:		Instrument Method:	TEHBAKE.MTH
Acquired on	: 07 Sep 96 04:43 PM	Analysis Method	: !TEH.MTH
Report Created on:	10 Sep 96 07:26 PM		

APPENDIX C
PHOTOGRAPHS



View of collapsed ground at centre of camp.

PHOTO 1



Waste rock piles at centre of camp.

PHOTO 2



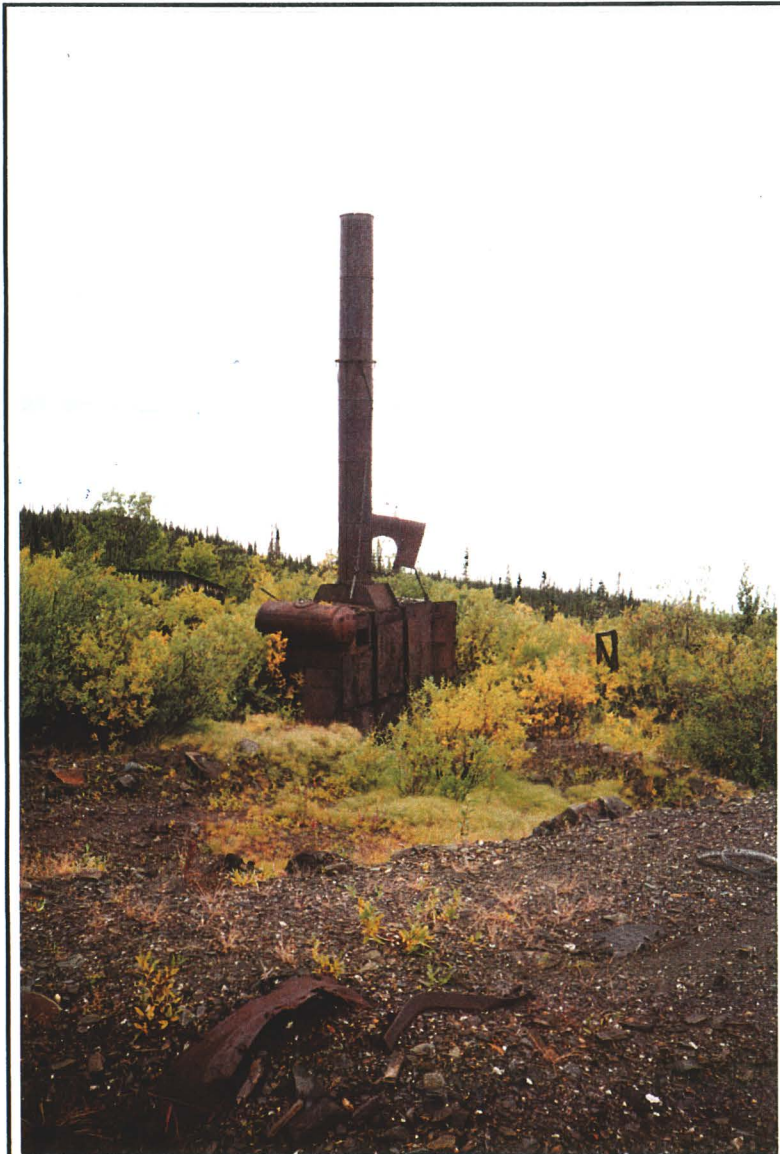
Collapsed building structure.

PHOTO 3



Collapsed mine workings and building structure at centre of camp.

PHOTO 4



Boiler house.

PHOTO 5



Scrap metal and waste dump down gradient of camp.

PHOTO 6



View of surface water in trench at north end of camp.

PHOTO 7



View of waste rock at north end of camp.

PHOTO 8

APPENDIX D

CANTEST LABORATORY QA/QC

CANTEST HISTORY AND DESCRIPTION

CANTEST Ltd. is a full service laboratory offering a broad spectrum of analytical services. In addition to providing superior, professional support in the air quality, environmental and industrial fields, CANTEST is often called upon by those in the areas of nutrition and biology as well as clinical and veterinary medicine.

Since incorporation in 1969, CANTEST has grown to become one of the largest independent laboratories in Western Canada. Originally started with a staff of five and two thousand square feet, the company now employs 85 chemists and technicians and occupies ten times the original laboratory space. As a member of the CANAM Group of Laboratories, CAN TEST belongs to an environmental testing network which ranks in the top twenty within North America based on revenues obtained through a survey conducted by IAETL. Revenues have generally doubled every five years and the client base now exceeds 1500.

It should be noted that CANTEST has clearly exhibited innovation with respect to methodology as the company was the first independent facility in Western Canada to employ Gas Chromatography/Mass Spectrometry (GC/MS), Inductively Coupled Argon and Plasma (ICAP) Spectroscopy, and Liquid Chromatography/Mass Spectrometry (LC/MS).

Located in Vancouver, B.C., the 25,000 square foot laboratory was designed specifically for a diversified and safe working environment. There are thirty one fumehoods, three walk-in refrigerators for sample storage, and twenty one individual working areas.

QUALITY ASSURANCE

CANTEST provides a comprehensive program of laboratory services in the areas of environmental, industrial, food, microbiological, and air quality testing. Conclusions based on the analytical data generated by CANTEST may have significant impact on the assessment of environmental quality and workplace safety, as well as on the economic burden placed on industry and the public. Therefore,

the establishment of a continuing program to ensure the reliability and validity of all analytical results is one of the fundamental responsibilities of the laboratory.

This Quality Assurance (QA) Program outlines the policies, organization and operations established for assuring the integrity of the analytical data generated by CANTEST.

Analytical Methodology and Validation

As one of the foremost laboratories in Canada, CANTEST is well known for its analytical capabilities and full-service facility. Regardless of whether an analysis procedure is obtained from a 'standard analytical reference' or developed in-house, methods employed are validated internally. The methods employed at CANTEST are taken from widely accepted sources such as:

- U.S. Environmental Protection Agency
- American Public Health Association/AWWA
- B.C. Ministry of Environmental Laboratory Manual
- American Society for Testing and Materials
- Association of Official Analytical Chemists
- Standards Methods for the Examination of Water and Wastewater

Standard Operating Procedures (CANTEST QA Manual)

CANTEST follows a set of Laboratory Standard Operating Procedures that were developed internally, based largely on those prescribed by the U.S./ E.P.A. Routine methods are written to describe the more common and frequently used laboratory practices. These standard operating procedures include:

- Sample collection, preservation, and holding times
- Sample custody, receipt and document control
- Analytical methods
- Instrument calibration, maintenance and repair
- Quality Control
- Safety, Chemical Hygiene

Confidentiality

These policies are consistent with regulatory guidelines and establish traceability of reagents, standards, samples, and analytical data. The standard operating procedures also provide for the complete documentation relative to the analysis and the reporting of data. This ultimately assures the validity and legal defensibility of the results reported by CANTEST.

Documentation

Chain of Custody relative to the collection of samples begins in the field. As such, the appropriate documentation is initiated at the time of collection by the client. The information submitted with the samples includes specific sample collection data, the identity of the sampler, time and date of collection and the analyses required. Field sampling by CANTEST personnel is documented in this fashion on CANTEST Chain of Custody Form.

At the time of receipt, the CANTEST sample custodian inspects the shipment, and assigns the sample a unique specific identifying number automatically generated by the Laboratory Information Management System (LIMS). With the assistance of the LIMS, the sample custodian enters the following information into the permanent sample record:

Date of receipt

Client demographic information

Client sample identification

Analyses requested

For all sample submissions, a sample transfer sheet is generated as part of the documentation package and follows the sample set through the laboratory during storage, sample preparation, generation of raw data and final reporting.

The samples are stored under conditions which maintain the viability of the parameters being analyzed. Typically this involves storage at 4 degrees Celsius for environmental samples. Special storage facilities are available for samples requiring additional security storage.

The LIMS system automatically generates a workschedule for each analytical parameter (or group of parameters where applicable). The analyses are assigned to specific individuals who perform the work. Raw data is recorded in laboratory notebooks or forms, and as instrument computer printouts. All raw data, including quality control information, calculations, and standard curves are maintained as permanent records. Raw data generated from analysis is used to produce final test results. Analysts who perform the analysis enter the final test results into the LIMS system. When a project is completed, the data is reviewed by either the Department Supervisor or the Department Coordinator before a final report is generated. The final report includes analysis results, method summaries and quality control information, where applicable. In addition to the information in the computer system, a file containing a copy of the final report, the chain of custody and other information submitted with the sample are maintained in secure storage.

QUALITY CONTROL

Introduction

Quality Control (QC) consists of specific activities and procedures designed to measure and control the quality of the data being produced. CANTEST uses a systematic approach to ensure the precision and accuracy of analyses by detecting errors and preventing their recurrence or by measuring the degree of error inherent in the methods applied. Confidence in the accuracy of analytical results and improvements in analytical precision are established by identification of the determinate sources of error. Precision is governed by the indeterminate errors inherent in the procedure and can be monitored by statistical methods.

CANTEST uses the following quality control techniques to assure accurate, precise and unbiased analytical data.

Purity and Contamination Checks

Sample preparation blanks are carried through the entire analytical procedure with the samples to serve as a check on reagent purity and possible laboratory contamination. Normally a blank is considered to be contaminated when it exceeds the method detection limit. When this does occur,

steps are taken to identify the source and eliminate or minimize the contaminant. Blanks are analyzed at a minimum frequency of one blank per sample set or at a level of ten percent.

The Analytical Method determines whether or not the blank values are subtracted from the analytical data prior to reporting.

Accuracy

Accuracy refers to the relationship of an analysis value to the true value. Accuracy can be determined by analysis of Standard Reference Materials (SRM's) obtained from reliable sources (e.g. NIST, EPA). Where SRM's or performance samples are not available, samples are "spiked" with a known quantity of the analyte at the beginning of the analysis. If the value obtained for the reference material or spike is not within a statistically acceptable range of the true value, the procedure is reworked to identify and correct the problem, and the sample set is reanalyzed. Accuracy Checks (SRM's or Spikes) are analyzed at a minimum frequency of one per sample set or at a level of ten percent.

Precision

Precision is a the measure of the reproducibility of an analysis. Precision is monitored by replicate analysis of samples. If the percentage variation between replicates is not within acceptable limits for the specific test, the procedure is reworked to make the precision acceptable and the sample set is reanalyzed. Precision checks (analysis of samples in duplicate) is performed at a minimum frequency of one per sample set or at a level of ten percent.

Standard Calibration Curves

At the beginning of each applicable analysis, a minimum of three standards are run in conjunction with the samples to provide a working standard curve. Calibration verification standards are analyzed upon completion of the standard curve. These solutions of known concentrations serve to verify the validity of the standard curve prior to the analysis of the samples. The samples are then quantified using the responses of the calibration curve. Samples are diluted or concentrated if necessary to fall within the working limits of the standard curve. The standard curve also functions as a check of the

proper operation of the analytical instrument. If the measured instrument response varies by more than 10% of the previous day's standardization, the operation of the instrument is checked and corrected if necessary. If a correction is made, a second standard curve is generated and verified before the analytical run.

Corrective Actions

Defensible data is dependent upon the evaluation of the quality control data. This must be initiated as early as possible in a project so that corrective actions and reanalysis are viable alternatives. The statistical basis for corrective actions are documented in the standard operating procedures. These are dependent upon spike recoveries, the relative percent difference between duplicates, and the blank values. Out of control events define a problem which ultimately requires a corrective action. If an analytical procedure is deemed out of control, CANTEST does not perform that particular test until the problem is resolved. Once the problem has been corrected, and the procedure is validated, sample analysis is allowed to continue.

Detection Limits

CANTEST employs procedures derived from CAEAL, the Ontario MISA program, and the U.S. EPA to determine Method Detection Limits. Section QA-11 of the CANTEST QA Manual provides a more detailed explanation of how the MDL's are derived. This document is available for review upon request.

Certification / Accreditation

Virtually every operating department in CANTEST is accredited by at least one of six internationally recognized agencies. Pursuit of this intra-disciplinary accreditation not only distinguishes CANTEST from other laboratories that may be narrowly focused, but also exemplifies a comprehensive approach to quality testing services that ultimately benefits the company as a whole.

CANTEST is a strong proponent of accreditation and has actively supported those programs which have a direct impact upon the market it serves. The accreditations that are most pertinent include:

1. CAEAL/SCC: CANTEST is accredited for a number of chemical and microbiological tests and as such are registered with the Canadian Association of Environmental Analytical Laboratories (CAEAL) and Standards Council of Canada (SCC).

The CAEAL/SCC accreditation is the formal recognition that an environmental analytical laboratory is competent to carry out specified tests. This implies that a laboratory's capability and performance be evaluated through the use of site inspections and performance evaluation samples. The current program encompasses a site inspection once every two years and the satisfactory participation in interlaboratory comparisons twice a year. Failure to meet specified requirements results in the withholding or removal of accreditation. The CAEAL/SCC certificate(s) are included in Appenix I.

Interlaboratory Studies (Round Robin Data)

Capacity and experience is only a secondary measure o a laboratory's capability as a commitment to the highest achievable quality result must be paramount. CANTEST clearly demonstrates this objective through its involvement in performance evaluation studies, both internally and externally.

As part of its effort to ensure excellent data quality, CANTEST has participated in approximately 140 environmentally orientated interlaboratory studies over the last three years. A brief list of some of the most recent undertakings include:

- CAEAL Certification and Accreditation Program
- B.C. MOELP EDQA Program
- U.S. EPA Performance Evaluation Samples
- Fisheries and Oceans Mercury in Fish Quality Assurance Program
- Ontario Ministry of Environment Interlaboratory Studies
- Federal/Provincial Quality Assurance Program (GLAP)
- Canadian Association of Pesticide Control Officers(CAPCO)
- Agriculture Canada Accreditation Check Sample Programs
- AIHA/NIOSH PAT program
- Regional Asbestos Round Robin Program
- UBC Clinical Microbiology Proficiency Testing

Round Robin Data is available for review upon request.

TURN-AROUND TIME

CANTEST is well aware of the role analytical data plays in all environmental projects. For this reason CANTEST will commit significant resources, including appropriate back-up equipment and personnel, to ensure all specified turnaround times are met and the integrity of data can not be questioned.

Analysis of samples will commence such that the analysis is completed within the time requirements of the proposal and within applicable sample holding times. Most analyses will be completed within a 7 - 10 working day period from the receipt of the samples with a certificate of analysis issued thereafter.

Testing sequence of a sample will be dictated by the recommended holding times for the specified analyte as specified in the attached tables. The attached tables summarize the recommended holding times for various parameters. It should be noted that these holding times are those generally accepted with the scientific community and by regulatory authorities and thus are not exclusive to CANTEST.

SAMPLE CONTAINERS AND SHIPPING

Appropriate sample containers complete with necessary preservatives for the requested analytical parameters will be provided by CANTEST at no additional charge. Sample containers will be shipped in coolers with "cold-packs" as required. Unless other arrangements are requested CANTEST will select a carrier based on destination and delivery time requirements. Coolers supplied by CANTEST remain the property of CANTEST and must be returned after two weeks. Unused sample containers may be retained by the client for future use.

Charges arising from the transportation of the sample containers to or from the laboratory are the responsibility of the client. Deliveries may be either sent collect or may be billed to an account set up by the client with a specific courier.

PRICING

Pricing is based on the proposed number of samples expected over the contract period. A volume discount has already been calculated based on this volume and is reflected in the quoted prices. Thus, the number of samples submitted at any one time will not affect the analytical charges for that submission. In some cases the analysis time can be decreased to accommodate specific requests. These rush turnaround times are typically in the order of 48 hours and normally result in a surcharge of approximately 25%. These surcharges may be waived if adequate advance notice is provided and laboratory capacity is such that "rush" work can be accommodated. There are certain instances where it is physically impossible to complete an analytical procedure in 48 hours and thus it is recommended that non-routine turnaround requests be handled on a job-by-job basis. See the attached tables for details on specific pricing for soil or water.