EBA Engineering Consultants Ltd.

EVALUATION OF
SURFACE CONTAMINATION DATA
GIANT MINE SITE
YELLOWKNIFE, N.W.T.

MARCH, 1998

NORTHWEST TERRITORIES WATER BOARD
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INDIAN AND NORTHERN
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WATER RESOURCES
DIVISION
YELLOWKNIFE, NT

EVALUATION OF
SURFACE CONTAMINATION DATA
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MARCH, 1998

0701-97-13097.3

eba

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March 11, 1998

Mr. Gordon Wray
Chairman
Northwest Territories Water Board
P.O. Box 1500
Yellowknife, N.T.
X1A 2R3

Dear Mr. Wray,

Re: Surface Contamination Study, Giant Mine

Please find enclosed ten copies of a report entitled "An Evaluation of Surface Contamination Data, Giant Mine Site, Yellowknife, N.W.T.", prepared for Royal Oak Mines by EBA Engineering Consultants Ltd. of Yellowknife. This work was commissioned in response to concerns expressed by the Water Board regarding the selection of control sites and the assessment of the risks associated with previously identified contamination, outlined in a letter dated July 17, 1997.

The EBA report identifies the lack of a universally accepted control site, that can be used to assess background levels of arsenic and other elements, as the outstanding issue of most concern at this time. The selection of an acceptable control site (or sites) would be fundamental to future assessment of the risks posed by soil contamination and the definition of criteria for the remediation of contaminated soils.

These are issues of concern to Royal Oak Mines, as well as other owners of potentially contaminated land in the Yellowknife area. Royal Oak Mines agrees with the recommendation of EBA, that this issue should be addressed as a priority and that all potential stakeholders should be invited to participate in the selection and acceptance of the control site, or sites.

In this regard, Royal Oak Mines is proposing to initiate a process to select potential sites, thoroughly characterize the sites, and sample and analyze soils at the sites according to rigorous standards. Wide stakeholder involvement will be encouraged, with the aim of achieving universal acceptance of the findings with regard to assessment of the Giant Mine site, and perhaps other potentially contaminated lands in the Yellowknife area. This work should proceed this coming summer season and Royal Oak Mines proposes to take the lead and make plans for a stakeholder meeting this spring.

This meeting would determine the level of interest and commitment from stakeholders in developing criteria for the control sites. Subsequent meetings would then finalize the work plan for the summer sampling season.

The EBA report notes that the sites selected for sampling in the studies conducted by Royal Oak Mines are concentrated in areas where contamination is known or suspected. Because of this, significant parts of the mine site lease area are not well characterized and the natural occurrence of arsenic in the soils and the dispersion of arsenic from anthropogenic sources are not well defined by the existing data. EBA recommends that additional sampling and analytical work be undertaken, using an unbiased grid system. Royal Oak Mines agrees with this recommendation and will conduct further soil sampling and analyses to address deficiencies in the existing database over the course of the summer of this year. A standardized quality control and quality assurance protocol will be developed and the sampled sites will be documented with photographs and intermittent, thorough soil characterization.

It is known that the various compounds of arsenic differ significantly in their degree of solubility and toxicity to living organisms. Such differences will significantly alter the risks posed by elevated levels of arsenic to human health and ecological integrity. Royal Oak Mines concurs with the EBA conclusion that the bioavailability of the arsenic compounds encountered in soils on the mine site will be a fundamental factor in the accurate evaluation of these risks. As part of the proposed sampling and analytical program for the summer of 1998, the issue of bioavailability will be addressed.

In March of 1997, the CCME published the "Recommended Canadian Soil Quality Guidelines", intended to replace the 1991 "Interim Canadian Soil Quality Guidelines". The new recommended criterion for inorganic arsenic in soils is 12 mg/kg, for all land uses. The CCME accepts that the levels of naturally occurring arsenic may exceed this level in some localities or regions of Canada and that, in these circumstances, a site- or region-specific guideline should be derived. The Yellowknife area, with it's known occurrence of arsenic enriched rocks, is likely to show relatively high levels of naturally occurring arsenic in soils. For this reason, Royal Oak Mines believes that a site specific remediation criterion will have to be developed, based on the real risks to human health and the environment. All further programs to collect data on soil quality will be designed to satisfy the requirements of a thorough risk assessment according to accepted protocols.

In the application for renewal of the current Giant Mine water licence, Royal Oak Mines has stated that the current Abandonment & Restoration Plan will be substantially revised and re-submitted by October 31, 1998. A summary and analysis of all data collected on soil quality, including the data proposed to be collected this coming summer, will be included with this submission. The findings of these various studies will be addressed in the plan.

Areas of the mine site contaminated with hydrocarbons were identified in the studies conducted by Royal Oak Mines. One such site has been fully restored and other priority sites are scheduled for clean up. A suitable location for 'land farming' hydrocarbon contaminated soils has been selected and this work will proceed during this coming summer season. The issue of arsenic contamination is considerably more complex and is dependent on the identification of a remediation criterion and the risk posed by the contamination. The resolution of these issues will receive immediate attention, as outlined in this letter.

We trust that this letter and the enclosed report will adequately address your concerns. Please contact us at (867) 669-3701, if you should have any questions.

Yours sincerely,

Royal Oak Mines Inc.

J Stard
Mar 11/98.

John Stard
Mine Manager
Giant Mine

Stephen Schultz

Stephen Schultz
Superintendent, Environmental Services
NWT Division

cc: R. Allan
L. Connell
E. Szol

EBA Engineering Consultants Ltd.

March 9, 1998

EBA File: 0701-97-13097-3

Royal Oak Mines
Corporate Office
5501 Lakeview Drive
Kirkland, WA
98033

Attention: Mr. Richard Allan, P. Eng.
Manager-Mining Projects

Dear Mr. Allan;

Re: Evaluation of Surface Contamination Data, Giant Mine Site, Yellowknife, N.W.T.

We are pleased to submit a report summarizing the results of the above evaluation. The evaluation was completed in accordance with a proposal dated January 23, 1998 (EBA File: 0701-97-P9792) and in response to a letter received from the Northwest Territories Water Board, dated July 17, 1997.

The objective of the evaluation was to identify potential information gaps that may exist in the existing surficial contamination database and assist in the development of a site specific remediation guideline for arsenic. The development of a site specific remediation criterion will form an integral component of Royal Oak's Abandonment and Restoration Plan.

We trust the enclosed information meets with your requirements. Please contact our office should there be any questions.

Yours truly
EBA Engineering Consultants Ltd.

R. Brent Murphy, M.Sc.
Senior Environmental Geologist

for Joseph Selann, M.Sc.
Vice President-Environmental Services

RBM/...

Attachments

EXECUTIVE SUMMARY

An evaluation of surface contamination data at the Giant Mine site, located in Yellowknife, N.W.T., was completed by EBA Engineering Consultants Ltd. The objective of this evaluation was to identify potential information gaps that may exist in the existing database and assist in the development of a site specific remediation criterion for arsenic.

The evaluation was based on a review of previous surface contamination studies completed by Royal Oak Mines Inc., during the period 1994 to 1996, in accordance with the requirements of their existing Water Licence (N1L2-0043). Additional surface contamination studies were recently completed by Royal Oak Mines Inc., in December 1997 and February 1998 and the preliminary results from these studies were also reviewed. The previously completed studies had identified elevated levels of total arsenic from soil samples collected within the confines of the Giant Mine Lease, near existing infrastructure. Additional analyses of soil samples were completed using the SWEP leachate analyses technique to determine the amount of leachable and mobile arsenic that was available. It was subsequently determined that the amount of leachable arsenic on the Giant Mine site was low, based on the results of the SWEP analyses procedures.

The evaluation concluded that the objectives of the original terms of reference developed for the surface contamination studies had been achieved. However, there was insufficient data to proceed with the development of a site specific remediation critierion for arsenic. The lack of data was identified on the basis of an assessment of the existing data quality, geochemical and analytical procedures.

The most significant data gap was the lack of an acceptable control site exhibiting background arsenic levels. Without a control site, an overall assessment of the degree of arsenic contamination at the Giant Mine site cannot be completed. The selection of a control site is therefore recommended as a priority.

Other data gaps include a lack of overall sample distribution across the mine lease area to identify regional arsenic levels. The survey also did not account for potential environmental factors which may impact on the dispersion of anthropogenic arsenic produced at the mine site (i.e. predominant wind direction). A proper QA/QC program was not implemented during the previous sampling studies.

Additional soil sampling is recommended to assist in the identification of regional arsenic levels. The additional sampling and resulting analytical procedures would also include arsenic speciation and toxicity analyses. These analyses would be completed to determine the bioavailability of arsenic at the Giant Mine site, factors that are fundamental in the development of a site specific remediation criterion for arsenic. The implementation of a QA/QC program is also recommended as a component of any future sampling program.

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1.0 INTRODUCTION

A review and evaluation of surface contamination data on file at the Royal Oak, Giant Mine site located in Yellowknife, N.W.T. has been completed by EBA Engineering Consultants Ltd. The review was completed at the request of Royal Oak Mines Inc., to assist in the development of a long term management plan to address site specific soil remediation issues associated with arsenic. An initial surface contamination study of the mine site was completed in 1994 in accordance with a requirement outlined in Part G, item 11 of the Water License (N1L2-0043), issued to the firm from the Northwest Territories Water Board. The initial study was followed by subsequent investigations and further detailed analytical testing completed throughout 1995 to 1996.

The following report provides information detailing naturally occurring background levels of arsenic in the environment surrounding Yellowknife, N.W.T., summarizes internal surface contaminant studies completed by Royal Oak Mines Inc., describes the methodology and presents conclusions and recommendations resulting from the project evaluation.

1.1 Project Rationale

The review of available surface contamination data at the Giant Mine site was requested by Royal Oak Mines as a preliminary measure prior to the development of a site specific remediation criterion and a management plan to mitigate the effects of potentially contaminated areas. The evaluation was also conducted in response to requests from the NWT Water Board to address areas contaminated by arsenic at the Giant Mine site.

1.2 Study Objectives

The objective of the study was to identify potential information gaps with the previously completed surface contamination studies to assist in the development of a site specific remediation guideline for arsenic. The evaluation included a review of a data package which consisted of a report entitled "Surface Contamination Study, The Giant Mine, Yellowknife, N.W.T.", correspondence between the N.W.T. Water Board and Royal Oak, an addendum to the surface contamination study, an update to the final surface contamination study, a wind rose diagram for the Yellowknife Airport, and the soil analytical results of the various studies in a computer file format. Various other internal and scientific documents were also reviewed during the study to provide background information.

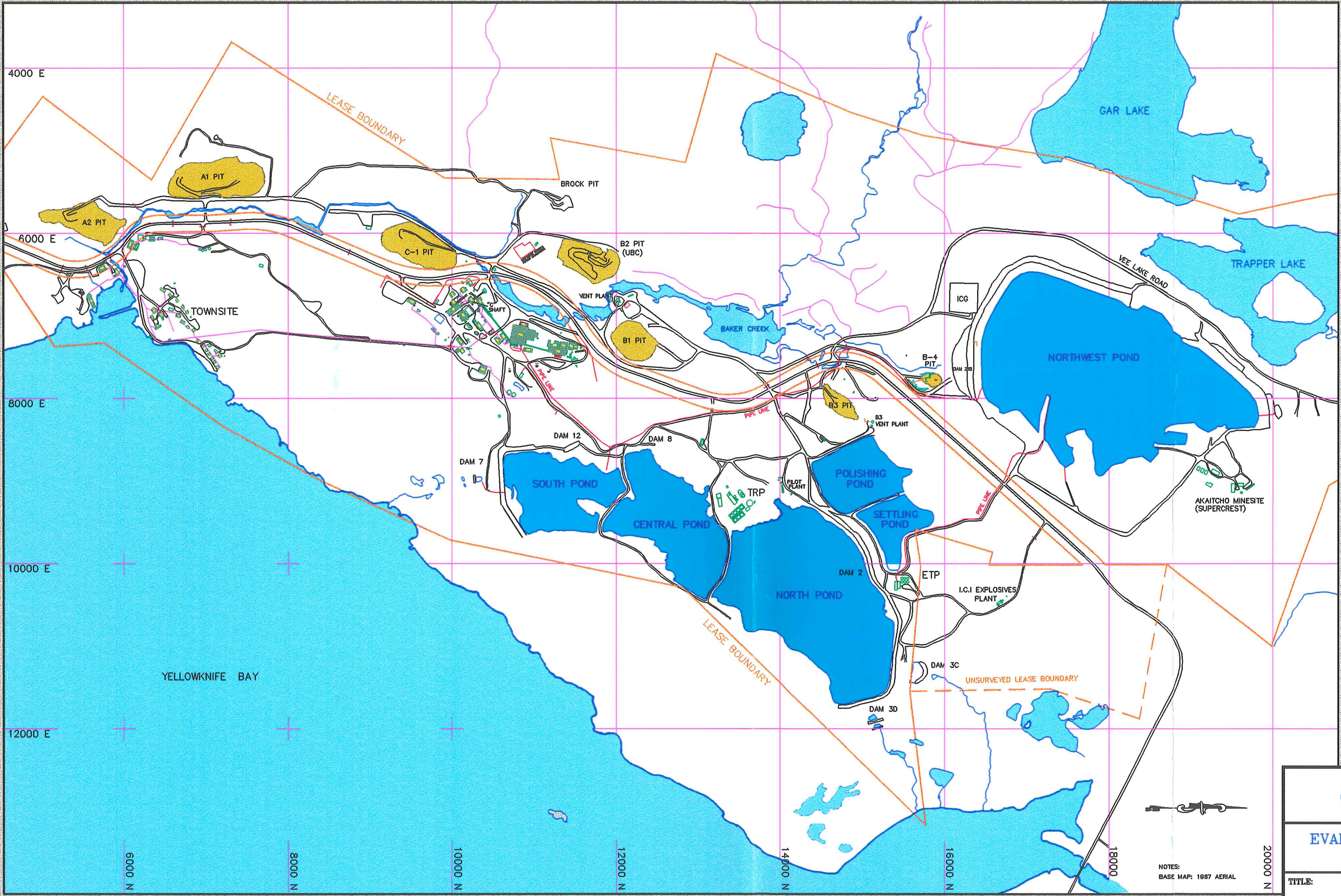
2.0 SITE DESCRIPTION

2.1 Physiography and Site Infrastructure

The Giant Mine Site is situated approximately five kilometres north of the City of Yellowknife, adjacent to Great Slave Lake along the western shore of Yellowknife Bay (Figure 2). The mine is situated within a zone of discontinuous permafrost and the local topography is characterized by a series of exposed bedrock highs with minor overburden deposits. The site is located within a northerly trending valley, at an approximate surface elevation of 220 metres, with prominent topographical highs forming the valley walls. Baker Creek flows southerly toward Yellowknife Bay along the valley floor.

The Giant Mine is operated primarily as an underground mine, at an approximate production rate of 1100 tonnes/day of ore. Several inactive open pits are also present on the site. The ore body has a strike length of over 4500 metres and is currently accessed through a main production shaft and two ramp systems. Mining is principally by mechanized cut and fill methods.

The mine site infrastructure consists of several buildings which are required for the production of gold. Included within the infrastructure are the mill, several office buildings, the mine headframe, and various buildings housing support service such as engineering, carpentry, and mechanic shops. Waste produced by the mining operation is currently deposited in two tailings impoundments, the Northwest Pond (primary) and the North Pond (secondary). There are also two additional ponds which are used for water treatment purposes, the Settling and Polishing ponds. All effluent discharge is treated in a plant then passed through the two ponds before final release to the environment (i.e. Baker Creek). A detailed site plan is provided as Figure 1.



NOTES:
BASE MAP: 1987 AERIAL

Royal Oak
Mines Inc.

EVALUATION OF SURFACE
CONTAMINATION

TITLE:
SITE PLAN

LEVEL: SURFACE	SCALE: 1"= NTS
DRAWN: MSL CHECK:	DATE: JAN. 29, 1997

Figure 1

File Name: MASTER\ARSENIC\SITEPLAN.DWG

Arsenic in the form of an arsenic trioxide bearing dust is currently produced at an approximate rate of 11 to 13 tons per day at the Giant Mine as a by product of the gold milling operation. The arsenic trioxide dust is produced when arsenopyrite is physically and chemically broken down to recover refractory gold mineralization, and the contained arsenic and sulphur mineralization is removed. The conversion process employed at the Giant Mine consists of roasting the arsenopyrite at high temperatures. The arsenic is volatilized and oxidized into arsenic trioxide which is recovered from the roaster gas stream in a conventional baghouse dust collector. The baghouse dust is then pneumatically conveyed into underground storage vaults. Discharge of the filtered gas stream is made through a 45 metre high roaster stack.

2.2 Geological Setting

The mine has been in operation since 1948, following the discovery of gold within the country rocks. The mine has produced over seven million ounces of gold since the initial discovery. The Giant Mine is located within the structurally complex Yellowknife Greenstone Belt of Archean Age on the geological time scale. The belt extends from Great Slave Lake for a distance of over 50 kilometres, and is comprised of a homoclinal steep easterly to vertically dipping sequence of metabasalts and metagabbros intruded by sheeted dykes and overlain by sedimentary units. The package of rocks was subsequently intruded by granitic intrusions.

Gold mineralization is present within the metabasalt units of the Kam Group, associated with arsenopyrite mineralization. The rocks have undergone middle greenschist to middle amphibolite facies metamorphism. Arsenopyrite is a naturally occurring arsenic bearing mineral. The gold mineralization is refractory meaning that the arsenopyrite mineralization must be broken down by oxidation to allow the recovery of the gold.

The Yellowknife Greenstone Belt is a structurally complex sequence of rocks. Three prominent fault trends exist within the Giant Mine; 000 to 025°, 060° , and 160°, with the main structural features known as the Townsite Fault, the 3-12 Fault, and the West Bay Fault. The 160° faults are prominent faults with variable easterly dips and are characterized by clay fault gouge and breccia. The sense of movement on these faults is sinistral. The 060° faults are generally characterized by having little or no clay gouge and may appear as thin hairline fractures. The sense of motion on these faults is dextral and they dip to the west. Faults with the 060° trend may occur as major faults or appear as lesser faults.

2.3 Potential Sources of Natural and Anthropogenic Arsenic

Arsenic and its compounds are designated as toxic materials under Section 11 of the Canadian Environmental Protection Act. Scientific evidence indicates that inorganic arsenic compounds are carcinogens and are considered to be "non-threshold" toxins which means that arsenic compounds may have adverse health effects at any exposure level. For these reasons, arsenic and its compounds are listed in Group 1 of the CEPA Priority Substances List and potential arsenic contamination within the Yellowknife area is a concern.

It is recognized that arsenic is present in the local environmental naturally. Arsenic enriched bedrock in the Yellowknife area is known to exist. Arsenic enrichment in the form of arsenopyrite mineralization is a common characteristic of Archean lode gold deposits, a feature which is also prevalent throughout the Yellowknife Greenstone Belt. The two operating gold mines in the Yellowknife area, the Giant and Miramar Con mines extract gold from ore zones which are naturally enriched with arsenic, in the form of arsenopyrite mineralization. Granitic intrusions, adjacent to the greenstone belts, are also known to contain arsenopyrite mineralization.

Arsenic levels within bedrock from the Yellowknife area can range from less than 5 ppm to values in excess of 6500 ppm (Boyle, 1979). Soil which is comprised of weathered and decomposed bedrock would therefore be expected to also contain significant levels of arsenic in excess of generally accepted background levels. The Royal Oak studies makes reference to the National Academy of Science (1977) study which indicates that natural arsenic concentrations within soil can vary from 0.1 to 40 ppm with an average of 5 to 6 ppm. It is to be noted that the referenced data does not include geochemical information from the Yellowknife region since, to date, no generally accepted control sites have been identified. However, based on the Royal Oak studies and other studies completed at the Miramar Con mine (EBA file 0701-10433) soil arsenic concentrations ranged from less than 10 ppm to in excess of 1000 ppm.

Review of available information did not specifically indicate potential anthropogenic sources of arsenic from the Royal Oak Mine operations or other sources within the Yellowknife area. However, historically two major sources of anthropogenic arsenic are known for the Yellowknife area. These include the former gold roaster that was located at the Con mine which ceased operation in 1971, and the existing roaster at the Giant mine. Studies both published and unpublished indicate that approximately 8.8 tonnes of arsenic is released into the atmosphere per year (presumably from roaster operations) within the Yellowknife area. Improvements to the roaster system at the Giant Mine have decreased the levels of arsenic being released to the atmosphere to an approximate level of 20 to 30 kilograms per day of arsenic equivalent, significantly reduced from a release level of several tons per day during the early and mid 1950's.

Arsenic releases can occur as a result of leaching from mill tailings and waste rock although it is felt that the most significant anthropogenic arsenic in the Yellowknife area in general and the Royal Oak Mine site in particular is arsenic trioxide (As_2O_3) which was deposited onto surface waters and soils from stack emissions. Therefore, it is expected that arsenic levels would be high in the vicinity of the existing and past operational roasters and downwind from the release points.

Discussions with staff members of the Giant Mine indicated that waste rock material, possibly enriched in arsenopyrite mineralization, has been used as fill material throughout the Giant site. The use and distribution of such material would also contribute to the overall presence of arsenic within the local environment, specifically in close proximity to the mine infrastructure.

3.0 TECHNICAL INVESTIGATIONS

3.1 Summary of Previous Royal Oak Studies

Four soil sampling investigations and/or analytical programs were completed at the Giant Mine site between 1994 and 1996. The purpose of these investigations was to characterize the extent and distribution of potential inorganic and organic contaminants on the mine property prior to the development of a site specific remediation criterion for arsenic.

The first study undertaken in 1994 consisted of a survey in which soil samples were collected at surface and from a depth of 0.2 metres below surface grade for a total of 94 sample sites (188 samples). The sample sites consisted of 91 locations on the mine property and 3 control sites located in the City of Yellowknife against which arsenic levels on the mine property could be compared. Samples of precipitation runoff were also collected from a total of 14 sites on two occasions in July and September 1994. Samples representative of standing water were collected on a similar time frame from an additional 14 sites. Sample locations of the 91 soils sites (S1to S91), the 14 precipitation sites (R1 to R14) and the fourteen standing water sites (W1 to W15) are shown in Figure 2, with the control sites (S92 to S94) depicted on Figure 3. Both figures are contained in pockets located at the back of this report.

The samples were submitted to Chemex Laboratories in North Vancouver and analyzed for the following parameters;

total cyanide
paste pH
ammonia (N)
total copper
total nickel
total zinc
total arsenic
total lead
oil and grease

The soil sample analytical results were compared against the Interim CCME remediation guidelines (1991) for industrial sites and the water analyses were compared to the water use discharge criteria established by the NWT Water Board in the Giant Mine water use license. Analytical results from this study are presented in Appendix A. The report dated March 22, 1995 is on file at the NWT Water Board for additional reference.

The study found with the exception of arsenic, the average concentration of all analytical parameters measured did not exceed the CCME remediation for industrial sites both for the samples collected at surface and at 0.2 metres below surface grade. It was also concluded that the average concentrations of all the study parameters were higher within the samples collected from the mine site as compared to the control sites located in the City.

Arsenic levels were determined to exceed CCME guidelines at the control sites and within samples collected from the mine site. The study found that the levels of total arsenic in the soil exceeded the CCME guideline limit of 50 ppm (1991 guideline value) in 173 of the samples analyzed. The average concentration of total arsenic was determined to be 2001 ppm. Arsenic levels at the mine site were several orders of magnitude higher than those levels identified in the control site samples. This relationship was identified both for the surface and the 0.2 metres below grade samples.

Additional analytical testing using SWEP leachate extraction tests on several of the samples containing high arsenic levels determined that the majority of the arsenic contained within the samples was not soluble in water under mildly acidic conditions.

Isolated pockets of elevated levels of copper, nickel, lead, and oil and grease were also observed during the study. Based on these observations and the high levels of arsenic identified, additional soil sampling was recommended in those areas of high arsenic.

The water sampling results indicated a general pattern of enriched arsenic concentrations within the runoff and standing water bodies. However the sampling results were contradictory and additional sampling was recommended.

A second study dated August 2, 1995 was also submitted to the NWT Water Board as a follow up to the initial study. This study consisted of the submission of 31 previously collected soil samples for analyses by the SWEP leachate extraction test to identify soluble arsenic levels. The samples which were analyzed represented the highest measured levels of total arsenic from the samples collected during the initial study.

The results indicated that soluble arsenic concentrations, as determined by the SWEP analytical procedure were below the CCME remediation guideline of 50 ppm (1991 guideline value) in 23 of the 31 sample sites. It was further concluded that it was probable that the total arsenic being measured at the various sample locations was not soluble under the SWEP leachate extraction test conditions (pH of 5.2). Analytical results are presented in Appendix B.

Eight sites were identified as being contaminated by significant levels of soluble arsenic in this study. These sites consisted of samples S19 near the old PCB storage building, sample S27 located between the North Pond and Great Slave Lake, sample S53 adjacent to the open pit crusher, samples S57 and S58 near the MEG building, and samples S83, S87, and S88 located adjacent to the roaster rack (Figure 2). Additional sampling was recommended at these sites to verify and assess the extent of soil contamination.

Based on the results of the first two studies as summarized in reports dated March 22 and August 2, 1995, respectively, a third study was commissioned. This study consisted of the collection of 50 additional soil samples from various locations on the mine property and was reported in the 1995 Annual report submitted to the NWT Water Board on March 28, 1996. The sites chosen for sampling purposes were in areas where previous sampling (1994) had indicated elevated levels of arsenic. The samples were labeled G1 to G50 and are depicted on Figure 2. Total arsenic and SWEP leachate analyses were completed on all samples collected. Analytical results are included in Appendix C.

Three additional control sites were also established during this phase of analytical work in response to the NWT Water Board's concern that the initial control sites were not representative of natural undisturbed soil. Soil samples were collected at surface and at 0.2 metres below surface grade at each of the three sites with the samples labeled G43 to G48. The control sites are depicted on Figure 3.

The 1995 sampling program identified 44 samples containing arsenic levels in excess of the CCME remediation guideline value of 50 ppm. Additionally, 18 of the 50 samples also contained soluble arsenic levels in excess of 50 ppm. The majority of these samples were located in close vicinity to the roaster/baghouse area on the mine site. Arsenic levels were similar in value to those identified during the initial study.

Additional sampling was completed in 1996 in an attempt to further identify control sites that would meet the approval of the NWT Water Board. Eight soil samples were collected from various locations northwest of the mine site and submitted for analyses of total arsenic. Sample locations are depicted on Figure 2 and the analytical results are presented in Appendix D.

3.2 Ongoing Studies at the Giant Mine Site

Royal Oak recently implemented several environmental studies designed to provide additional characterization of the mine site to assist in development of an abandonment and restoration plan. These studies consisted of the construction of testpits and monitoring wells at various locations on the site. Brief summaries of each program are provided below.

A testpitting program consisting of three testpits was completed at the mine site on December 15, 1997. The objective of the program was to investigate and document soil conditions in the vicinity of the existing mill structure as a component of an overall arsenic trioxide management plan. Testpit locations are presented on Figure 4.

Testpit depths ranged from 4.1 to 7.2 metres below surface grade. Site stratigraphy as observed within the testpits consisted of a one metre thick layer of waste rock underlain by a thin organic layer. A basal clay, red to brown in colour, several metres in thickness, was noted in all three testpits. Atterberg Limits testing of the clay indicated soil plastic limits of 22.0% and a liquid limit of 38.5%.

Permafrost was encountered in the testpit situated closest to the mill building, at 4.8 metres below grade.

Soil samples were collected from various intervals within two of the testpits (TP-1 and TP-2) and submitted for total arsenic and oil and grease analyses at Chemex Laboratories. Analytical results are presented in Table 1. The results indicated the presence of elevated levels of arsenic within the waste rock fill material, and low arsenic levels within the basal clay layer. Oil and grease analyses ranged from 0.005 to 2.18% in all samples submitted. Based on the results received from this study, the presence of the basal clay unit may act as an effective barrier, preventing the vertical migration of potentially anthropogenically derived arsenic from surface layers.

Additional drilling and monitoring well construction were conducted on February 27 and 28, 1998. The objectives of this program were to characterize the stratigraphy of the site immediately topographically downgradient of the roaster/baghouse, and to identify depth to bedrock at various locations along a mine property transect across Baker Creek. The location of the 1998 drilling is also depicted on Figure 4.

TABLE 1: Analytical Results
Testpitting Program
December 1997

Testpit #/Location	Sample Depth (metres)	Total Arsenic Levels (ppm)	Oil And Grease (%)	Stratigraphy
TP-1 - old waste oil storage yard	0	1740	2.18	rock crush fill
	0.2	806	0.866	clay
	1.0	9.0	0.117	clay
	3.0	10.0	0.009	clay
	4.0	9.0	0.005	clay
TP-2 - near tailings pipe trestle	0	1315	0.016	rock crush fill
	0.2	1685	0.025	rock crush fill
	1.0	35	0.007	clay
	3.0	9.0	0.007	clay
	5.0	10.0	0.003	clay

A third testhole was constructed downgradient of the roaster/baghouse to allow the installation of a groundwater monitoring well. Stratigraphy at this location consisted of approximately one metre of gravel fill underlain by one to two metres of silty sand clay till. This till layer was underlain by a red brown to greyish brown clay layer which extended to approximately 7.0 metres below grade, Bedrock was intersected at this depth. A groundwater monitoring well consisting of 50 mm diameter PVC screen was subsequently installed in the hole.

Soil samples representative of the soil profile were collected during the drilling and representative samples are currently being selected for inorganic analyses. Water samples will also be collected with the onset of warmer weather. The recent drilling further confirmed the presence of a basal clay layer which underlies the Giant Mine site.

3.3 Review of CCME Guidelines

In 1991, the Canadian Council of Ministers of the Environment published a set of interim soils quality criterion for various contaminants including arsenic. The arsenic remediation criteria or SQG in the interim guidelines document ranged from 20 ppm for agricultural land to 50 ppm for commercial and industrial land. Surface contamination studies undertaken by Royal Oak Mines at the Giant Mine site make reference to numerical criterion listed in the 1991 interim soils quality criterion. It was CCME's opinion that these criteria were not scientifically defensible. Therefore, the interim criterion was updated to include current toxicological data and the Recommended Canadian Soil Quality Guidelines were published in March 1997 which included an arsenic remediation guideline of 12 ppm..

The new guidelines are based on the lowest values for human health and environmental protection. According to the CCME, the new arsenic limit of 12 ppm for all land use is consistent with lifetime incremental cancer risk of 10^{-6} above background for all land use options and the interim soils quality criterion limit of 50 ppm for arsenic was repealed with the publication of the CCME Recommended Soil Quality Guidelines.

3.4 Development of a Site Specific Remediation Criterion for Arsenic

The CCME Recommended Soil Quality Guidelines for arsenic recognizes that in some areas of Canada, the 1997 recommended CCME guideline of 12 ppm for all land use options is below the naturally occurring background levels. Under these conditions, the development of site or region specific guidelines, incorporating the local/regional background arsenic concentrations must be developed.

The development of the site or region specific guidelines would be completed on a risk based approach, assessing both human health risk and qualitative environmental health assessment. Health risk assessment refers to the technical, scientific assessment of the nature and magnitude of risk and uses a factual base to define the health effects of exposure of individuals or populations to hazardous contaminants and situations. Risk is defined as the probability of an adverse event. One can also describe risk with the following expression.

Risk = Severity of event (Hazard) x Exposure

All relevant health endpoints, both cancer and non-cancer, must be assessed. The quality of the assessment is governed to a large degree by the quality of the toxicological and exposure information that goes into it and the professional judgement of those who conduct the assessment. Uncertainty is inherent in the process.

The goal of an environmental health assessment would be to predict potential adverse effects and when appropriate, to measure existing adverse effects of chemical contaminants on the biota, on or near a site or facility, and to determine levels of those chemicals in the environment that would not be expected to adversely affect the biota. Field observations are suggested as a supplement to the predictive ecological risk evaluation when contamination is present and has been present for a period of time sufficient to have caused an adverse ecological impact.

4.0 EVALUATION AND REVIEW OF ROYAL OAK STUDIES

4.1 Data Quality Assessment

The initial evaluation of the surface contamination data indicated that the studies completed by Royal Oak were conducted in accordance with the Terms of Reference developed for the studies dated May 1993 and on file at the NWT Water Board. The stated objective within the original terms of reference was to determine the presence of contaminated soils, water or runoff samples on the Giant Mine leases. Samples were to be analyzed for a variety of inorganic and organic parameters.

The study or studies did identify the presence of elevated levels of various inorganic and organic parameters in the vicinity of the existing infrastructure. The various parameter levels were subsequently compared to existing regulatory guidelines such as the CCME Guidelines and the NWT Remediation Criteria and on that comparison it was concluded that surface contamination was present on the site, specifically with regards to organic contaminants and arsenic.

It is noted that a better understanding and appreciation of the issues associated with potential surface contamination issues has been achieved by all the stakeholders involved with the Giant Mine since the development of the terms of reference for the surface studies and the completion of the studies. This understanding has resulted in the identification of potential processes and/or study components that have evolved beyond the original study scope, thereby creating an incomplete database with regards to surface contaminant issues at the Giant Mine.

The evaluation of the data quality with respect to existing Royal Oak in-house investigations, within the context of potential future study processes such as future risk assessment data needs, indicate the following general observations.

Review of soil contamination data did not identify a standardized quality assurance/quality control (QA/QC) approach with regards to the sampling program implemented at the site. Quality assurance samples such as field/trip blanks or duplicates were not identified within the database. Therefore, the quality of the data in terms of precision, accuracy, or reproduceability is unknown. However it is known that all samples had been collected by experienced Royal Oak employees with training in field procedures. It is believed that all samples were analyzed by a qualified commercial laboratory under standard protocols, therefore, no basis exists to dismiss any of the total arsenic results.

A review of field procedures, specifically field notes describing each sample location, indicated a lack of data. Descriptions of soil types, make ups, potential nearby anthropogenic sources for various contaminants was not available. Data and field information of this type is essential in evaluating potential impacts to the environment of various contaminants within future studies. It is known that arsenic has differing characteristics with regards to form (speciation) and toxicity effects to the environment, dependent upon the depth of arsenic enrichment, soil chemistry and characteristics.

An evaluation of the sample distribution of the previously completed studies as indicated on Figure 2, identified several geographic data gaps and that the current data may unfairly characterize the site by indicating conditions are worse than they may actually be on site. Sampling during the previous studies concentrated on the collection of samples within close proximity to the existing infrastructure at known or suspected contaminant hot spots (i.e. close to the roaster stack). Initially, there was no systematic approach to the collection of samples on a regional basis followed by additional studies at sample locations depicting elevated parameter levels.

The lack of a systematic sampling approach is illustrated when the Environment Canada windrose is overlain on the site map, indicating that sample locations located to the north, northeast, and southeast of contaminant discharge points (i.e. downwind direction) are scarce. Specifically, there are few sample locations situated between the plantsite and Yellowknife Bay. A systematic regional approach to sampling over the whole of the mine lease on a similar density may assist in the identification of regional background levels for various inorganic parameters including arsenic.

The previous studies attempted to identify natural background levels of the inorganic parameters in an attempt to determine potential contaminant loading to the environment. An acceptable control site was unfortunately not selected due to various concerns expressed by the regulatory agency (NWT Water Board). The lack of a suitable control site prevented a full and thorough evaluation of the data and is an issue that must be resolved prior to the development and completion of future studies such as risk assessment. The issue of a control site will be further addressed in Section 4.3.

Data quality issues that would preclude the use of the available information in future risk assessment were not identified during the evaluation, although it must be recognized if a risk assessment process is implemented, additional data needs to further characterize the site will be identified and required.

4.2 Review of Analytical Procedures for Arsenic

Soil arsenic levels for the previously completed studies were determined on the basis of total arsenic as analyzed by Chemex Laboratories. Sample preparation and digestion of the soil samples for arsenic analyses were completed in accordance with EPA (Environmental Protection Agency) Standard Reference 3050. This reference method refers to a nitric acid digestion process in which one to two grams of the soil sample is oxidized. Following digestion, the level of arsenic within the sample was determined by atomic absorption techniques within a graphite reference tube. A further explanation of the total arsenic analytical method is presented in Appendix E.

The toxicity of arsenic within the environment is determined by the speciation or form of the arsenic. Inorganic arsenic is more toxic than organic forms of arsenic. Furthermore, the toxicity of As (III), an inorganic form of arsenic, is greater than As (V).

Royal Oak in recognition that the mobility and toxicity of arsenic in the environment would be dependent on solubility of arsenic within the environment, completed SWEP Leachate Analyses in the previous studies. These analyses were completed to determine the potential leachability of the total arsenic contained within the soils at the mine site.

The SWEP Leachate Analyses is an interim analytical method that is used to determine whether a waste exhibits the characteristic of extraction procedure toxicity. The procedure was developed to simulate the leaching which a waste may undergo if disposed of in a sanitary landfill. The test is usually run at a pH level of 5.2 units. Additional details of the analytical procedure are presented in Appendix E.

Use of the SWEP Leachate analyses with regards to potential arsenic mobilization and toxicity at the Giant site may provide inaccurate results with regards to arsenic toxicity, as it will only provide an incomplete database. The SWEP procedure is applicable to a leachate produced by a sanitary landfill with an assumed pH of 5.2. This procedure may not account for the natural soil conditions at Giant that could have a substantially higher pH, therefore affecting the solubility of arsenic.

The data presented by Royal Oak for review recognizes that the chemical forms of arsenic present on site will, to a large extent, determine the potential adverse health effects that may result. It is assumed that the biologic availability is the principal determining factor in ingestion and inhalation exposure scenarios associated with a potential human health risk assessment scenario. Therefore, before the relevance of elevated arsenic levels can be determined, EBA recommends that the issue of bioavailability within the Giant site must be dealt with. There are two options available to resolve the issue of bioavailability. These are:

1. Arsenic compounds chemical speciation, and
2. Characterization of arsenic compounds without speciation.

EBA agrees with Royal Oak in that it may not be possible to determine the species of arsenic present on site with sufficient level of accuracy for subsequent use in a quantitative risk assessment or that multiple forms might be present, or the bioavailability of the predominant species of arsenic determined to be present on site is unknown in literature. For these reasons it is preferred to address the issue of arsenic bioavailability by determining the solubility of the dominant arsenic compounds. However, EBA does not agree that the special waste extraction procedure (SWEP) adequately determines bioavailability *in-vitro.*

USEPA and the BC Environment have developed a “physiologically relevant extraction procedure” (PREP) for use in soil analysis. This PREP extraction method attempts to simulate human digestive conditions. Therefore, for the data to be relevant, the following information will be required.

1. total arsenic concentration,
2. PREP arsenic concentration, and
3. SWEP arsenic concentration.

It is anticipated that the PREP arsenic concentrations will be higher than the SWEP arsenic concentration levels.

Following the completion of PREP analyses either on future soil samples or pulps retained from previously collected samples, it will be determined whether an acceptable degree of correlation exists between total and PREP derived arsenic concentration levels to allow direct conversion of total arsenic concentrations to bioavailable PREP arsenic concentrations. If such correlation is determined to exist, it will be necessary to develop an equation for converting existing arsenic concentration data based on total chemical analysis to bioavailable arsenic concentrations.

4.3 Geochemical Evaluation and Spatial Distribution of Arsenic Soil Anomalies

Soil arsenic levels contained within soil samples collected in 1994 were evaluated using a geochemical plotting program to determine potential relationships associated with sample location and site infrastructure. Two maps representing geochemical contour representations of the analytical data obtained from surficial and samples at 0.2 metres depth were generated using the SURFER geochemical program (Figures 5 and 6).

The SURFER plot for the surface analytical data indicates the presence of four zones of arsenic enrichment in close proximity to the existing mine infrastructure (Figure 5). The first soil anomaly is located in the vicinity of the C Shaft, the second anomaly is located to the southeast corner of the mill building, the third anomaly is located in the immediate vicinity of the baghouse, with the fourth anomaly located to the northwest of the baghouse structure. A regional broad enriched dispersion zone of arsenic is also evident in the area situated north of the mine site (i.e. C shaft area) and the Northwest Tailings Pond.

Review of the SURFER plot for the analytical data at 0.2 metres depth as shown on Figure 6 indicated a similar type pattern of arsenic enriched zones as compared to the surficial data. However, the strength, intensity, and lateral extent of the four soil anomalies located in close proximity to the existing mine infrastructure has been reduced. The broad regional anomaly situated north of the mine infrastructure is present also at or about the same intensity as is evidenced in the surficial data.

The reason or reasons for the occurrence of the arsenic anomalies is unknown at this time due to an incomplete database. It is reasonable to assume that the soil arsenic level located in the vicinity of the baghouse may be due to anthropogenic sources associated with the roaster and baghouse operations. However there is insufficient data to relate the occurrences of the remaining three arsenic soil anomalies situated in proximity to the mine infrastructure to similar type sources. The lessening of the strength of the anomalies with depth may be an indication of surficial enrichment from anthropogenic sources associated with industrial operations at the mine site. However the presence of the broad regional anomaly situated north of the mine site may be indicative of natural enrichment processes as it is located both at surface and at depth (0.2 metres) and is in an area with less development.

The occurrence and dispersion patterns of the arsenic soil anomalies are a function of sample density and location. The frequency of the soil samples to the north of the existing mine infrastructure is less than the frequency of samples collected near the mill structure. For this reason, the broad regional anomaly located north of the mine infrastructure, as evidenced on Figures 5 and 6, may be a function of a lack of sample density.

The SURFER plots indicate enriched levels of arsenic in the soil. However the plots do not indicate whether the noted arsenic enrichment is relevant as compared to naturally occurring background levels of arsenic, or the source of the arsenic. For this reason the identification of background arsenic levels is important along with further data evaluation in an attempt to identify potential anthropogenic sources of arsenic on the Giant Mine site. This data would include the identification of existing and historical waste or ore piles.

4.4 Natural Background Levels of Arsenic in Soil

It is recognized that arsenic is present in the local environment naturally. Arsenic enriched bedrock, present as background concentrations is known to exist in the Yellowknife area. The Royal Oak study makes reference to the National Academy of Science (1977) study that indicates that natural arsenic concentrations can vary from 0.1 to 40 ppm with an average of 5 to 6 ppm. It is to be noted that the referenced data does not include geochemical information from the Yellowknife region since, to date, no generally accepted control sites have been identified.

The current data does not attempt to distinguish between background and anthropogenic arsenic present on the Royal Oak site. And, at this time, it is not known whether or not the background levels of arsenic on the site exceed the CCME Soil Quality Guidelines (1997) for inorganic arsenic of 12 mg/kg for all land use options.

Therefore on this basis, it is recommended that a control site representative of the Yellowknife area be established so that natural background levels of arsenic can be identified. It is further imperative that the control site be selected prior to or in conjunction with potential future studies relating to surface contamination issues that may be conducted at the Royal Oak Mine.

The issue of the selection of the control site, is an issue that transcends site specific concerns solely related to the Giant Mine site, as arsenic within the Yellowknife environment involves several stakeholders including the NWT Water Board, Resources, Wildlife and Economic Development, Municipal and Community Affairs, the Department of Health, DIAND, the City of Yellowknife, and Miramar Con Mine. It is therefore proposed that a multi-stakeholder advisory group be formed with the sole purpose of identifying a control site exhibiting background levels of inorganic parameters.

The proposed control site would be representative of the Yellowknife environment as a whole, prior to industrial development. It is anticipated that the control site would also be located in an area exhibiting similar characteristics to Yellowknife, such as geology, topography, etc., and would be located in an area removed from potential impacts from industrial pollution. Proposed selection criteria for a control site is presented in Appendix F.

4.5 Risk Management Approach

Review of the Royal Oak surface contamination studies by the NWT Water Board , in a letter dated July 27, 1995, recognized that the Interim CCME guideline of 50 ppm was unrealistic and unachievable. Based on this conclusion, it can therefore be surmised that the 1997 CCME Recommended Soil Quality Guidelines of 12 ppm for arsenic would also not be achievable.

Based on the above evaluation, it is suggested that it will be necessary to develop site specific risk based arsenic remediation criterion for the Giant Mine site. It is anticipated that the criterion would be based on quantitative human health risk assessment and qualitative environmental health assessment.

The risk based approach should be based on the following information;

a) levels and distribution of arsenic compounds and their availability.

b) exposure to arsenic compounds scenarios consistent with future land use options.

c) the potential exposure levels and doses of arsenic compounds.

d) a comparison of exposure levels to current knowledge of the health effects from those exposure and dosage levels.

e) an estimation of health effects from background concentrations in the Yellowknife environment and comparison with the added health risks associated with anthropogenic arsenic in the area.

f) a calculation of incremental cancer and non-cancer health effects associated with anthropogenic arsenic in the area. The calculation of residual anthropogenic arsenic compound levels in the environment to meet predetermined (agreed upon) incremental health risks would be used to develop remediation strategies.

It will be necessary to develop exposure scenarios consistent with future land use options of the abandoned mine site, as a major component of any risk management approach. These scenarios will incorporate ingestion, inhalation, and dermal contact as potential exposure scenarios.

Non-cancer risks will be presented as hazard indices with cancer risks presented as incremental lifetime risks over background. It is generally accepted in Canada that residual carcinogenic substances in the environment are unacceptable if these residuals increase the incremental lifetime cancer incident rate by more than seven in a million. Assuming a constant population of 25,000 this incremental lifetime cancer risk would be one every 300 years. If the risk assessment indicated that the incremental lifetime cancer risk exceeds the generally accepted limit, steps will have to be developed to limit exposure.

The risk assessment approach will not be restricted to the confines of the Royal Oak property, but will involve a regional assessment and evaluation. It should be recognized that the presence of arsenic within the Yellowknife area is not related entirely to the actions or management activities of one party alone, but encompasses several organizations. On this basis the development of a risk assessment approach should be a multi-stakeholder approach comprised of all concerned parties within the community.

5.0 CONCLUSIONS AND RECOMMENDATIONS

An evaluation of data pertaining to surficial contaminant issues at the Giant mine site was completed in accordance with a proposal submitted to Royal Oak. The objective of the evaluation was to identify potential information gaps within the previously completed studies to assist in the potential development of a site specific remediation criterion for arsenic.

The evaluation determined that the objectives of the original Terms of Reference for the surface contamination studies conducted at the Giant mine site were achieved. Elevated levels of various inorganic and organic parameters were identified across the Giant Mine site by the various studies. However the studies were found to be lacking in several areas pertaining to data quality and the lack of applicable data specific to arsenic, to assist in the development of a site remediation criterion for arsenic.

Therefore, as the process for the development of site remediation criterion proceeds and assuming that a human health risk assessment will determine what site remediation work ultimately will be required, the following issues should be considered:

1. The most significant issue at this time is the lack of a universally accepted control site that could be used for background data. The availability of a control site will be necessary to segregate natural and anthropogenic arsenic. It will be necessary to have regulatory and public involvement in the selection of appropriate control sites since such a control site would then be used for all future assessments in the Yellowknife area.

disagree

2. The issue of arsenic bioavailability has not been resolved. It will be necessary to undertake some literature review and to develop an analytical protocol for bioavailability studies. The results could then be used to re-interpret all existing data. It is EBA's opinion that the SWEP protocol is designed to simulate landfill conditions and it does not adequately simulate human digestive conditions.

   bioavailability through inhalation in addition digestion

   EBA recognizes that the quality of the work has to be of the highest calibre for this project. Reviews can be anticipated from a variety of sources with various interests. Therefore, it will be appropriate to undertake some additional speciation work as well. While it is recognized that the toxicological effects of arsenic III and arsenic V are not significantly different, arsenic III is somewhat more toxic than arsenic V. The potential uptake and metabolization of the two inorganic forms could be different. In addition, it is recognized that organic arsenic compounds have a lower toxicity than inorganic

what use [illegible] to [illegible]

inhalation more likely [illegible]

compounds, some speciation in terms of mono-methylated arsenic (MMA) and di-methylated arsenic (DMA) will enhance the quality of the work.

3. It will be necessary to begin the process to identify future land use options for the Royal Oak site. Post closure/reclamation uses of the site will determine exposure scenarios which are an integral part of the risk assessment process. It must be recognized that if risk assessment based remediation criterion will be applied to the site, a permanent caveat, defining land use options will be attached to the site. Therefore, all potential future land use options should be reviewed and the most realistic/ restrictive scenarios selected. agree

4. Based on the representation developed by the geostatistical SURFER program, areas of the plantsite not adequately characterized should be identified and additional sampling/analytical work be undertaken. This sampling should be conducted on a grid system to ensure adequate representation of the site, accounting for potential environmental concerns such as wind direction. Other inorganic parameters , such as copper, should be evaluated with the SURFER program to identify potential relationships that may be indicative of natural enrichment processes. agree what do they mean?

5. In conjunction with the additional sampling program a standardized QA/QC program be adopted and implemented. Also descriptions of the sampling sited should be included as a component of any future sampling program. agree

The above listed issues are not prioritized. It is EBA's opinion that work should begin simultaneously in all areas to ensure that the risk assessment portion of the work can proceed.

Lisa

compounds found in ambient conditions (5). Particulate arsenic compounds, such as arsenic trioxide, are appreciably volatile. Therefore losses may be suspected during and after collection. Based upon the equilibrium established between solid particulates on the filter, and vapour in the passing air, the significance of this loss will depend upon the pollution level, increasing with decreasing levels, and may be significant at the very low levels encountered in the community (5). This problem of ambient sampling is not considered to be a major constraint with respect to the significance of ambient air-quality data collected in Yellowknife in recent years, since even large variations in the accuracy of measured results would still provide acceptable levels. It has also been noted that collection by the high-volume sampling method may only be efficient at low temperatures (5), possibly a positive consideration in the Yellowknife case. It is recommended that ambient-air monitoring techniques for arsenic be based upon the most up-to-date advice available through close consultation with the Environmental Protection Service.

(b) *Soil and Vegetation*

The natural arsenic content in virgin soils varies from 0.1 to 40 ppm with an average of about 5-6 ppm. Arsenic levels in plants not treated with arsenical spray or exposed to arsenic fall-out seldom exceed 0.5 ppm fresh weight (5 ppm dry weight) (10).

Studies conducted in the Yellowknife area have consistently indicated (12) considerable contamination by arsenic compounds in the soil and vegetation of the area. In addition, there is minor contamination by antimony and trace contamination by other heavy metals. Soils in the city of Yellowknife contain a highly variable concentration of arsenic ranging from 1 to 600 ppm. In the vicinity of the mines, levels of more than 4,000 ppm have been reported (8). Also arsenic concentrations up to 10,000 ppm were measured in lichen, and up to 100 ppm in black spruce and willow leaves (13). Background levels of arsenic in soil approximately 80 kilometres from Yellowknife have been found to be approximately 25 ppm (14). Road-dust samples contain from 20-200 ppm (14).

Vegetables in the area seem to contain far less arsenic than the soil in which they grow (this is consistent with results of studies conducted in other areas) and arsenic levels in garden vegetables in Yellowknife do not appear to indicate heavy contamination. Vegetables do not have a significant arsenic content even when grown in soils containing high concentrations of applied arsenic trioxide (10). In addition, there appears to be little chance that animals would be poisoned by consuming plants containing arsenic residues taken up from contaminated soils, because plant injury occurs before toxic concentrations could build up. Nevertheless, surface contamination of plants due to heavy arsenic fall-out could present a potential hazard to ruminants (10).

DAN BILLING

FINAL REPORT

CANADIAN PUBLIC HEALTH ASSOCIATION
TASK FORCE ON ARSENIC
Yellowknife, Northwest Territories

1977

T.A.C.
Memo

Northwest Territories Water Board
Technical Advisory Committee

April 2, 1998

To: Distribution

File: TAC General
N1L2-0043

From: Jim McCaul
Head,
Regulatory Approvals Section

Subject: **Royal Oak Mines Inc. - Giant Minesite**
Evaluation of Surface Contamination Data - March 1998

Enclosed for your review and comment is a copy of the above mentioned report submitted by Royal Oak Mines Inc.

In the first recommendation of the report (page 22), it states that "it will be necessary have regulatory and public involvement in the selection of appropriate control sites since such a control site would then be used for all future assessments in the Yellowknife area." I feel this is an important issue and a general TAC meeting will be scheduled shortly after this review period to discuss the topic of surface contamination, remediation criteria and control sites for the Yellowknife area. You will be notified of this meeting once it has been scheduled.

Please provide any comments you may have on the report on or before **May 8, 1998.** If no response if received by this date we will assume that you have no concerns.

If you have any concerns or questions, please do not hesitate to contact me at (867) 669-2653, or Sevn Bohnet, Project Coordinator, at (867) 669-2696.

for/
J. McCaul(403-669-2653) (fax-669-2716)
(e-mail "mccaulj@inac.gc.ca")

cc: D. Milburn
B. Latham
S. Bohnet
Yellowknife District

Distribution List

L. Dyer	- GNWT/RWED
T. Stephenson	- DFO
S. Harbicht	- EP
F. Hamilton	- GNWT/Health
B. Williams	- MACA, Lands
G. Craig	- City of Yellowknife
S. Wong	- W.C.B./MS
	- Yellowknives Dene First Nation
C. Paul	- North Slave Metis Association

Agree with
recommendations
3, 4, 5

Disagree w/ 1 & 2

More details on risk
when how the
assessment will be conducted

Risk assessment should
consider ecological receptors
in addition to human
receptors

S. Chounaird - NWT Medical Association
E. Berthelet - Canadian Public Health Association
- Ecology North

APPENDIX A

1994 TOTAL ARSENIC ANALYTICAL DATA

Giant Mine – Surface Contamination Study

Soil Sampling Analytical Results

Sample Location	Station #	Sample Tag #	Depth Below Surface m	Total Cyanide ppm	Paste pH	Ammonia ppm N	Copper mg/kg	Nickel mg/kg	Zinc mg/kg	Arsenic mg/kg	Lead mg/kg	Oil & Grease ug/g
CCME Remediation Criteria				500 mg/kg	6 to 8	NA	500 mg/kg	500 mg/kg	1500 mg/k	50 mg/kg	1000 mg/k	5000 ug/g
Behind A2 Open Pit	S1	35251	surface	< 1	6.9	< 1.00	43	42	96	22.0	18	90
	S1	35252	0.2	< 1	7.0	9.00	39	42	95	9.8	20	130
Behind A2 Open Pit	S2	35253	surface	28	7.5	< 1.00	56	56	359	2380	214	300
	S2	35254	0.2	7	7.8	< 1.00	37	37	101	350	35	110
Near Yacht Club	S3	35255	surface	3	8.3	< 1.00	76	76	216	3240	73	140
	S3	35256	0.2	3	8.1	< 1.00	77	77	214	3580	54	90
Between A1 & A2 Open Pits	S4	35257	surface	1	5.2	11.00	45	45	92	52.0	17	130
	S4	35258	0.2	< 1	5.8	31.0	42	42	91	22.0	19	130
Behind A Shaft	S5	35259	surface	< 1	7.8	< 1.00	40	40	60	53.0	15	110
	S5	35260	0.2	< 1	8.2	< 1.00	56	56	80	520	22	70
Near Townsite	S6	35261	surface	< 1	7.7	< 1.00	71	58	138	2000	44	80
	S6	35262	0.2	< 1	7.9	< 1.00	68	70	178	3300	68	70
Tanks on Road to A Shaft	S7	35263	surface	< 1	7.5	< 1.00	45	42	93	280	22	130
	S7	35264	0.2	1	7.9	< 1.00	66	54	99	830	14	280
Behind A1 Open Pit	S8	35265	surface	1	7.8	< 1.00	38	39	80	120	18	120
	S8	35266	0.2	1	8.0	< 1.00	49	38	78	270	23	130
Near A1 Open Pit	S9	35267	surface	1	7.7	< 1.00	62	50	95	330	15	390
	S9	35268	0.2	2	7.7	< 1.00	56	42	88	590	17	140
Gowganda Yard	S10	35269	surface	1	7.5	10.0	57	29	60	290	14	150
	S10	35270	0.2	1	7.4	11.0	44	36	75	360	16	170
Back Road	S11	35271	surface	< 1	6.1	43.0	36	16	56	260	20	1860
	S11	35272	0.2	< 1	7.0	4.0	26	30	58	40	14	160
Gowganda Yard	S12	35273	surface	1	7.9	< 1.00	1280	72	196	1770	158	220
	S12	35274	0.2	< 1	8.0	< 1.00	131	68	104	680	34	110
Near Pit Shop	S13	35275	surface	< 1	7.7	< 1.00	47	44	87	370	16	160
	S13	35276	0.2	< 1	7.3	9.0	44	45	84	540	22	250
Behind #7 Dam	S14	35277	surface	1	7.0	26.0	65	21	66	140	14	1070
	S14	35278	0.2	< 1	7.1	10.0	27	29	70	81	16	80
Brock Quarry	S15	35279	surface	< 1	7.6	< 1.00	34	32	69	25	16	20
	S15	35280	0.2	< 1	7.8	< 1.00	33	31	66	17	20	120
Behind South Pond	S16	35281	surface	1	7.1	24.0	62	76	220	420	28	450
	S16	35282	0.2	< 1	7.0	< 1.00	20	37	71	130	12	180
Ingraham Trail (behind mill)	S17	35283	surface	< 1	7.2	< 1.00	35	38	77	220	22	150
	S17	35284	0.2	< 1	7.0	7.0	30	34	70	120	18	150
UBC Quarry	S18	35285	surface	< 1	7.6	< 1.00	76	48	83	320	15	220
	S18	35286	0.2	< 1	7.7	< 1.00	60	50	87	560	15	120
Old PCB Storage Building	S19	35287	surface	< 1	8.1	< 1.00	90	70	142	3180	43	230
	S19	35288	0.2	< 1	8.2	< 1.00	72	72	250	3640	153	130
TRP Plant Site	S20	35289	surface	2	5.7	15.0	34	34	60	200	18	250
	S20	35290	0.2	1	5.9	13.0	35	35	60	160	17	240
TRP Plant Site	S21	35291	surface	< 1	8.0	< 1.00	166	91	124	430	22	130
	S21	35292	0.2	< 1	6.5	8.0	48	38	55	68	22	190
Polishing Pond	S22	35293	surface	< 1	6.9	22.0	64	38	93	400	1220	570
	S22	35294	0.2	< 1	6.9	8.0	60	42	72	240	1330	210

Giant Mine – Surface Contamination Study

Soil Sampling Analytical Results

Sample Location	Station #	Sample Tag #	Depth Below Surface m	Total Cyanide ppm	Paste pH	Ammonia ppm N	Copper mg/kg	Nickel mg/kg	Zinc mg/kg	Arsenic mg/kg	Lead mg/kg	Oil & Grease ug/g
CCME Remediation Criteria				500 mg/kg	6 to 8	NA	500 mg/kg	500 mg/kg	1500 mg/k	50 mg/kg	1000 mg/k	5000 ug/g
Carbon Columns	S23	35295	surface	1	7.9	< 1.00	38	38	86	140	214	100
	S23	35296	0.2	2	7.9	< 1.00	44	43	262	810	186	100
B3 Open Pit Area	S24	35297	surface	54	8.1	< 1.00	144	70	540	3100	350	90
	S24	35298	0.2	75	7.8	13.0	209	63	478	2160	274	150
Pocket Lake Area	S25	35299	surface	2	4.9	17.0	18	23	46	560	22	490
	S25	35300	0.2	1	4.9	8.0	22	30	43	140	18	140
Near North Pond	S26	35301	surface	1	7.4	6.0	37	35	74	114	22	110
	S26	35302	0.2	1	7.4	< 1.00	36	36	74	10	19	160
North Pond to GSL	S27	35303	surface	133	6.7	30.0	976	58	830	2020	24	570
	S27	35304	0.2	28	6.7	6.0	16	14	106	280	16	100
Near Dam #3	S28	35305	surface	36	8.0	6.0	70	54	139	530	40	170
	S28	35306	0.2	41	7.9	< 1.00	80	55	147	680	54	170
Near Northwest Pond	S29	35307	surface	11	6.8	10.0	29	41	68	590	12	530
	S29	35308	0.2	7	6.7	4.0	32	40	54	460	16	880
ICG Tank Farm	S30	35309	surface	3	8.2	< 1.00	93	81	102	2940	9	1970
	S30	35310	0.2	< 1	7.0	< 1.00	62	54	86	2860	12	750
Behind NW Pond	S31	35311	surface	3	7.4	< 1.00	42	30	42	760	20	1210
	S31	35312	0.2	2	7.0	6.0	36	39	62	210	18	320
Hazardous Waste Dump Site	S32	35313	surface	2	8.6	< 1.00	240	82	255	190	1570	10300
	S32	35314	0.2	4	8.6	< 1.00	167	82	164	2340	534	2470
Akaitcho	S33	35315	surface	6	5.3	37.0	28	12	24	210	54	6200
	S33	35316	0.2	4	6.5	17.0	96	31	37	109	15	570
Akaitcho	S34	35317	surface	4	7.8	< 1.00	30	29	46	160	20	160
	S34	35318	0.2	4	8.0	< 1.00	79	66	110	1160	17	180
Near 22B Dam	S35	35319	surface	9	8.1	< 1.00	87	75	146	2240	20	300
	S35	35320	0.2	14	8.0	< 1.00	86	67	132	1230	20	180
Near Administration Building	S36	35321	surface	14	7.0	10.0	52	43	116	1180	52	590
	S36	35322	0.2	10	7.6	< 1.00	32	28	44	510	17	120
Fuel Tanks across from C Dry	S37	35323	surface	10	7.6	< 1.00	38	38	75	1020	28	9640
	S37	35324	0.2	12	7.7	< 1.00	29	34	57	250	20	7590
Fuel Tanks across from C Dry	S38	35325	surface	8	6.8	< 1.00	28	32	60	270	20	47100
	S38	35326	0.2	2	7.7	< 1.00	89	50	200	1280	40	14200
Main Gate Area	S39	35327	surface	< 1	8.4	< 1.00	101	72	149	2440	43	2000
	S39	35328	0.2	1	8.2	< 1.00	102	74	152	3260	55	1900
Near Catchbasin at C Dry	S40	35329	surface	< 1	8.0	< 1.00	152	82	289	4400	87	3870
	S40	35330	0.2	1	7.7	< 1.00	63	60	165	3400	45	11300
Near C Dry	S41	35331	surface	4	8.2	< 1.00	108	76	147	1720	31	900
	S41	35332	0.2	2	7.8	< 1.00	104	71	132	2340	138	1130
Diesel Fuel Storage	S42	35333	surface	2	8.2	< 1.00	97	78	134	2880	27	410
	S42	35334	0.2	4	8.4	19.0	111	79	100	1080	12	100
Diesel Fuel Storage	S43	35335	surface	3	8.1	< 1.00	87	84	168	2320	39	440
	S43	35336	0.2	1	8.2	< 1.00	107	76	155	2100	57	90

Giant Mine – Surface Contamination Study

Soil Sampling Analytical Results

Sample Location	Station #	Sample Tag #	Depth Below Surface m	Total Cyanide ppm	Paste pH	Ammonia ppm N	Copper mg/kg	Nickel mg/kg	Zinc mg/kg	Arsenic mg/kg	Lead mg/kg	Oil & Grease ug/g
CCME Remediation Criteria				500 mg/kg	6 to 8	NA	500 mg/kg	500 mg/kg	1500 mg/kg	50 mg/kg	1000 mg/kg	5000 ug/g
Near C Dry	S44	35337	surface	3	8.3	< 1.00	72	66	114	730	23	1390
	S44	35338	0.2	3	8.4	< 1.00	95	75	123	1830	24	890
Rail	S45	35339	surface	< 1	8.4	< 1.00	94	76	158	2000	39	1450
	S45	35340	0.2	3	8.4	< 1.00	109	70	118	1150	14	430
Old Electrical Shop Area	S46	35341	surface	5	8.4	< 1.00	116	77	183	2900	52	9050
	S46	35342	0.2	4	8.6	< 1.00	87	72	194	3320	44	12000
Near Hoist Room	S47	35343	surface	1	8.0	< 1.00	50	52	208	430	18	140
	S47	35344	0.2	2	8.0	< 1.00	80	66	154	1730	39	70
Hoist – C Shaft	S48	35345	surface	2	8.2	< 1.00	99	82	136	1710	34	60
	S48	35346	0.2	3	8.3	< 1.00	95	90	138	2000	50	50
Crusher	S49	35347	surface	5	8.1	< 1.00	98	85	304	7920	156	140
	S49	35348	0.2	5	8.2	< 1.00	100	79	172	3760	66	150
New Electrical Shop	S50	35349	surface	4	8.4	< 1.00	84	81	112	1130	37	5450
	S50	35350	0.2	3	8.1	< 1.00	74	67	106	840	21	220
Warehouse	S51	35351	surface	4	7.8	< 1.00	93	65	116	1060	29	930
	S51	35352	0.2	4	8.3	< 1.00	96	65	133	1440	94	530
BC across from Crusher	S52	35353	surface	4	8.2	< 1.00	100	72	151	1660	23	80
	S52	35354	0.2	4	8.1	< 1.00	92	76	148	1900	16	90
Open Pit Crusher	S53	35355	surface	5	9.9	< 1.00	2220	1760	770	5680	258	270
	S53	35356	0.2	5	9.1	< 1.00	180	146	220	3080	124	70
Open Pit Crusher	S54	35357	surface	1	8.3	< 1.00	146	93	416	9760	215	30000
	S54	35358	0.2	< 1	8.5	< 1.00	158	77	292	8080	147	1960
Crusher	S55	35359	surface	< 1	8.1	< 1.00	128	74	281	5040	187	550
	S55	35360	0.2	2	8.2	< 1.00	102	82	203	2580	64	230
BC – Crusher	S56	35361	surface	2	8.0	< 1.00	104	71	200	3280	89	110
	S56	35362	0.2	2	8.1	< 1.00	87	70	137	2600	28	450
MEG	S57	35363	surface	2	6.8	15.0	36	70	88	2140	50	270
	S57	35364	0.2	2	7.5	< 1.00	26	30	42	230	16	90
MEG	S58	35365	surface	1	5.1	52.0	277	37	160	6000	119	2200
	S58	35366	0.2	4	6.0	9.0	23	30	54	1130	22	90
BC Screenhouse	S59	35367	surface	4	8.1	< 1.00	39	35	92	810	30	80
	S59	35368	0.2	4	8.2	< 1.00	64	76	106	100	5	90
Southwest Mill	S60	35369	surface	9	8.2	< 1.00	96	80	284	3260	71	170
	S60	35370	0.2	6	8.4	< 1.00	91	74	221	4160	49	70
BC Refinery	S61	35371	surface	4	7.7	< 1.00	48	34	90	1090	48	190
	S61	35372	0.2	4	8.2	< 1.00	80	71	129	1450	22	80
Refinery	S62	35373	surface	5	7.3	11.0	56	45	118	1210	20	220
	S62	35374	0.2	3	8.2	< 1.00	38	42	75	130	15	160
Assay Lab	S63	35375	surface	3	8	< 1.00	103	75	348	11800	227	140
	S63	35376	0.2	2	8.6	< 1.00	90	78	270	7440	154	110
Fuel Storage – Lumber Yard	S64	35377	surface	< 1	7.8	< 1.00	121	79	247	5360	96	160
	S64	35378	0.2	< 1	7.2	< 1.00	54	36	75	860	33	140
Fuel Storage – Lumber Yard	S65	35379	surface	4	7.3	< 1.00	38	38	90	270	22	190
	S65	35380	0.2	5	7.8	< 1.00	60	49	94	3760	20	340

Giant Mine – Surface Contamination Study

Soil Sampling Analytical Results

Sample Location	Station #	Sample Tag #	Depth Below Surface m	Total Cyanide ppm	Paste pH	Ammonia ppm N	Copper mg/kg	Nickel mg/kg	Zinc mg/kg	Arsenic mg/kg	Lead mg/kg	Oil & Grease ug/g
CCME Remediation Criteria				500 mg/kg	6 to 8	NA	500 mg/kg	500 mg/kg	1500 mg/kg	50 mg/kg	1000 mg/kg	5000 ug/g
Fuel Storage – Lumber Yard	S66	35381	surface	5	5.8	10.0	28	28	63	1430	32	1540
	S66	35382	0.2	5	6.1	5.0	20	29	46	590	19	2570
Fuel Storage – Lumber Yard	S67	35383	surface	3	6.8	7.0	37	34	70	990	24	85400
	S67	35384	0.2	2	5.8	11.0	32	27	59	1460	21	112000
Fuel Storage – Lumber Yard	S68	35385	surface	3	7.6	4.0	51	45	100	430	27	440
	S68	35386	0.2	< 1	7.8	< 1.00	54	52	108	1160	27	960
Fuel Storage – Lumber Yard	S69	35387	surface	< 1	8.0	< 1.00	109	69	125	1640	23	130
	S69	35388	0.2	6	8.3	< 1.00	126	72	132	1790	23	50
Lumber Yard	S70	35389	surface	6	8.4	< 1.00	94	101	186	1600	33	13300
	S70	35390	0.2	5	7.0	< 1.00	105	108	145	1740	20	220
Lumber Yard	S71	35391	surface	2	7.8	< 1.00	524	88	193	5280	101	1400
	S71	35392	0.2	2	8.2	< 1.00	96	88	216	3460	134	110
Lumber Yard Stack	S72	35393	surface	2	8.2	< 1.00	96	72	172	2320	62	760
	S72	35394	0.2	1	8.2	< 1.00	98	78	259	5600	106	160
Quonset Hut	S73	35395	surface	2	8.1	< 1.00	149	69	261	2800	113	70
	S73	35396	0.2	1	8.3	< 1.00	119	56	264	870	61	30
Quonset Hut	S74	35397	surface	4	9.0	< 1.00	1080	65	174	2680	32	380
	S74	35398	0.2	3	8.7	< 1.00	160	75	134	2080	9	110
Mill Yard	S75	35399	surface	7	8.1	5.0	144	85	284	2340	64	970
	S75	35400	0.2	2	8.4	< 1.00	99	77	214	2320	78	240
Refinery Sump	S76	35401	surface	1	5.8	23.0	29	26	52	810	18	700
	S76	35402	0.2	2	6.2	15.0	33	30	54	490	16	510
Refinery Sump	S77	35403	surface	2	7.7	< 1.00	36	31	74	390	30	490
	S77	35404	0.2	< 1	7.9	< 1.00	80	46	124	740	23	430
Behind AC	S78	35405	surface	< 1	8.0	< 1.00	65	58	112	1720	60	780
	S78	35406	0.2	< 1	8.3	< 1.00	90	80	140	2140	43	150
Roaster	S79	35407	surface	< 1	6.7	4.0	38	32	72	1180	21	240
	S79	35408	0.2	< 1	7.0	18.0	42	26	60	940	17	420
BC Roaster	S80	35409	surface	3	6.5	12.0	31	28	61	650	16	310
	S80	35410	0.2	< 1	6.8	10.0	32	29	64	170	14	210
Stack	S81	35411	surface	< 1	8.1	< 1.00	79	64	116	530	13	130
	S81	35412	0.2	< 1	8.2	< 1.00	103	64	129	410	29	190
Stack	S82	35413	surface	< 1	8.3	< 1.00	110	90	124	1680	32	220
	S82	35414	0.2	< 1	8.4	< 1.00	99	86	117	1460	25	70
Stack	S83	35415	surface	11	7.6	< 1.00	256	104	600	14200	650	200
	S83	35416	0.2	2	7.6	< 1.00	73	56	132	3780	82	100
Baghouse	S84	35417	surface	1	7.6	6.0	38	36	85	1360	27	120
	S84	35418	0.2	1	7.5	5.0	33	34	71	410	19	100
Stack	S85	35419	surface	1	7.4	< 1.00	48	48	103	1490	39	110
	S85	35420	0.2	1	7.8	5.0	62	43	90	1300	34	90
Stack	S86	35421	surface	1	8.2	< 1.00	106	97	124	2120	19	60
	S86	35422	0.2	1	8.1	< 1.00	128	81	213	610	11	50
Stack	S87	35423	surface	1	6.0	58.0	39	21	129	8400	98	2900
	S87	35424	0.2	< 1	6.5	9.0	23	25	58	440	17	80

Giant Mine – Surface Contamination Study

Soil Sampling Analytical Results

Sample Location	Station #	Sample Tag #	Depth Below Surface m	Total Cyanide ppm	Paste pH	Ammonia ppm N	Copper mg/kg	Nickel mg/kg	Zinc mg/kg	Arsenic mg/kg	Lead mg/kg	Oil & Grease ug/g
CCME Remediation Criteria				500 mg/kg	6 to 8	NA	500 mg/kg	500 mg/kg	1500 mg/kg	50 mg/kg	1000 mg/kg	5000 ug/g
Stack	S88	35425	surface	< 1	8.4	4.0	79	68	272	2100	136	150
	S88	35426	0.2	1	7.1	< 1.00	82	72	170	2380	63	60
B Shaft	S89	35427	surface	1	7.3	< 1.00	24	24	45	135	22	80
	S89	35428	0.2	1	7.4	< 1.00	29	26	46	58	16	50
B Shaft	S90	35429	surface	1	6.2	< 1.00	79	58	143	1100	32	90
	S90	35430	0.2	< 1	7.3	< 1.00	84	41	112	780	62	190
B Shaft	S91	35431	surface	1	7.2	4.0	54	45	261	1230	370	2900
	S91	35432	0.2	< 1	7.3	< 1.00	26	25	42	220	21	200
Control Site – Yellowknife	S92	35433	surface	< 1	9.2	< 1.00	41	39	66	160	25	880
	S92	35434	0.2	< 1	7.4	5.0	36	30	60	100	32	120
Control Site – Yellowknife	S93	35435	surface	< 1	7.2	11.0	26	28	53	100	45	240
	S93	35436	0.2	1	7.8	< 1.00	8	14	29	36	19	80
Control Site – Yelowknife	S94	35437	surface	< 1	7.1	31.0	31	15	34	140	27	3200
	S94	35438	0.2	1	7.5	< 1.00	13	21	33	13	16	40

Giant Mine – Surface Contamination Study

Soil Sampling Analytical Results
Total Arsenic Concentrations in Excess of the Study Average of 2,001 ppm

Sample Location	Station #	Surface Arsenic ppm	0.2 M Depth Arsenic ppm
Near Yacht Club	S3	3240	3580
Near Townsite	S6	2000	3300
Old PCB Storage Building	S19	3180	3640
B3 Open Pit Area	S24	3100	2160
North Pond to GSL	S27	2020	280
ICG Tank Farm	S30	2940	2860
Near 22B Dam	S35	2240	1230
Main Gate Area	S39	2440	3260
Near Catchbasin at C Dry	S40	4400	3400
Diesel Fuel Storage	S42	2880	1080
Diesel Fuel Storage	S43	2320	2100
Rail	S45	2000	1150
Old Electrical Shop Area	S46	2900	3320
Crusher	S49	7920	3760
Open Pit Crusher	S53	5680	3080
Open Pit Crusher	S54	9760	8080
Crusher	S55	5040	2580
BC – Crusher	S56	3280	2600
MEG	S57	2140	230
MEG	S58	6000	1130
Southwest Mill	S60	3260	4160
Assay Lab	S63	11800	7440
Fuel Storage – Lumber Yard	S64	5360	860
Lumber Yard	S71	5280	3460
Lumber Yard Stack	S72	2320	5600
Quonset Hut	S73	2800	870
Quonset Hut	S74	2680	2080
Mill Yard	S75	2340	2320
Stack	S83	14200	3780
Stack	S86	2120	610
Stack	S87	8400	440
Stack	S88	2100	2380
Average		4317	2713

Giant Mine – Surface Contamination Study

Precipitation Runoff Sampling Analytical Results

Sample Location	Station #	Sampling Date	Total Cyanide ppm	Total Arsenic ppm	Total Copper ppm	Total Lead ppm	Total Nickel ppm	Total Zinc ppm	pH	Total Ammonia ppm N	Oil & Grease ppm
Giant Water License Limits – Avg Conc			0.80	0.50	0.30	0.20	0.50	0.20	Between		5.00
Giant Water License Limits – Max Grab			1.60	1.00	0.60	0.40	1.00	0.40	6.0 and 9.5	19.5	
CCME Remediation Criteria											
Freshwater – Aquatic Life			–	0.05	0.002–0.004	0.001 – 0.00	0.025–0.15	0.03	6.5 and 9.0	1.37 – 2.2	
Drinking Water			0.02	0.025	1.00	0.01	–	5.00	6.5 and 8.5	–	
Btwn Hoistroom & Ingraham Trail	R1	July 18	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Sept 22	<0.01	0.13	<0.02	<0.02	0.02	0.02	7.40	0.28	0.50
Btwn Surf Crusher & Ingraham Trail	R2	July 18	0.03	0.20	0.03	0.02	0.02	0.03	7.60	NA	NA
		Sept 22	<0.01	0.15	0.02	<0.02	0.02	0.02	7.50	0.76	0.08
Btwn Surf Crusher & Baker Creek	R3	July 18	<0.02	0.22	<0.02	<0.02	<0.02	<0.02	7.40	1.30	0.05
		Sept 22	0.14	0.16	0.02	0.02	<0.02	<0.02	7.40	1.15	0.04
Btwn Ore Stockpile & Baker Creek	R4	July 18	0.04	0.76	<0.02	<0.02	0.02	0.02	7.60	32.00	0.04
		Sept 22	<0.01	0.14	<0.02	<0.02	<0.02	<0.02	7.60	4.00	0.02
Btwn Refinery & Baker Creek	R5	July 18	0.02	0.72	0.02	0.02	<0.02	<0.02	7.90	0.48	<0.02
		Sept 22	<0.01	0.28	<0.02	<0.02	<0.02	<0.02	7.60	0.29	0.03
Btwn Roaster & Baker Creek	R6	July 18	<0.02	1.11	0.02	0.02	<0.02	<0.02	7.80	0.27	<0.02
		Sept 22	NA	NA	NA	NA	NA	NA	NA	NA	NA
Btwn Cottrell & Ingraham Trail	R7	July 18	0.03	1.02	0.02	<0.02	0.02	0.02	7.20	0.52	<0.02
		Sept 22	NA	NA	NA	NA	NA	NA	NA	NA	NA
Under Tlgs Line Trestle at Quonset	R8	July 18	0.04	0.54	0.04	0.02	0.02	0.02	7.95	0.23	<0.02
		Sept 22	<0.01	0.17	0.02	<0.02	<0.02	<0.02	7.90	0.43	0.03
Lumber Yard	R9	July 18	0.03	0.17	0.03	0.02	0.05	0.04	7.95	0.21	<0.02
		Sept 22	0.01	0.51	<0.02	<0.02	<0.02	<0.02	7.30	0.23	<0.02
"A" Boiler Towards Baker Creek	R10	July 18	0.02	0.48	0.04	0.02	0.04	0.04	7.60	0.60	0.09
		Sept 22	<0.01	0.46	<0.02	<0.02	<0.02	<0.02	8.00	0.90	0.04
Btwn "A" Shaft & Baker Creek	R11	July 18	0.02	0.37	0.03	0.02	<0.02	0.02	7.60	0.28	0.05
		Sept 22	<0.01	0.38	<0.02	<0.02	<0.02	<0.02	7.40	0.30	<0.02
Btwn "A" Shaft Oil Tnks & Ingraham Tra	R12	July 18	0.02	0.39	0.06	0.03	0.02	0.02	7.00	0.40	0.05
		Sept 22	<0.01	0.18	<0.02	<0.02	<0.02	<0.02	7.00	0.60	0.04
Road past B1 Pit towards Ingraham Tr	R13	July 18	0.21	0.30	0.02	0.02	0.03	0.02	8.15	0.21	0.02
		Sept 22	<0.01	0.52	<0.02	<0.02	<0.02	<0.02	7.10	0.22	0.08
Above A1 Open Pit	R14	July 18	<0.02	0.40	0.09	0.04	0.04	0.02	7.90	0.11	<0.02
		Sept 22	<0.01	0.39	<0.02	<0.02	<0.02	<0.02	7.40	0.38	0.04
Btwn UBC Quarry & Ingraham Trail	R15	July 18	<0.02	0.52	0.04	0.02	0.04	0.02	7.60	0.33	0.05
		Sept 22	<0.01	0.41	<0.02	<0.02	<0.02	<0.02	7.50	0.78	0.06
Average			0.02	0.37	0.02	0.01	0.01	0.01	6.81	1.58	0.04

Giant Mine – Surface Contamination Study

Precipitation Runoff Sampling Results for July 18,1994

Sample Location	Station #	Sampling Date	Total Cyanide ppm	Total Arsenic ppm	Total Copper ppm	Total Lead ppm	Total Nickel ppm	Total Zinc ppm	pH	Total Ammonia ppm N	Oil & Grease ppm
Giant Water License Limits – Avg Conc			0.80	0.50	0.30	0.20	0.50	0.20	Between		5.00
Giant Water License Limits – Max Grab			1.60	1.00	0.60	0.40	1.00	0.40	6.0 and 9.5	19.5	
CCME Remediation Criteria											
Freshwater – Aquatic Life			–	0.05	0.002–0.004	0.001 – 0.00	0.025–0.150	0.03	6.5 and 9.0	1.37 – 2.20	
Drinking Water			0.02	0.025	1.00	0.01	–	5.00	6.5 and 8.5	–	
Btwn Hoistroom & Ingraham Trail	R1	July 18	NA	NA	NA	NA	NA	NA	NA	NA	NA
Btwn Surf Crusher & Ingraham Trail	R2	July 18	0.03	0.20	0.03	0.02	0.02	0.03	7.60	NA	NA
Btwn Surf Crusher & Baker Creek	R3	July 18	<0.02	0.22	<0.02	<0.02	<0.02	<0.02	7.40	1.30	0.05
Btwn Ore Stockpile & Baker Creek	R4	July 18	0.04	0.76	<0.02	<0.02	0.02	0.02	7.60	32.00	0.04
Btwn Refinery & Baker Creek	R5	July 18	0.02	0.72	0.02	0.02	<0.02	<0.02	7.90	0.48	<0.02
Btwn Roaster & Baker Creek	R6	July 18	<0.02	1.11	0.02	0.02	<0.02	<0.02	7.80	0.27	<0.02
Btwn Cottrell & Ingraham Trail	R7	July 18	0.03	1.02	0.02	<0.02	0.02	0.02	7.20	0.52	<0.02
Under Tlgs Line Trestle at Quonset	R8	July 18	0.04	0.54	0.04	0.02	0.02	0.02	7.95	0.23	<0.02
Lumber Yard	R9	July 18	0.03	0.17	0.03	0.02	0.05	0.04	7.95	0.21	<0.02
"A" Boiler Towards Baker Creek	R10	July 18	0.02	0.48	0.04	0.02	0.04	0.04	7.60	0.60	0.09
Btwn "A" Shaft & Baker Creek	R11	July 18	0.02	0.37	0.03	0.02	<0.02	0.02	7.60	0.28	0.05
Btwn "A" Shaft Oil Tnks & Ingraham Tra	R12	July 18	0.02	0.39	0.06	0.03	0.02	0.02	7.00	0.40	0.05
Road past B1 Pit towards Ingraham Tr	R13	July 18	0.21	0.30	0.02	0.02	0.03	0.02	8.15	0.21	0.02
Above A1 Open Pit	R14	July 18	<0.02	0.40	0.09	0.04	0.04	0.02	7.90	0.11	<0.02
Btwn UBC Quarry & Ingraham Trail	R15	July 18	<0.02	0.52	0.04	0.02	0.04	0.02	7.60	0.33	0.05
Average			0.03	0.48	0.03	0.02	0.02	0.02	7.15	2.46	0.02

Giant Mine – Surface Contamination Study

Precipitation Runoff Sampling Results for September 22,1994

Sample Location	Station #	Sampling Date	Total Cyanide ppm	Total Arsenic ppm	Total Copper ppm	Total Lead ppm	Total Nickel ppm	Total Zinc ppm	pH	Total Ammonia ppm N	Oil & Grease ppm
Giant Water License Limits – Avg Conc			0.80	0.50	0.30	0.20	0.50	0.20	Between		5.00
Giant Water License Limits – Max Grab			1.60	1.00	0.60	0.40	1.00	0.40	6.0 and 9.5	19.5	
CCME Remediation Criteria											
Freshwater – Aquatic Life			–	0.05	0.002–0.00	0.001 – 0.00	0.025–0.15	0.03	6.5 and 9.0	1.37 – 2.2	
Drinking Water			0.02	0.025	1.00	0.01	–	5.00	6.5 and 8.5	–	
Btwn Hoistroom & Ingraham Trail	R1	Sept 22	<0.01	0.13	<0.02	<0.02	0.02	0.02	7.40	0.28	0.50
Btwn Surf Crusher & Ingraham Trail	R2	Sept 22	<0.01	0.15	0.02	<0.02	0.02	0.02	7.50	0.76	0.08
Btwn Surf Crusher & Baker Creek	R3	Sept 22	0.14	0.16	0.02	0.02	<0.02	<0.02	7.40	1.15	0.04
Btwn Ore Stockpile & Baker Creek	R4	Sept 22	<0.01	0.14	<0.02	<0.02	<0.02	<0.02	7.60	4.00	0.02
Btwn Refinery & Baker Creek	R5	Sept 22	<0.01	0.28	<0.02	<0.02	<0.02	<0.02	7.60	0.29	0.03
Btwn Roaster & Baker Creek	R6	Sept 22	NA	NA	NA	NA	NA	NA	NA	NA	NA
Btwn Cottrell & Ingraham Trail	R7	Sept 22	NA	NA	NA	NA	NA	NA	NA	NA	NA
Under Tlgs Line Trestle at Quonset	R8	Sept 22	<0.01	0.17	0.02	<0.02	<0.02	<0.02	7.90	0.43	0.03
Lumber Yard	R9	Sept 22	0.01	0.51	<0.02	<0.02	<0.02	<0.02	7.30	0.23	<0.02
"A" Boiler Towards Baker Creek	R10	Sept 22	<0.01	0.46	<0.02	<0.02	<0.02	<0.02	8.00	0.90	0.04
Btwn "A" Shaft & Baker Creek	R11	Sept 22	<0.01	0.38	<0.02	<0.02	<0.02	<0.02	7.40	0.30	<0.02
Btwn "A" Shaft Oil Tnks & Ingraham Tra	R12	Sept 22	<0.01	0.18	<0.02	<0.02	<0.02	<0.02	7.00	0.60	0.04
Road past B1 Pit towards Ingraham Tr	R13	Sept 22	<0.01	0.52	<0.02	<0.02	<0.02	<0.02	7.10	0.22	0.08
Above A1 Open Pit	R14	Sept 22	<0.01	0.39	<0.02	<0.02	<0.02	<0.02	7.40	0.38	0.04
Btwn UBC Quarry & Ingraham Trail	R15	Sept 22	<0.01	0.41	<0.02	<0.02	<0.02	<0.02	7.50	0.78	0.06
Average			0.01	0.26	0.00	0.00	0.00	0.00	6.47	0.69	0.06

Giant Mine – Surface Contamination Study

Standing Water Sampling Results for July 18,1994

Sample Location	Station #	Sampling Date	Total Cyanide ppm	Total Arsenic ppm	Total Copper ppm	Total Lead ppm	Total Nickel ppm	Total Zinc ppm	pH	Total Ammonia ppm N	Oil & Grease ppm
Giant Water License Limits – Avg Conc			0.80	0.50	0.30	0.20	0.50	0.20	Between		5.00
Giant Water License Limits – Max Grab			1.60	1.00	0.60	0.40	1.00	0.40	6.0 and 9.5	19.5	
CCME Remediation Criteria											
Freshwater – Aquatic Life			–	0.05	0.002–0.004	0.001 – 0.00	0.025–0.150	0.03	6.5 and 9.0	1.37 – 2.20	
Drinking Water			0.02	0.025	1.00	0.01	–	5.00	6.5 and 8.5	–	
Pond Btwn Rec Hall and A1 Open Pit	W1	July 18	<0.02	0.08	<0.02	<0.02	0.03	0.02	7.4	0.46	0.05
Pond on Back Rd Btwn Townsite & Mine	W2	July 18	<0.02	0.10	<0.02	<0.02	<0.02	0.02	7.60	0.41	0.59
Pond at Junction of Back Rd & MEG Rd	W3	July 18	0.04	0.08	0.02	<0.02	0.04	0.02	7.50	0.35	0.11
Ponds Below Catchbasin #7	W4	July 18	0.02	0.11	0.02	0.02	0.04	0.02	9.05	0.18	0.42
Ponds Below Catchbasin #7	W5	July 18	<0.02	0.09	<0.02	<0.02	<0.02	<0.02	9.00	0.14	1.20
Ponds Below Catchbasin #7	W6	July 18	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	8.05	0.30	0.07
Pond Btwn Central Pond & YK Bay	W7	July 18	0.04	0.08	<0.02	<0.02	<0.02	<0.02	7.50	0.30	0.07
Pond Btwn North Pond & YK Bay	W9	July 18	0.04	0.13	0.02	0.02	<0.02	0.02	8.20	0.78	1.09
Pond Below Dam #3	W10	July 18	0.04	0.12	0.02	0.02	0.02	0.02	8.70	0.15	0.08
Pond Below Dam #3	W11	July 18	<0.02	0.11	<0.02	0.02	<0.02	<0.02	7.60	0.21	0.06
Pond Below Dam #3	W12	July 18	<0.02	0.06	<0.02	<0.02	<0.02	<0.02	7.50	0.18	0.08
Pond Behind Supercrest on Vee Lk Rd	W13	July 18	0.02	0.12	<0.02	<0.02	<0.02	<0.02	7.00	0.45	0.08
Pond Btwn Ingraham Tr &PCB Stor Bldg	W14	July 18	0.04	0.14	<0.02	<0.02	0.02	0.02	7.80	1.20	0.15
Pond Behind UBC Zone Portal	W15	July 18	0.04	0.57	0.02	0.02	0.02	0.02	7.60	0.35	0.19
Average			0.02	0.13	0.01	0.01	0.01	0.01	7.89	0.39	0.30

Giant Mine – Surface Contamination Study

Standing Water Sampling Results for September 27,1994

Sample Location	Station #	Sampling Date	Total Cyanide ppm	Total Arsenic ppm	Total Copper ppm	Total Lead ppm	Total Nickel ppm	Total Zinc ppm	pH	Total Ammonia ppm N	Oil & Grease ppm
Giant Water License Limits – Avg Conc			0.80	0.50	0.30	0.20	0.50	0.20	Between		5.00
Giant Water License Limits – Max Grab			1.60	1.00	0.60	0.40	1.00	0.40	6.0 and 9.5	19.5	
<u>CCME Remediation Criteria</u>											
Freshwater – Aquatic Life			–	0.05	0.002–0.004	0.001 – 0.00	0.025–0.150	0.03	6.5 and 9.0	1.37 – 2.20	
Drinking Water			0.02	0.025	1.00	0.01	–	5.00	6.5 and 8.5	–	
Pond Btwn Rec Hall and A1 Open Pit	W1	Sept 27	<0.01	0.05	0.02	<0.02	0.02	0.02	7.7	0.85	<0.02
Pond on Back Rd Btwn Townsite & Mine	W2	Sept 27	<0.01	0.03	<0.02	<0.02	<0.02	<0.02	7.20	22.00	<0.02
Pond at Junction of Back Rd & MEG Rd	W3	Sept 27	<0.01	0.06	0.02	0.02	0.02	<0.02	7.40	0.33	<0.02
Ponds Below Catchbasin #7	W4	Sept 27	0.06	0.08	0.02	<0.02	0.02	<0.02	9.00	0.24	0.05
Ponds Below Catchbasin #7	W5	Sept 27	<0.01	0.04	<0.02	<0.02	<0.02	<0.02	9.00	0.22	0.02
Ponds Below Catchbasin #7	W6	Sept 27	<0.01	0.02	<0.02	<0.02	<0.02	<0.02	8.30	0.32	<0.02
Pond Btwn Central Pond & YK Bay	W7	Sept 27	<0.01	0.10	0.05	0.02	0.02	0.02	7.60	0.25	<0.02
Pond Btwn North Pond & YK Bay	W9	Sept 27	<0.01	0.22	<0.02	<0.02	<0.02	<0.02	7.40	0.46	<0.02
Pond Below Dam #3	W10	Sept 27	<0.01	0.27	0.05	0.02	0.02	0.02	7.80	0.20	<0.02
Pond Below Dam #3	W11	Sept 27	<0.01	0.18	0.04	<0.02	<0.02	<0.02	7.20	4.20	<0.02
Pond Below Dam #3	W12	Sept 27	<0.01	0.12	0.02	<0.02	<0.02	<0.02	8.00	0.28	<0.02
Pond Behind Supercrest on Vee Lk Rd	W13	Sept 27	<0.01	0.08	0.02	<0.02	<0.02	<0.02	7.20	0.60	<0.02
Pond Btwn Ingraham Tr &PCB Stor Bldg	W14	Sept 27	<0.01	0.22	0.02	<0.02	0.02	<0.02	7.80	1.80	<0.02
Pond Behind UBC Zone Portal	W15	Sept 27	<0.01	0.05	0.15	0.02	0.04	0.03	7.50	0.32	<0.02
Average			0.00	0.11	0.03	0.01	0.01	0.01	7.79	2.29	0.01

Giant Mine – Surface Contamination Study

Standing Water Sampling Analytical Results

Sample Location	Station #	Sampling Date	Total Cyanide ppm	Total Arsenic ppm	Total Copper ppm	Total Lead ppm	Total Nickel ppm	Total Zinc ppm	pH	Total Ammonia ppm N	Oil & Grease ppm
Giant Water License Limits – Avg Conc			0.80	0.50	0.30	0.20	0.50	0.20	Between		5.00
Giant Water License Limits – Max Grab			1.60	1.00	0.60	0.40	1.00	0.40	6.0 and 9.5	19.5	
CCME Remediation Criteria											
Freshwater – Aquatic Life			–	0.05	0.002–0.004	0.001 – 0.00	0.025–0.150	0.03	6.5 and 9.0	1.37 – 2.20	
Drinking Water			0.02	0.025	1.00	0.01	–	5.00	6.5 and 8.5	–	
Pond Btwn Rec Hall and A1 Open Pit	W1	July 18	<0.02	0.08	<0.02	<0.02	0.03	0.02	7.4	0.46	0.05
		Sept 27	<0.01	0.05	0.02	<0.02	0.02	0.02	7.7	0.85	<0.02
Pond on Back Rd Btwn Townsite & Mine	W2	July 18	<0.02	0.10	<0.02	<0.02	<0.02	0.02	7.60	0.41	0.59
		Sept 27	<0.01	0.03	<0.02	<0.02	<0.02	<0.02	7.20	22.00	<0.02
Pond at Junction of Back Rd & MEG Rd	W3	July 18	0.04	0.08	0.02	<0.02	0.04	0.02	7.50	0.35	0.11
		Sept 27	<0.01	0.06	0.02	0.02	0.02	<0.02	7.40	0.33	<0.02
Ponds Below Catchbasin #7	W4	July 18	0.02	0.11	0.02	0.02	0.04	0.02	9.05	0.18	0.42
		Sept 27	0.06	0.08	0.02	<0.02	0.02	<0.02	9.00	0.24	0.05
Ponds Below Catchbasin #7	W5	July 18	<0.02	0.09	<0.02	<0.02	<0.02	<0.02	9.00	0.14	1.20
		Sept 27	<0.01	0.04	<0.02	<0.02	<0.02	<0.02	9.00	0.22	0.02
Ponds Below Catchbasin #7	W6	July 18	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	8.05	0.30	0.07
		Sept 27	<0.01	0.02	<0.02	<0.02	<0.02	<0.02	8.30	0.32	<0.02
Pond Btwn Central Pond & YK Bay	W7	July 18	0.04	0.08	<0.02	<0.02	<0.02	<0.02	7.50	0.30	0.07
		Sept 27	<0.01	0.10	0.05	0.02	0.02	0.02	7.60	0.25	<0.02
Pond Btwn North Pond & YK Bay	W9	July 18	0.04	0.13	0.02	0.02	<0.02	0.02	8.20	0.78	1.09
		Sept 27	<0.01	0.22	<0.02	<0.02	<0.02	<0.02	7.40	0.46	<0.02
Pond Below Dam #3	W10	July 18	0.04	0.12	0.02	0.02	0.02	0.02	8.70	0.15	0.08
		Sept 27	<0.01	0.27	0.05	0.02	0.02	0.02	7.80	0.20	<0.02
Pond Below Dam #3	W11	July 18	<0.02	0.11	<0.02	0.02	<0.02	<0.02	7.60	0.21	0.06
		Sept 27	<0.01	0.18	0.04	<0.02	<0.02	<0.02	7.20	4.20	<0.02
Pond Below Dam #3	W12	July 18	<0.02	0.06	<0.02	<0.02	<0.02	<0.02	7.50	0.18	0.08
		Sept 27	<0.01	0.12	0.02	<0.02	<0.02	<0.02	8.00	0.28	<0.02
Pond Behind Supercrest on Vee Lk Rd	W13	July 18	0.02	0.12	<0.02	<0.02	<0.02	<0.02	7.00	0.45	0.08
		Sept 27	<0.01	0.08	0.02	<0.02	<0.02	<0.02	7.20	0.60	<0.02
Pond Btwn Ingraham Tr &PCB Stor Bldg	W14	July 18	0.04	0.14	<0.02	<0.02	0.02	0.02	7.80	1.20	0.15
		Sept 27	<0.01	0.22	0.02	<0.02	0.02	<0.02	7.80	1.80	<0.02
Pond Behind UBC Zone Portal	W15	July 18	0.04	0.57	0.02	0.02	0.02	0.02	7.60	0.35	0.19
		Sept 27	<0.01	0.05	0.15	0.02	0.04	0.03	7.50	0.32	<0.02
Average			0.01	0.12	0.02	0.01	0.01	0.01	7.84	1.34	0.15

APPENDIX B

1994 SWEP LEACHATE ANALYSES

Giant Mine - Surface Contamination Study

SWEP Leachate Test Results for Arsenic

Sample Location	Station #	Lab Sample I.D. #	Initial Soil Analysis Total As mg/Kg	SWEP Leachate Soluble As mg/l	SWEP Leachate Soluble As mg/Kg	% of Total As Soluble at pH 5.2
CCME Remediation Criteria			50		50	
Near Yacht Club	S3	35255	3,240	0.093	1.86	0.06%
Near Townsite	S6	35261	2,000	0.198	3.96	0.20%
Old PCB Storage Building	**S19**	**35287**	**3,180**	**2.950**	**59.00**	**1.86%**
B3 Open Pit Area	S24	35297	3,100	0.194	3.88	0.13%
North Pond to GSL	**S27**	**35303**	**2,020**	**15.900**	**318.00**	**15.74%**
ICG Tank Farm	S30	35309	2,940	0.086	1.72	0.06%
Near 22B Dam	S35	35319	2,240	0.045	0.90	0.04%
Main Gate Area	S39	35327	2,440	0.044	0.88	0.04%
Near Catchbasin at C Dry	S40	35329	4,400	0.720	14.40	0.33%
Diesel Fuel Storage	S42	35333	2,880	0.128	2.56	0.09%
Diesel Fuel Storage	S43	35335	2,320	0.160	3.20	0.14%
Rail	S45	35339	2,000	0.060	1.20	0.06%
Old Electrical Shop	S46	35341	2,900	0.131	2.62	0.09%
Crusher	S49	35347	7,920	0.146	2.92	0.04%
Open Pit Crusher	**S53**	**35355**	**5,680**	**22.100**	**442.00**	**7.78%**
Near Open Pit Crusher	S54	32357	9,760	0.260	5.20	0.05%
Crusher	S55	35359	5,040	0.185	3.70	0.07%
BC Crusher	S56	35361	3,280	0.670	13.40	0.41%
MEG	**S57**	**35363**	**2,140**	**17.100**	**342.00**	**15.98%**
MEG	**S58**	**35365**	**6,000**	**38.300**	**766.00**	**12.77%**
Southwest Mill	S60	35369	3,260	0.200	4.00	0.12%
Adjacent to Assay Lab	S63	35375	11,800	0.166	3.32	0.03%
Fuel Storage - Lumber Yard	S64	35377	5,360	0.244	4.88	0.09%
Lumber Yard	S71	35391	5,280	0.111	2.22	0.04%
Lumber Yard Stack	S73	35393	2,320	0.560	11.20	0.48%
Quonset Hut	S74	35397	2,680	0.860	17.20	0.64%
Mill Yard	S75	35399	2,340	0.358	7.16	0.31%
Stack	**S83**	**35415**	**14,200**	**271.000**	**5420.00**	**38.17%**
Stack	S86	35421	2,120	0.363	7.26	0.34%
Stack	**S87**	**35423**	**8,400**	**62.000**	**1240.00**	**14.76%**
Stack	**S88**	**35425**	**2,100**	**4.600**	**92.00**	**4.38%**
Average			4,366		283.83	6.50%
Column 1	2	3	4	5	6	7

08/03/95

APPENDIX C

1995 ANALYTICAL DATA

TOTAL ARSENIC AND SWEP LEACHATE ANALYSES

Table 1:

Sample ID #	Sample Location	
G1	Near Akaitcho warehouse	S
G2	Below east side of Akaitcho bunkhouses near S33	S
G3	NW pond hazardous dump site near S32 - rockfill	S
G4	NW pond hazardous dump site near S32 - rockfill	D
G5	Fuelling station across from C dry - obvious oil staining on ground - rockfill	S
G6	30 feet west from site G5 outside obvious oil staining	S
G7	C Dry oil storage tank outside berm on north side near S40 - rock fill	S
G8	C Dry oil storage tank inside berm on north side - peat moss	S
G9	Near site S39	S
G10	C Dry bunker C fuel storage tanks near S37	S
G11	SE corner of C dry mechanical shop near S46 - rockfill	S
G12	Electrical Shop area near S50	S
G13	Northwest side of crushing plant near S 54	S
G14	Fuel storage in lumber yard near S66	S
G15	Mill Bunker C fuel storage tank near S67	S
G16	Lumber storage area near S70	S
G17	Roaster Stack are near S87	S
G18	B Shaft area - near S91	S
G19	Approximately 30 feet north of the base of the roaster stack near the As silo - gravel & rock	S
G20	Approximately 20 feet west of the base of the roaster stack towards HCD plant - gravel & rock	S
G21	In swampy area immediately to the east of the roaster stack - peat moss - near S83	S
G22	100 feet North of baghouse near roadway - light soil over rockfill	S
G23	20 feet north of baghouse - rockfill & gravel	S
G24	15 feet east of cottrell building under stack flues - gravel & rock	S
G25	On bank immediately to the west of the AC kiln building - north end of bank - soil over rockfill	S
G26	On bank immediately to the west of the AC kiln building - south end of bank - soil over rockfill	S
G27	On bank alongside old Prelude Lake Hwy west of baghouse building - soil over rockfill	S
G28	On bank alongside old Prelude Lake Hwy west of roaster building - soil over rockfill	S
G29	On bank alongside old Prelude Lake Hwy west of AC Kiln building near raise house - soil over rockfill	S
G30	On bank alongside old Prelude Lake Hwy west of AC Kiln building west of G25 - soil over rockfill	S
G31	On bank alongside old Prelude Lake Hwy west of AC Kiln building west of G26 - soil over rockfill	S
G32	On bank alongside old Prelude Lake Hwy west of yard between the mill and the roaster near rse hse	S
G33	On bank alongside old Prelude Lake Hwy west of mill (solution sump area) - soil over rockfill	S
G34	Open Pit Crusher - 50 feet south of transfer conveyor to headframe - gravel & rock - near S53	S
G35	Open Pit Crusher - 20 feet south of open pit crusher building - gravel & rock - near S53	S
G36	Southeast side of MEG garage - approximately 50 feet from the garage (gravelly soil) - near S57	S
G37	North side of MEG Garage close to oil containment sump for boiler fuel tank - gravel & rock - near S58	S
G38	mill reagent storage area quonset hut yard near S74	S
G39	Lumber storage yard near S71	S
G40	Approximately 200 yards north of the old PCB building - gravelly soil - near S19	S
G41	Approximately 100 yards south of the old PCB building - gravelly soil - near S19	S
G42	Gowganda scrap yard near S12	S
G43	Between Legislative Assembly Building parking lot and Frame Lake shoreline - organic peat moss soil	S
G44	Between Legislative Assembly Building parking lot and Frame Lake shoreline - organic peat moss soil	D
G45	Shore of Frame Lake - 100 yards west of the curling club building - sandy soil 10 yards froi the lake shore	S
G46	Shore of Frame Lake - 100 yards west of the curling club building - sandy soil 10 yards froi the lake shore	D
G47	Kam Lake Road - in the bush near the Telsat Base	S
G48	Kam Lake Road - in the bush near the Telsat Base	D
G49	Downstream of Dam #3 near site S27	S
G50	Downstream of Dam #1 near site S24	S

GIANT SURFACE CONTAMINATION STUDY

Table 2 - ADDITIONAL SWEP TEST RESULTS - (REMAINDER OF SURFACE SOIL SAMPLES FROM INITIAL SAMPLING)

Sample Location	Station #	Lab ID #	Initial Soil Analysis Total As mg/kg	SWEP Leachate Soluble As mg/L	SWEP Leachate Soluble As mg/kg	% of Total As Soluble at pH 5.2
CCME Remediation Criteria			50		50	
Behind A2 Open Pit	S1	35251	22.0	0.006	0.12	0.55%
Behind A2 open Pit	S2	35253	2380.0	0.910	18.20	0.76%
Between A1 & A2 Pits	S4	35257	52.0	0.013	0.26	0.50%
Behind a Shaft	S5	35259	53.0	0.019	0.38	0.72%
Tanks on road to A-shaft	S7	35263	280.0	0.093	1.86	0.66%
Behind A-1 Open Pit	S8	35265	120.0	0.041	0.82	0.68%
Near A-1 Open Pit	S9	35267	330.0	0.090	1.80	0.55%
Gowganda Yard	S10	35269	290.0	1.610	32.20	11.10%
Back Road	**S11**	35271	260.0	4.340	**86.80**	33.40%
Gowganda Yard	S12	35273	1770.0	0.242	4.84	0.27%
Near Pit Shop	S13	35275	370.0	0.079	1.58	0.43%
Behind #7 Dam	**S14**	35277	140.0	2.920	**58.40**	41.70%
Brock Quarry	S15	35279	25.0	0.008	0.16	0.64%

GIANT SURFACE CONTAMINATION STUDY

Table 2 - ADDITIONAL SWEP TEST RESULTS - (REMAINDER OF SURFACE SOIL SAMPLES FROM INITIAL SAMPLING)

Sample Location	Station #	Lab ID #	Initial Soil Analysis Total As mg/kg	SWEP Leachate Soluble As mg/L	SWEP Leachate Soluble As mg/kg	% of Total As Soluble at pH 5.2
CCME Remediation Criteria			50		50	
Behind South Pond	S16	35281	420.0	1.130	22.60	5.40%
Ingraham Trail (behind mill)	S17	35283	220.0	0.390	7.80	3.50%
UBC Quarry	S18	35285	??	0.101	2.02	0.63%
TRP Plant Site	S20	35289	200.0	0.390	7.80	3.90%
TRP Plant Site	S21	35291	430.0	0.018	0.36	0.08
Polishing Pond	S22	35293	400.0	0.820	16.40	4.10%
Carbon Columns	S23	35295	140.0	0.160	3.20	2.30%
Pocket Lake Area	S25	35299	560.0	0.990	19.80	3.60%
Near North Pond	S26	35301	114.0	0.025	0.50	0.44%
Near Dam #3	S28	35305	530.0	0.700	14.00	2.60%
Near Northwest Pond	S29	35307	590.0	0.205	4.10	0.69%
Behind Northwest Pond	S31	35311	760.0	0.700	14.00	1.80%
Hazardous Waste Dumpsite	S32	35313	190.0	0.110	2.20	1.20%

GIANT SURFACE CONTAMINATION STUDY

Table 2 - ADDITIONAL SWEP TEST RESULTS - (REMAINDER OF SURFACE SOIL SAMPLES FROM INITIAL SAMPLING)

Sample Location	Station #	Lab ID #	Initial Soil Analysis Total As mg/kg	SWEP Leachate Soluble As mg/L	SWEP Leachate Soluble As mg/kg	% of Total As Soluble at pH 5.2
CCME Remediation Criteria			**50**		**50**	
Akaitcho	S33	35315	210.0	1.120	22.40	10.70%
Akaitcho	S34	35317	160.0	0.043	0.86	0.50%
Near Administ. Building	**S36**	35321	1180.0	2.510	**50.20**	4.3%
Fuel Tanks Across from C-Dry	S37	35323	1020.0	0.500	10.00	0.98%
Fuel Tanks Across from C-Dry	S38	35325	270.0	0.410	8.20	3.00%
Near C-Dry	S41	35331	1720.0	0.066	1.32	0.08%
Near C-Dry	S44	35337	730.0	0.040	0.80	0.11%
Near Hoist Room	S47	35343	430.0	0.031	0.62	0.14%
Hoist - C-Shaft	S48	35345	1710.0	0.040	0.80	0.05%
New Electrical Shop	S50	35349	1130.0	0.122	2.44	0.22%
Warehouse	S51	35351	1060.0	0.115	2.30	0.22%
BC Across From Crusher	S52	35353	1660.0	0.047	0.94	0.06%
BC Screenhouse	S59	35367	810.0	0.470	9.40	1.20%
BC Refinery	S61	35371	1090.0	0.345	6.90	0.63%
Refinery	S62	35373	1210.0	2.390	47.80	4.00%

GIANT SURFACE CONTAMINATION STUDY

Table 2 - ADDITIONAL SWEP TEST RESULTS - (REMAINDER OF SURFACE SOIL SAMPLES FROM INITIAL SAMPLING)

Sample Location	Station #	Lab ID #	Initial Soil Analysis Total As mg/kg	SWEP Leachate Soluble As mg/L	SWEP Leachate Soluble As mg/kg	% of Total As Soluble at pH 5.2
CCME Remediation Criteria			**50**		**50**	
Fuel Storage - Lumber Yard	S65	35379	270.0	0.074	1.48	0.55%
Fuel Storage - Lumber Yard	**S66**	35381	1430.0	13.900	**278.00**	19.40%
Fuel Storage - Lumber Yard	S67	35383	990.0	2.450	49.00	4.90%
Fuel Storage - Lumber Yard	S68	35385	430.0	0.285	5.70	1.30%
Fuel Storage - Lumber Yard	S69	35387	1640.0	0.231	4.62	0.28%
Lumber Yard	S70	35389	1600.0	0.225	4.50	0.28%
Lumber Yard Stack	S72	35393	2320.0	0.440	8.80	0.38%
Refinery Sump	**S76**	35401	810.0	9.800	**196.00**	24.10%
Refinery Sump	S77	35403	390.0	1.050	21.00	5.40%
Behind AC	**S78**	35405	1720.0	4.900	**98.00**	5.70%
Roaster	**S79**	35407	1180.0	11.300	**226.00**	19.20%
BC Roaster	**S80**	35409	650.0	4.100	**82.00**	12.60%
Stack	S81	35411	530.0	0.730	14.60	2.80%

GIANT SURFACE CONTAMINATION STUDY

Table 2 - ADDITIONAL SWEP TEST RESULTS - (REMAINDER OF SURFACE SOIL SAMPLES FROM INITIAL SAMPLING)

Sample Location	Station #	Lab ID #	Initial Soil Analysis Total As mg/kg	SWEP Leachate Soluble As mg/L	SWEP Leachate Soluble As mg/kg	% of Total As Soluble at pH 5.2
CCME Remediation Criteria			50		50	
Stack	S82	35413	1680.0	6.200	**124.00**	7.40%
Baghouse	S84	35417	1360.0	17.100	**342.00**	25.10%
Stack	S85	35419	1490.0	9.900	**198.00**	13.30%

GIANT SURFACE CONTAMINATION STUDY - 1995 SAMPLING PROGRAM

TABLE 3 - RESULTS FROM ADDITIONAL SAMPLING CONDUCTED (SAMPLES G1 - G50)

Sample ID/Lab ID #	T/As (mg/kg)	T/Cu (mg/kg)	T/Ni (mg/kg)	T/CN (mg/kg)	Oil & Grease (mg/kg)	Ammonia (mg/kg)	Paste pH
CCME REMEDIATION CRITERIA	**50**	**500**	**500**	**500**	**2500**	**NC**	**6-8**
G1	60	Na	Na	Na	150	Na	Na
G2	**450**	Na	Na	Na	**2130**	Na	Na
G3	**2100**	Na	Na	Na	1570	Na	Na
G4	**4500**	Na	Na	Na	**27811**	Na	Na
G5	**2000**	Na	Na	Na	**13700**	Na	Na
G6	**2200**	Na	Na	Na	**4520**	Na	Na
G7	**2050**	Na	Na	Na	**7480**	Na	Na
G8	**2000**	Na	Na	Na	1570	Na	Na
G9	**2250**	Na	Na	Na	**2610**	Na	Na
G10	**160**	Na	Na	Na	**13450**	Na	Na
G11	**4500**	Na	Na	Na	**4840**	Na	Na
G12	**350**	Na	Na	Na	**33200**	Na	Na
G13	**8000**	Na	67	Na	**38900**	Na	Na

GIANT SURFACE CONTAMINATION STUDY - 1995 SAMPLING PROGRAM

TABLE 3 - RESULTS FROM ADDITIONAL SAMPLING CONDUCTED (SAMPLES G1 - G50)

Sample ID/Lab ID #	T/As (mg/kg)	T/Cu (mg/kg)	T/Ni (mg/kg)	T/CN (mg/kg)	Oil & Grease (mg/kg)	Ammonia (mg /kg)	Paste pH
CCME REMEDIATION CRITERIA	**50**	**500**	**500**	**500**	**2500**	**NC**	**6-8**
G14	**940**	Na	Na	Na	300	Na	Na
G15	320	Na	Na	Na	**32100**	Na	Na
G16	**540**	43	Na	Na	230	Na	Na
G17	**3500**	Na	Na	Na	1800	<0.1	Na
G18	**700**	Na	Na	Na	**3260**	Na	Na
G19	**7700**	Na	Na	Na	Na	Na	Na
G20	**3500**	Na	Na	Na	Na	Na	Na
G21	**15800**	Na	Na	Na	Na	Na	Na
G22	**3200**	Na	Na	Na	Na	Na	Na
G23	**4000**	Na	Na	Na	Na	Na	Na
G24	**3100**	Na	Na	Na	Na	Na	Na

GIANT SURFACE CONTAMINATION STUDY - 1995 SAMPLING PROGRAM

TABLE 3 - RESULTS FROM ADDITIONAL SAMPLING CONDUCTED (SAMPLES G1 - G50)

Sample ID/Lab ID #	T/As (mg/kg)	T/Cu (mg/kg)	T/Ni (mg/kg)	T/CN (mg/kg)	Oil & Grease (mg/kg)	Ammonia (mg/kg)	Paste pH
CCME REMEDIATION CRITERIA	**50**	**500**	**500**	**500**	**2500**	**NC**	**6-8**
G25	1350	Na	Na	Na	Na	Na	Na
G26	600	Na	Na	Na	Na	Na	Na
G27	1600	Na	Na	Na	Na	Na	Na
G28	2000	Na	Na	Na	Na	Na	Na
G29	1500	Na	Na	Na	Na	Na	Na
G30	490	Na	Na	Na	Na	Na	Na
G31	1460	Na	Na	Na	Na	Na	Na
G32	920	Na	Na	Na	Na	NA	Na
G33	1110	Na	Na	Na	Na	Na	Na
G34	3500	3	60	Na	450	Na	7.8
G35	5700	1620	55	Na	930	Na	9.5
G36	920	Na	Na	Na	410	<0.1	Na
G37	300	Na	Na	Na	8990	<0.1	Na

GIANT SURFACE CONTAMINATION STUDY - 1995 SAMPLING PROGRAM

TABLE 3 - RESULTS FROM ADDITIONAL SAMPLING CONDUCTED (SAMPLES G1 - G50)

Sample ID/Lab ID #	T/As (mg/kg)	T/Cu (mg/kg)	T/Ni (mg/kg)	T/CN (mg/kg)	Oil & Grease (mg/kg)	Ammonia (mg/kg)	Paste pH
CCME REMEDIATION CRITERIA	50	500	500	500	2500	NC	6-8
G38	600	240	Na	Na	70	Na	Na
G39	1450	94	Na	Na	2230	Na	Na
G40	100	Na	Na	Na	30	Na	Na
G41	2700	Na	Na	Na	90	Na	Na
G42	400	20	Na	Na	350	Na	Na
G43	310	25	12	Na	4680	Na	Na
G44	110	9	5	Na	3690	Na	Na
G45	50	26	33	Na	640	Na	Na
G46	33	20	30	Na	350	Na	Na
G47	40	30	37	Na	550	Na	Na
G48	13	34	43	Na	110	Na	Na
G49	24	Na	Na	<1.0	Na	Na	Na
G50	2050	Na	Na	30	Na	Na	Na

GIANT SURFACE CONTAMINATION STUDY - 1995 SAMPLING PROGRAM

TABLE 4 - RESULTS FROM ARSENIC SWEP TEST (SAMPLES G1 - G50)

Sample ID/Lab ID #	Initial Soil Analysis Total As mg/kg	SWEP Leachate Soluble As mg/L	SWEP Leachate Soluble As mg/kg	% of Total As Soluble at pH 5.2
CCME REMEDIATION CRITERIA	50		50	
G1	60	0.025	0.5	0.83%
G2	450	0.170	3.4	0.76%
G3	2100	0.460	9.2	0.44%
G4	4500	0.110	2.2	0.05%
G5	2000	0.127	2.5	0.13%
G6	2200	0.245	4.9	0.23%
G7	2050	0.193	3.9	0.19%
G8	2000	0.302	6.0	0.30%
G9	2250	0.085	1.7	0.08%
G10	160	0.198	4.0	2.50%
G11	4500	0.097	1.9	0.04%
G12	350	0.047	0.9	0.26%
G13	8000	0.054	1.1	0.01%
G14	940	8.500	170.0	18.00%

GIANT SURFACE CONTAMINATION STUDY - 1995 SAMPLING PROGRAM

TABLE 4 - RESULTS FROM ARSENIC SWEP TEST (SAMPLES G1 - G50)

Sample ID/Lab ID #	Initial Soil Analysis Total As mg/kg	SWEP Leachate Soluble As mg/L	SWEP Leachate Soluble As mg/kg	% of Total As Soluble at pH 5.2
CCME REMEDIATION CRITERIA	**50**		**50**	
G15	320	1.140	22.8	7.10%
G16	540	0.222	4.4	0.81%
G17	3500	12.200	**244.0**	7.00%
G18	700	0.031	0.62	0.09%
G19	7700	75.000	**1500.0**	19.50%
G20	3500	5.700	**114.0**	3.30%
G21	15800	179.000	**3580.0**	22.70%
G22	3200	60.000	**1200.0**	37.50%
G23	4000	55.000	**1100.0**	27.50%
G24	3100	75.000	**1500.0**	48.40%
G25	1350	10.000	**200.0**	14.80%
G26	600	3.200	**64.0**	10.70%
G27	1600	25.000	**500.0**	31.30%
G28	2000	23.000	**460.0**	23.00%

GIANT SURFACE CONTAMINATION STUDY - 1995 SAMPLING PROGRAM

TABLE 4 - RESULTS FROM ARSENIC SWEP TEST (SAMPLES G1 - G50)

Sample ID/Lab ID #	Initial Soil Analysis Total As mg/kg	SWEP Leachate Soluble As mg/L	SWEP Leachate Soluble As mg/kg	% of Total As Soluble at pH 5.2
CCME REMEDIATION CRITERIA	**50**		**50**	
G29	1500	26.500	**530.0**	35.30%
G30	490	4.500	**90.0**	18.40%
G31	1460	18.000	**360.0**	24.70%
G32	920	8.800	**176.0**	19.10%
G33	1110	26.000	**520.0**	46.80%
G34	3500	0.500	10.0	0.29%
G35	5700	0.650	13.0	0.23%
G36	920	0.980	19.6	2.10%
G37	300	0.490	9.8	3.30%
G38	600	0.260	5.2	0.87%
G39	1450	0.500	10.0	0.69%
G40	100	0.060	1.2	1.20%
G41	2700	0.200	4.0	0.15%
G42	400	3.190	**63.8**	15.90%

GIANT SURFACE CONTAMINATION STUDY - 1995 SAMPLING PROGRAM

TABLE 4 - RESULTS FROM ARSENIC SWEP TEST (SAMPLES G1 - G50)

Sample ID/Lab ID #	Initial Soil Analysis Total As mg/kg	SWEP Leachate Soluble As mg/L	SWEP Leachate Soluble As mg/kg	% of Total As Soluble at pH 5.2
CCME REMEDIATION CRITERIA	50		50	
G43	310	1.410	28.2	9.10%
G44	110	0.380	7.6	6.90%
G45	50	0.078	1.6	3.20%
G46	33	0.089	1.8	5.40%
G47	40	0.029	0.6	1.50%
G48	13	0.017	0.4	3.10%
G49	24	0.204	4.1	17.10%
G50	2050	0.004	0.1	0.01%

GIANT SURFACE CONTAMINATION STUDY - 1995 SAMPLING PROGRAM

TABLE 5 - SOIL SAMPLING ANALYTICAL RESULTS - CONTROL POINTS

Sample Location	Sample ID Lab ID #	Depth or Surface	T/As (mg/kg)	T/Cu (mg/kg)	T/Ni (mg/kg)	Oil & Grease (mg/kg)
Between Legislative building parking lot and Frame Lake Shoreline.	G43	surface	310	25	12	4680
Between Legislative building parking lot and Frame Lake Shoreline.	G44	depth	110	9	5	3690
Shore of Frame Lake - 100 yds west of curling club.	G45	surface	50	26	33	640
Shore of Frame Lake - 100 yds west of curling club.	G46	depth	33	20	30	350
Kam Lake Road - in the bush near the Telesat	G47	surface	40	30	37	550
Kam Lake Road - in the bush near the Telestat	G48	depth	13	34	43	110

APPENDIX D

1996 ANALYTICAL DATA

CONTROL SITES

SURFACE CONTAMINATION STUDY - CONTROL SITE SOIL SAMPLES

	SITE	DEPTH	Total Arsenic mg/Kg	Total Copper mg/Kg	Total Nickel mg/Kg	Total Zinc mg/Kg	Total Lead mg/Kg	Oil & Grease mg/Kg	Ammonia mg/L	SOLUBLE Arsenic mg/L
1996 Sites	**CS-1**	0 cm to 10 cm	58.0	32	37	38	6	11000	132.5	0.320
	CS-2	10 cm to 20 cm	7.0	5	1	1	4	5500	95.4	0.200
	CS-3	0 cm to 10 cm	10.0	9	14	30	6	210	22.2	0.012
	CS-4	10 cm to 20 cm	9.0	6	11	22	4	140	9.7	0.023
	CS-5	0 cm to 10 cm	81.0	8	11	22	4	750	39.9	0.404
	CS-6	10 cm to 20 cm	40.0	6	14	23	4	130	22.1	0.115
	CS-7	0 cm to 10 cm	138.0	11	12	20	6	100	20.8	0.630
	CS-8	10 cm to 20 cm	12.0	6	15	27	4	110	6.6	0.001
	CS-9	0 cm to 10 cm	70.0	10	18	33	6	110	10.8	0.064
	CS-10	10 cm to 20 cm	58.0	7	10	16	2	120	4.9	0.122
1995 Sites *	**G43**	surface	310.0	25	12	n/a	n/a	4680	n/a	1.410
	G44	depth	110.0	9	5	n/a	n/a	3690	n/a	0.380
	G45	surface	50.0	26	33	n/a	n/a	640	n/a	0.078
	G46	depth	33.0	20	30	n/a	n/a	350	n/a	0.089
	G47	surface	40.0	30	37	n/a	n/a	550	n/a	0.029
	G48	depth	13.0	34	43	n/a	n/a	110	n/a	0.017

Soluble Arsenic determined by SWEP leachate method

* See Final report for a description of these sites

APPENDIX E

ANALYTICAL PROCEDURES

DETERMINATION OF ARSENIC IN SEDIMENTS, SLUDGES & SOILS

Chemex Parameter Code: 772
Detection Limit: 0.10 mg/kg

DIGESTION AND PREPARATON: A sample (1 - 2 grams) is digested with 10 ml of 1:1 nitric acid for 15 minutes, cooled, then refluxed with 5 ml of concentrated nitric acid for 30 minutes. Further refluxing with additional 5-ml portions of nitric acid is carried out as necessary to completely oxidize the sample. The sample is evaporated to 5 ml, 2 ml of deionized water and 3 ml of 30% hydrogen peroxide are added, and the sample is heated, adding 1 ml peroxide at a time until effervescence is minimal. The sample is then reduced to 5 ml, made up to a final volume of 100 ml with deionized water, filtered through Whatman No. 41 filter paper and again made up to a final volume of 100 ml with deionized water.

(Reference: EPA 3050)

DETERMINATION BY GFAA: The digested and prepared sample, with matrix modifier added, is injected into the Graphite furnace tube, and the level of arsenic measured at 193.7 nm with background correction (Zeeman). The concentration of arsenic in the sample is determined by measurement against matrix-matched calibration standards.

(Reference: EPA 7060)

METHOD 3050

ACID DIGESTION OF SEDIMENTS, SLUDGES, AND SOILS

1.0 SCOPE AND APPLICATION

1.1 This method is an acid digestion procedure used to prepare sediments, sludges, and soil samples for analysis by flame or furnace atomic absorption spectroscopy (FLAA and GFAA, respectively) or by inductively coupled argon plasma spectroscopy (ICP). Samples prepared by this method may be analyzed by ICP for all the listed metals, or by FLAA or GFAA as indicated below (see also Paragraph 2.1):

FLAA

Aluminum
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Molybdenum
Nickel
Potassium
Sodium
Thallium
Vanadium
Zinc

GFAA

Arsenic
Beryllium
Cadmium
Chromium
Cobalt
Iron
Molybdenum
Selenium
Thallium
Vanadium

2.0 SUMMARY OF METHOD

2.1 A representative 1- to 2-g (wet weight) sample is digested in nitric acid and hydrogen peroxide. The digestate is then refluxed with either nitric acid or hydrochloric acid. Dilute hydrochloric acid is used as the final reflux acid for (1) the ICP analysis of As and Se, and (2) the flame AA or ICP analysis of Al, Ba, Be, Ca, Cd, Cr, Co, Cu, Fe, Mo, Pb, Ni, K, Na, Tl, V, and Zn. Dilute nitric acid is employed as the final dilution acid for the furnace AA analysis of As, Be, Cd, Cr, Co, Pb, Mo, Se, Tl, and V. A separate sample shall be dried for a total solids determination.

3.0 INTERFERENCES

3.1 Sludge samples can contain diverse matrix types, each of which may present its own analytical challenge. Spiked samples and any relevant standard reference material should be processed to aid in determining whether Method 3050 is applicable to a given waste.

METHOD 3051

MICROWAVE ASSISTED ACID DIGESTION OF SEDIMENTS, SLUDGES, SOILS, AND OILS

1.0 SCOPE AND APPLICATION

1.1 This method is applicable to the microwave assisted acid digestion of sludges, sediments, soils, and oils for the following elements:

Aluminum
Antimony
Arsenic
Boron
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silver
Sodium
Strontium
Thallium
Vanadium
Zinc

1.2 This method is provided as an alternative to Method 3050. It is intended to provide a rapid multielement acid leach digestion prior to analysis so that decisions can be made about site cleanup levels, the need for TCLP testing of a waste and whether a BDAT process is providing acceptable performance. If a decomposition including hydrochloric acid is required for certain elements, it is recommended that Method 3050A be used. Digests produced by the method are suitable for analysis by flame atomic absorption (FLAA), graphite furnace atomic absorption (GFAA), inductively coupled plasma emission spectroscopy (ICP-ES) and inductively coupled plasma mass spectrometry (ICP-MS). Due to the rapid advances in microwave technology, consult your manufacturer's recommended instructions for guidance on their microwave digestion system and refer to the SW-846 "DISCLAIMER" when conducting analyses using Method 3051.

2.0 SUMMARY OF METHOD

2.1 A representative sample of up to 0.5 g is digested in 10 mL of concentrated nitric acid for 10 min using microwave heating with a suitable laboratory microwave unit. The sample and acid are placed in a fluorocarbon (PFA or TFM) microwave vessel. The vessel is capped and heated in the microwave unit. After cooling, the vessel contents are filtered, centrifuged, or allowed to settle and then diluted to volume and analyzed by the appropriate SW-846 method (Ref. 1).

3.0 INTERFERENCES

3.1 Very reactive or volatile materials that may create high pressures when heated may cause venting of the vessels with potential loss of sample and analytes. The complete decomposition of either carbonates, or carbon based samples, may cause enough pressure to vent the vessel if the sample size is greater than 0.25 g when used in the 120 mL vessels with a pressure relief device that has an upper limit of 7.5 ± 0.7 atm (110 ± 10 psi).

SWEP Leachate Extraction Test Procedure

SWEP

SCHEDULE 4

(am. B.C. Reg. 132/92, s. 26)

ANALYTICAL METHODS

NOTE: This procedure is applicable to solids, liquids and mixtures of solids and liquids.

PART 1

LEACHATE EXTRACTION PROCEDURE

(1) Sampling

1.1 For wastes with 0.5% solids weight by volume or greater, collect a sufficient amount of sample to provide approximately 100 g of solid material using techniques which ensure that the sample is representative of the waste.

1.2 If the waste has less than 0.5% solids weight by volume, collect at least 1 ℓ of sample.

(2) Equipment

2.1 Sieve, 9.5 mm mesh opening, stainless steel or plastic material.

2.2 Stainless steel filtration unit, 142 mm diameter, minimum 1 ℓ capacity, capable of sustaining a pressure of 5 kg/cm², applied to the material to be filtered.

2.3 Membrane filter, 142 mm diameter, 0.45 µm diameter pore size, made of synthetic organic material such as cellulose acetate, cellulose nitrate, nylon or polycarbonate and which is compatible with the leachate to be filtered. Teflon is recommended for organic constituents.

2.4 Glass fibre prefilter, 124 mm diameter 3 µm to 12 µm pore size range.

2.5 Vacuum filtration unit, 90 mm diameter.

2.6 Membrane filter 90 mm diameter as per Step 2.3.

2.7 Glass fibre filter 70 mm diameter as per Step 2.4.

2.8 Solid waste rotary extractor – a device that rotates the bottles end-over end about a central axis through 360°, with a speed of 10 rpm. The dimensions of the box will depend on the needs of each laboratory (Figure 1).

2.9 Structural Integrity Tester with a 3.18 cm diameter hammer weighing 0.33 kg and having a free fall of 15.24 cm (Figure 2).

2.10 pH meter, with a readability of 0.01 pH unit and accuracy of ± 0.1 pH units.

2.11 Cylindrical bottles, wide mouth, 1 250 mℓ capacity, polyethylene or glass with Teflon lined cap for inorganic constituents; glass with Teflon-lined cap or Teflon bottles for organic constituents.

2.12 Cleaning Procedure

All glassware and equipment that comes into contact with the sample should be cleaned in the following way before each use:

- 2.12.1 Wash with a non-phosphate detergent solution.
- 2.12.2 Rinse twice with tap water.
- 2.12.3 Rinse twice with reagent water.

- 2.12.4 Wash with 10% nitric acids.
- 2.12.5 Rinse several times with reagent water.
- 2.12.6 Store bottles filled with 10% nitric acids, until ready to use.
- 2.12.7 Rinse several times with reagent water before use.
- 2.12.8 Rinse clean oven dried bottles with methylene chloride, followed by methanol, for organic constituents.

(3) Reagents

3.1 Acetic acid, 0.5 N. Dilute 29.4 mℓ of concentrated acetic acids (ACS grade) to 1 000 mℓ with reagent water.

3.2 Reagent water, Type IV (ASTM Specification D 1193). For organic parameters, the reagent water should be free of any organic substances to be analyzed (ASTM Type 1).

3.3 Nitric acid, 10% (v/v). Add 100 mℓ of concentrated nitric acid (ACS grade) to 900 mℓ of reagent water.

3.4 Nitrogen gas, pre-purified, scrubbed through a molecular sieve.

(4) Separation Procedure

If the sample is not a dry solid separate it into its component phases using the following procedure:

4.1 Determine the dry weight of the solids in the sample at 60°C, using a well homogenized sample. Use this weight to determine the amount of material to be filtered.

4.2 Assemble the filtration unit with a filter bed consisting of a 0.45 µm pore size membrane filter and a coarse glass fibre pre-filter upstream of the membrane filter (per manufacturer's instructions).

4.3 Select one or more blank filters from each batch of filters. Filter 50 mℓ portions of reagent water through each test filter and analyze the filtrate for the analytical parameters of interest. Note the volume required to reduce the blank values to acceptable levels.

4.4 Wash each filter used in the leach procedure with at least this predetermined volume of water. Filter under pressure until no water flows through the filtrate outlet.

4.5 Remove the moist filter bed from the filtration unit and determine its weight to the nearest ± 0.01 g.

4.6 Re-assemble the filtration unit, replacing the filter beds, as before.

4.7 Comminute the sample, with a mortar and pestle, to a size that will pass through the opening of the filtration unit (less than 9.5 mm).

4.8 Agitate the sample by hand and pour a representative aliquot part of the solid and liquid phases into the opening of the filtration unit. Filter a sufficient amount of the sample to provide at least 60 g of dry solid material.

4.9 Pressurize the reservoir very slowly with nitrogen gas by means of the regulating valve on the nitrogen gas cylinder, until liquid begins to flow freely from the filtrate outlet.

4.10 Increase the pressure in increments of 0.5 kg/cm² to a maximum of 5 kg/cm², as the flow diminishes. Continue filtration until the liquid flow ceases or the pressurizing gas begins to exit from the filtrate outlet of the filter unit.

4.11 De-pressurize the filtration unit slowly using the release valve on the filtration unit. Remove and weigh the solid material together with the filter bed to ± 0.01 g. Record the weight of the solid material.

4.12 Measure and record the volume and pH of the liquid phase. Store the liquid at 4°C under nitrogen until required in Step 5.13.

4.13 Discard the solid portion, if the weight is less than 0.5% (w/v) of the aliquot part taken and proceed to step 5.14. If not, proceed to Step 5.1.

<u>Note</u>: For mixtures containing coarse grained solids, where separation can be performed without imposing a 5 kg/cm² differential pressure, a vacuum filtration unit with a filter bed as per Step 4.2 may be used. Vacuum filtration must not be used if volatile organic compounds are to be analysed.

(5) Extraction Procedure

5.1 Prepare a solid sample for extraction by crushing, cutting or grinding, to pass through a 9.5 mm mesh sieve. If the original sample contains both liquid and solid phases, use the solid material from Step 4.13. The structural integrity procedure, Step 6, should be used for monolithic wastes which are expected to maintain their structural integrity in a landfill, (e.g. some slags and treated solidified wastes).

<u>Note</u>: Do not allow the solid waste material to dry prior to the extraction step.

5.2 Determine the moisture content of the de-watered sample, by drying a suitable aliquot part to constant weight at 60°C in an oven. Discard the dried solid material.

5.3 Place the equivalent of 50 g dry weight of the de-watered undried material into a 1 250 mℓ wide mouth cylindrical bottle. Use additional bottles if a larger volume of leachate is required for the analysis.

5.4 Add 800 mℓ (less the moisture content of the sample in mℓ) of reagent water to the bottle.

5.5 Cap the bottle and agitate it in the rotary extractor for 15 minutes before pH measurement.

5.6 Measure and record the pH of the solution in the bottle using a pH meter calibrated with buffers at pH 7.00 and pH 4.00. The solution should be stirred during the pH measurement.

5.7 Proceed to Step 5.10.1, if the pH is less than 5.2.

5.8 Add a sufficient volume of 0.5 N acetic acid if the pH is greater than 5.2 to bring the pH to 5.0 ± 0.2.

<u>Note</u>: Maximum Amount of Acid: No more than 4 mℓ of 0.5 N acetic acid per gram of dry weight of sample may be added during the entire procedure.

no weak ch or acid

If the pH is not lowered to 5.0 ± 0.2 with this amount, proceed with the extraction.

5.9 Cap the bottle and place it in the tumbling apparatus. Rotate the bottle and its contents at 10 rpm for 24 hours at room temperature (20°C to 25°C).

5.10 Monitor, and manually adjust the pH during the course of the extraction, if it is greater than 5.0 ± 0.2. The following procedure should be carefully followed:

5.10.1 Measure the pH of the solution after 1 hour, 3 hours and 6 hours from the starting time. If the pH is above 5.2, reduce it to pH 5.0 ± 0.2 by addition of 0.5 N acetic acid. If the pH is below 5.0 ± 0.2, do not make any adjustments.

5.10.2 Adjust the volume of the solution to 1 000 mℓ with reagent water, if the pH is below 5.0 ± 0.2 after 6 hours.

5.10.3 Measure and reduce the pH to 5.0 ± 0.2, if required, after 22 hours and continue the extraction for an additional 2 hours.

5.11 Add enough reagent water at the end of the extraction period so that the total volume of liquid is 1 000 mℓ. Record the amount of acid added and the final pH of the solution.

5.12 Separate the material into its component liquid and solid phases as described under the Separation Procedure, Step 4. Discard the solid portion.

<u>Note</u>: It may be necessary to centrifuge the suspension at high speed before filtration, for leachates containing very fine grained particles.

5.13 Calculate the amount of free liquid from Step 4.12 corresponding to 50 g of the dry solid material. Add this amount to the leachate from Step 5.12.

<u>Note</u>: If the analysis is not performed immediately, store separate aliquot parts of the leachate at 4°C, after adding appropriate preservatives for the analytical parameters of interest.

5.14 If the weight of the solid portion in Step 4.1 was less than 0.5% (w/v), analyze the free liquid from Step 4.13; otherwise, analyze the combined solutions from Step 5.13 for contaminants listed in Table 1 of this Schedule that are likely to be present.

5.15 Report concentrations of contaminants in the combined leachate and the free liquid solution as mg/ℓ.

5.16 Carry a blank sample through the entire procedure, using dilute acetic acid at pH 5.0 ± 0.2.

(6) Structural Integrity Procedure

6.1 This procedure may be required prior to extraction for some samples as indicated in Step 5.1. It may be omitted for wastes with known high structural integrity.

6.2 Fill the sample holder with the material to be tested. If the sample of the waste is a large monolithic block, cut a portion from the block measuring 3.3 cm in diameter by 7.1 cm in length. For a treated waste (e.g. solidified waste) samples may be cast in a form with the above dimensions for the purposes of conducting this test. In such cases, the waste should be allowed to cure for 30 days prior to further testing.

6.3 Place the sample holder in the structural integrity tester, then raise the hammer to its maximum height and allow it to fall. Repeat this procedure 14 times.

6.4 Remove the material from the sample holder, and proceed to Step 6.2. If the sample has not disintegrated, it may be sectioned; alternatively use the entire sample (after weighing) and a sufficiently large bottle as the extraction vessel. The volume of reagent water to be initially added is 16 mℓ/g of dry sample weight. The maximum amount of 0.5 N acetic acid to be added is 4 mℓ/g of dry sample weight. The final volume of the leachate should be 20 mℓ/g of dry sample weight.

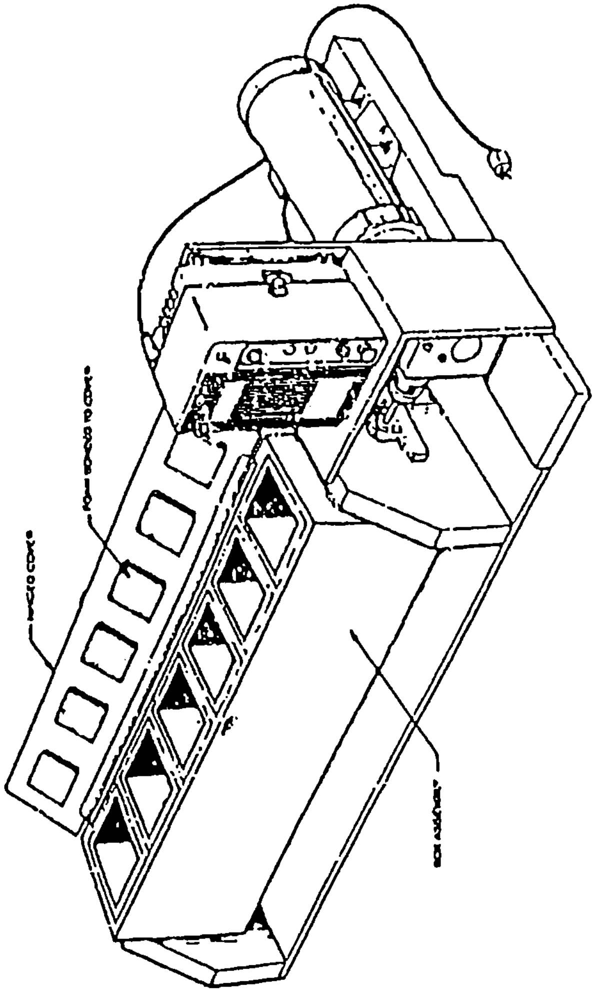


FIGURE 1
SOLID WASTE ROTARY EXTRACTOR

NOTES:

1. 1995 SOIL SAMPLE LOCATIONS, G43 TO G48 ARE LOCATED ON FIGURE 3.
2. CONTROL SITES CS-1-96 TO CS-9-96 ARE LOCATED 2.8 TO 8.3km NORTH OF VEE LAKE ROAD ENTRANCE; SITES ARE AT TRAPPER LAKE AND RATER LAKE, AT FINGER LAKE AND VEE LAKE BOAT LAUNCH.
3. SAMPLE LOCATION W8 DOES NOT EXIST.

LEGEND:

✕ S1	1994 SOIL SAMPLE LOCATION (S1 TO S91)
◉ W1	1994 STANDING WATER SAMPLE LOCATIONS (W1 TO W15)
□ R1	1994 PRECIPITATION RUNOFF SAMPLE SITES (R1 TO R15)
△ G1	1995 SOIL SAMPLE LOCATION (G1 TO G42, G49, G50)
⊗ CS-10-96	1996 CONTROL LOCATION – SOIL ANALYSES (CS-1-96 TO CS-10-96) (SEE NOTE 2)

NOTES:
BASE MAP: 1987 AERIAL

NO.	REVISION	DATE	BY	APP'D

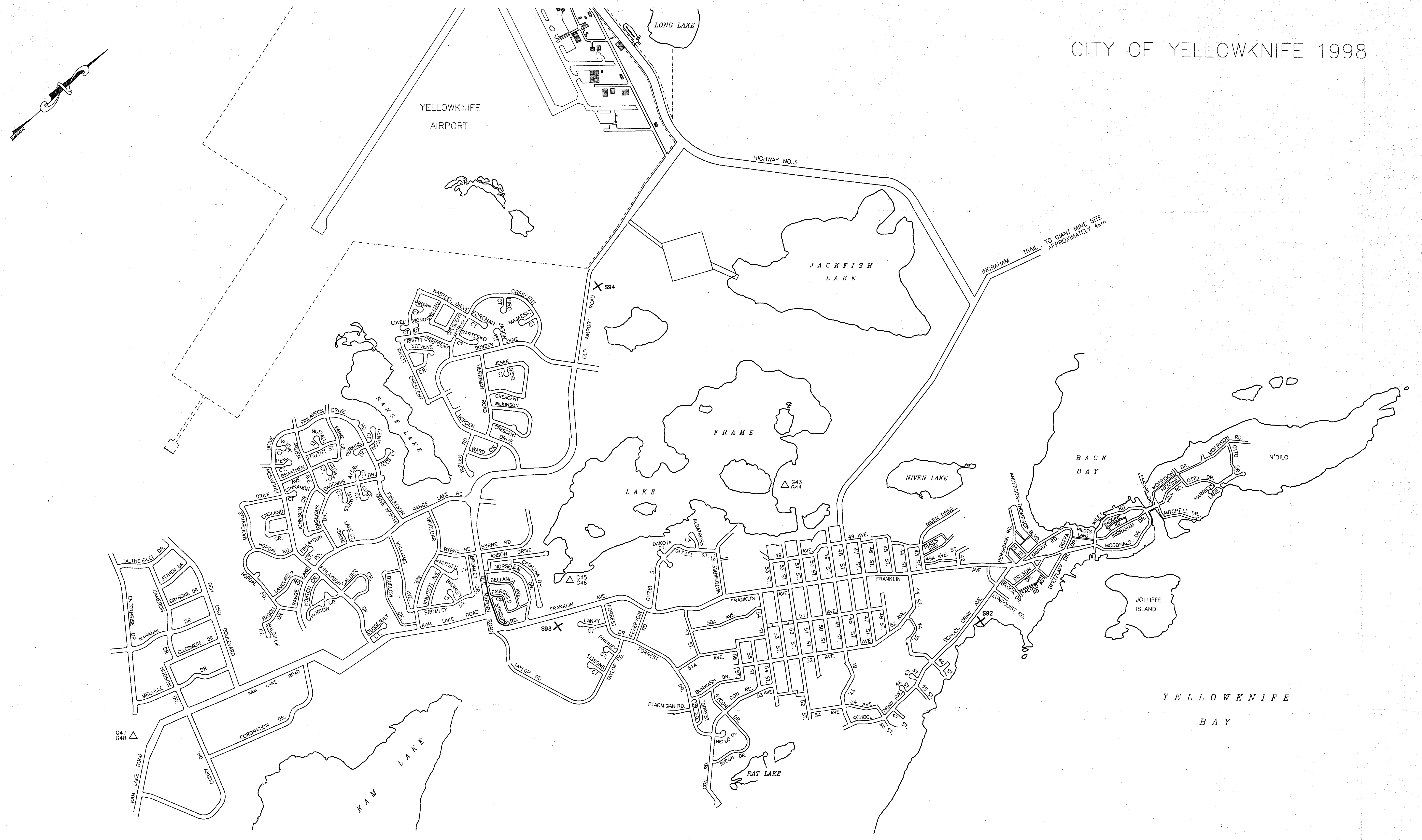
Royal Oak
Mines Inc.

EVALUATION OF
SURFACE CONTAMINATION

DRAWING TITLE
SAMPLE LOCATION MAP

DRAWN BY	SCALE 1" = 500'
CHECKED BY	DATE NOV. 1992
FILE NUMBER 701-13097R02	
DRAWING NO. FIGURE 2	

CITY OF YELLOWKNIFE 1998



LEGEND:

- S92 ✕ 1994 CONTROL SOIL SAMPLE LOCATION (S92 TO S94)
- △G43 1995 CONTROL SOIL SAMPLE LOCATION (G43 TO G48)

NOTES:
BASE MAP: CITY OF YELLOWKNIFE (1998)

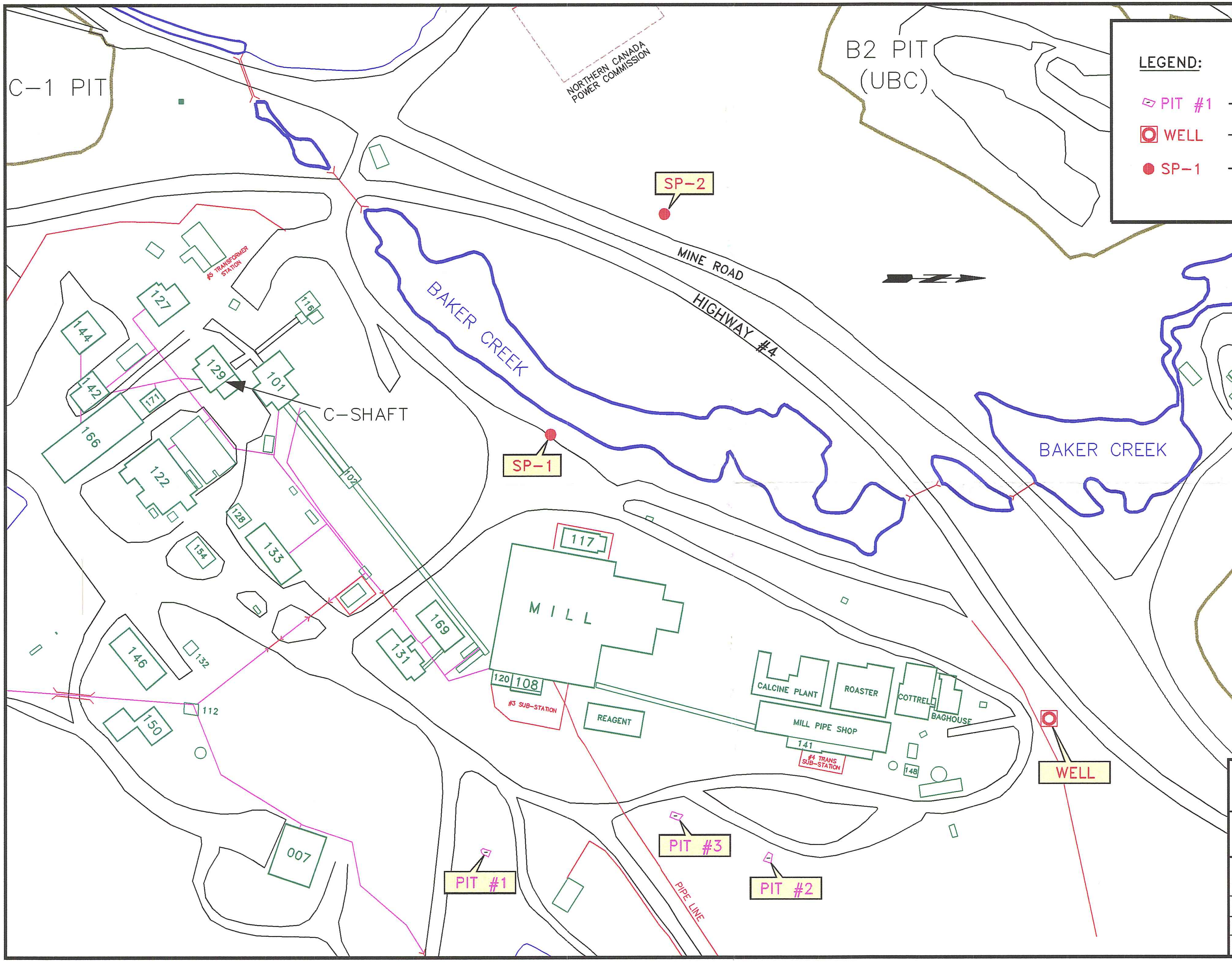
NO	REVISION	DATE	BY	APP'D

Royal Oak
Mines Inc.

EVALUATION OF
SURFACE CONTAMINATION

DRAWING TITLE
CONTROL SAMPLE LOCATION MAP
CITY OF YELLOWKNIFE

DRAWN BY
SCALE N.T.S.
CHECKED BY
DATE NOV. 1992
FILE NUMBER 701-13097R03
DRAWING NO
FIGURE 3



Royal Oak Mines Inc.

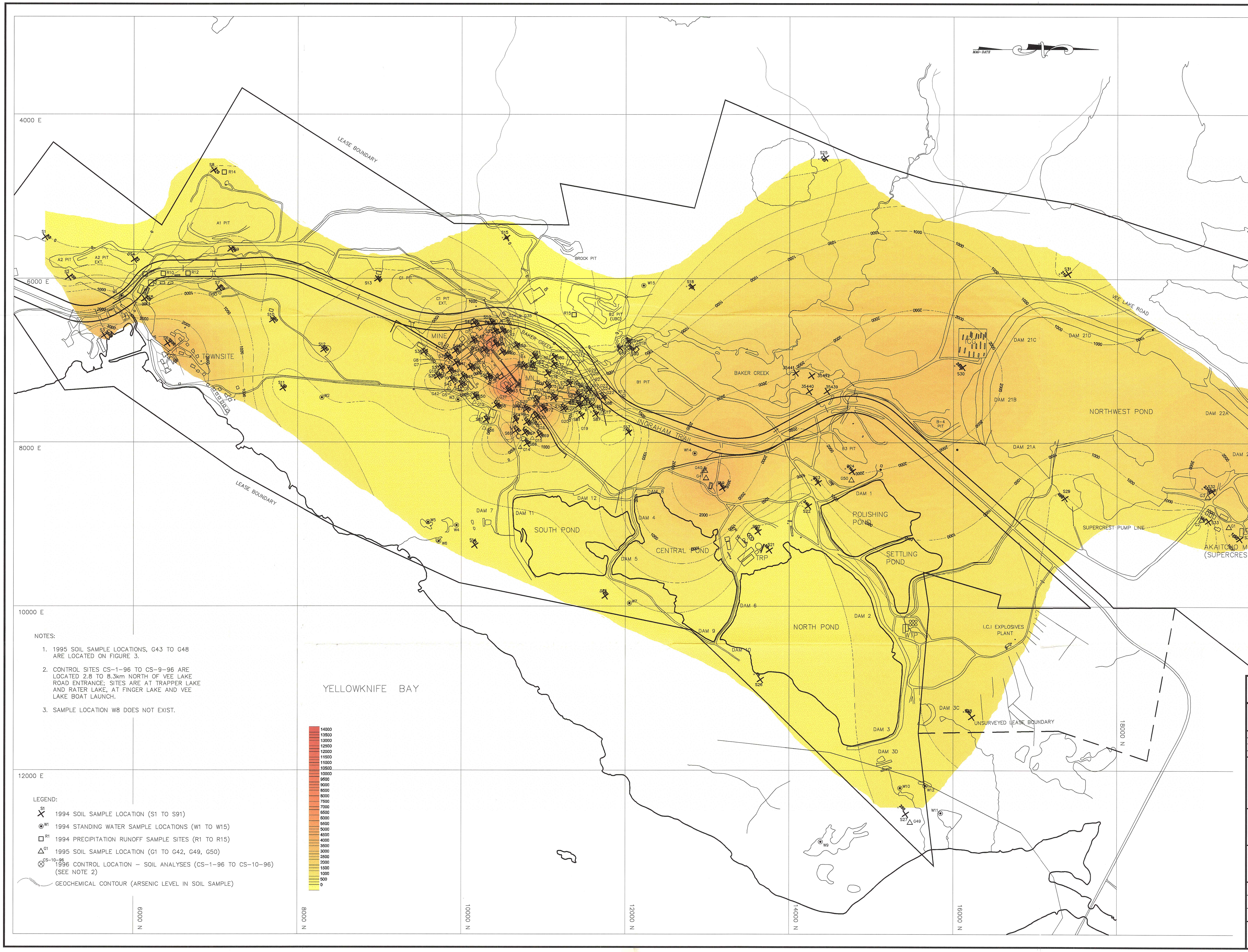
EVALUATION OF SURFACE CONTAMINATION

TITLE: 1997-1998 SITE CHARACTERIZATION MAP

LEVEL: SURFACE	SCALE: 1"= NTS
DRAWN: MSL	CHECK:	DATE: JAN. 29, 1997

Figure 4

File Name: MASTER\ARSENIC\TESTPITS.DWG



NOTES:

1. 1995 SOIL SAMPLE LOCATIONS, G43 TO G48 ARE LOCATED ON FIGURE 3.
2. CONTROL SITES CS-1-96 TO CS-9-96 ARE LOCATED 2.8 TO 8.3km NORTH OF VEE LAKE ROAD ENTRANCE; SITES ARE AT TRAPPER LAKE AND RATER LAKE, AT FINGER LAKE AND VEE LAKE BOAT LAUNCH.
3. SAMPLE LOCATION W8 DOES NOT EXIST.

LEGEND:

- S1 ✕ 1994 SOIL SAMPLE LOCATION (S1 TO S91)
- ⊙ W1 1994 STANDING WATER SAMPLE LOCATIONS (W1 TO W15)
- ☐ R1 1994 PRECIPITATION RUNOFF SAMPLE SITES (R1 TO R15)
- △ G1 1995 SOIL SAMPLE LOCATION (G1 TO G42, G49, G50)
- ⊗ CS-10-96 1996 CONTROL LOCATION – SOIL ANALYSES (CS-1-96 TO CS-10-96) (SEE NOTE 2)
- 1000ppm GEOCHEMICAL CONTOUR (ARSENIC LEVEL IN SOIL SAMPLE)

EBA Engineering Consultants Ltd.

eba

PREPARED BY:

NOTES:
BASE MAP: 1987 AERIAL

NO	REVISION	DATE	BY	APP'D

Royal Oak
Mines Inc.

EVALUATION OF
SURFACE CONTAMINATION

DRAWING TITLE

GEOCHEMICAL CONTOUR PLOT –
1994 ANALYTICAL DATA
AT 0.2m DEPTH

DRAWN BY
SCALE 1" = 500'
CHECKED BY
DATE NOV. 1992
FILE NUMBER 701–13097R05
DRAWING NO

FIGURE 6