Mt Nansen Tailings Porewater Assessment

April 2008

Table of Contents

Table of Contents

LIST OF FIGURES

LIST OF TABLES

1. Introduction

1. Introduction

The Mount Nansen gold mine operated between 1997 and 1999. Oxide and sulphide ores were mined from the Brown-McDade Pit, producing approximately 250,000 tonnes of arsenic- and cyanide-bearing tailings which were stored in an impoundment within the Dome Creek watershed down-gradient of the mill. Water quality in the tailings pond shows evidence of elevated concentrations of sulphate, ammonia, thiocyanate, and some trace elements (*e.g.*, iron, arsenic, copper). In seepage waters from the tailings facility, sulphate, thiocyanate and ammonia are the primary parameters showing enriched levels in comparison to discharge criteria or other water quality guidelines. The pit has partially flooded since mine closure, and now hosts a shallow lake.

As part of on-going closure planning for the site, consideration has been given to re-locating the tailings to the Brown-McDade Pit. The in-pit disposal of tailings to the pit lake offers several potential advantages over the long term. These include: a) geotechnically-sound containment and associated elimination of the potential long-term liability associated with the maintenance and management of a water-retaining dam; b) enhanced stability of sulphide-bearing tailings through the potential for the permanent submergence of tailings materials; c) increased containment of tailings-related drainages, allowing for more control over environmental compliance; and d) potential for natural attenuation of contaminants which migrate out of the pit lake through the groundwater environment. As well, tailings placement in the pit offers the potential for a “walk-away” solution which may require minimal site management and monitoring.

In order to assess environmental considerations for tailings re-location, Lorax Environmental Services Ltd. was retained by the Yukon Territorial Government to assess the porewater composition in the tailings facility. As part of this program, eleven (11) porewater samples were obtained from discrete intervals within the tailings mass at 4 borehole sites. Samples were analyzed for a full suite of physical and chemical parameters. The major objectives of the porewater program were to characterize the porewater composition, and to discuss the environmental implications and liabilities associated with tailings re-location to the pit.

The following report presents the methods (Chapter 2) and results (Chapter 3) of the porewater study. In Chapter 3, the porewater data are compared to pond and seepage values, as well as to relevant water quality guidelines. Collectively, the porewater, pond and seepage data are used to define the dominant geochemical mechanisms governing the distribution and behaviour of the major parameters of interest. Implications of the data with respect to in-pit tailings disposal are discussed in Chapter 4. Consideration is also given to other potential tailings management scenarios. The report concludes in Chapter 4 with a discussion of proposed recommendations.

2. Methods

2. Methods

The Mount Nansen tailings facility is located in the Dome Creek valley and contains approximately 250,000 tonnes of tailings over an area of approximately seven hectares. The maximum depth of the tailings is approximately 9 metres and averages between 5 and 6 metres deep. The tailings mass is composed of sulphide and oxide tails ranging from clay to silt with minor sand. In 2001, a total of 19 boreholes ranging in depth from 2.4 to 9.7 metres were drilled through the tailings impoundment (Kwong, 2002). Samples were collected for static test-work and porewater analysis. The objective of this study is to collect porewaters from varying depths at five borehole locations. The methodology used to collect porewaters is described below.

2.1 Porewater Sampling Locations

Borehole locations were selected by Government Yukon (GY) based on the work by Kwong (2002). The targets were intended to be on the drier portions of the tailings impoundment and at locations represented by a mix of zones containing both sulphidic and oxide tails. The five borehole locations and their approximate depths include B4 (4 m), B6 (5.5 m), B14, (6 m), B15 (9 m), and B16(5 m).

2.2 Porewater Sampling Methods

Three methods were employed to collect porewaters from the Mount Nansen tailings facility. These methods include 1) *in-situ* extraction of porewater with a drive-point profiler; 2) in-situ collection of porewater from a bore-hole drilled with BQ rods; and 3) removal of tailings with a split-spoon coring device for future porewater extraction.

The preferred method for collection of porewater samples utilized the drive-point profiler (Figure 2-1). The profiler tip was hammered to depth using steel AW rods and a Pionjar portable hammer drill. As the tip was advanced, distilled water was pumped through the tip port with a peristaltic pump via 4 mm HDPE tubing to inhibit clogging due to the clay-rich tails. Upon reaching the desired depth, the pump direction was immediately reversed and porewaters were evacuated to surface. Approximately 250 mL of formation water was pumped to surface prior to sampling. All samples were filtered. Approximately 250 mL of formation water was used to rinse the in-line filter (0.45 µm Pall Corporation AquaPrep) prior to sampling. Dissolved metal samples were immediately preserved with nitric acid.

The utilization of distilled water when driving the Waterloo Profiler is the standard method, as described by Pitkin *et al* (1999). Upon reaching the sampling depth, the peristaltic pump was immediately reversed in order to minimize the amount of distilled water pumped into formation (less than 50 mL). Any residual distilled water was removed from the formation prior to sample collection during development and filter rinsing. As the volume of water removed from the formation prior to sampling (~250 mL) is five times greater than the volume introduced during drilling, the effects of using distilled water is presumably negligible.

Figure 2-1: Drive-point Profiler (above) and Pionjar Hammer (below).

In the bore-hole method, BQ rods fitted with an aluminum fencepost cap at the base were hammered to depth and then pulled back to remove the cap and expose the inner rods to the porous, unconsolidated tailings. Porewaters were then allowed to seep into the vacant void, where they were pumped to surface using a peristaltic pump, where samples were immediately filtered to minimize the potential for sample oxidation.

Lastly, core samples were collected using a three foot long, split-spoon coring device. Upon extraction, core samples were sealed in plastic bags and frozen for future extraction of porewater by centrifuge. While the samples were not preserved under anoxic conditions, freezing does prevent the ingress of oxygen and inhibits oxidation. In the event these samples are processed for porewater extraction, they should be thawed and centrifuged within a glove bag under nitrogen or argon gas.

The sampling protocols utilized for porewater collection greatly minimize the potential for oxidation artifacts during sample collection. Suboxic conditions often occur in groundwater environments which may support elevated levels of parameters that are sensitive to the presence of molecular oxygen. Such parameters include ferrous iron (Fe^{2+}), manganese, nitrite, ammonia, and cyanide species. If appropriate precautions are not taken, and samples are allowed to oxidize prior to filtration and preservation, erroneous measurements may result. Specifically, the oxidation of ferrous iron results in the precipitation of hydrous ferric oxides, which are effective sorbers of numerous trace elements, especially copper and arsenic. Therefore, by allowing a sample to come into contact with atmospheric conditions prior to filtration, there is a great risk of generating false metal measurements. Sample contact with the atmosphere can also result in the oxidation of ammonia, nitrite and cyanide compounds. The sampling methods employed here (in-line filtration and measurement of parameters by in-line flow-through cell) greatly minimize the potential for the oxidation artifacts described above. When using the drive-point profiler method, porewater samples were pumped through the flow-through cell for parameter measurement prior to sampling. Indeed, all samples measured 0.0 mg/L dissolved oxygen, demonstrating that the sampling method did not allow the ingress of oxygen prior to filtration and preservation.

A summary of field observations and methods used to collect porewater samples are provided per location in Table 2-1. A total of eleven porewater samples were collected in the field, including a duplicate sample from location B-6 at five feet below surface. Ten samples were collected using the profiling method, while one sample from location B-16 was pumped from a BQ bore-hole. Additionally, six core samples were collected, stored, and frozen for the potential future extraction of porewaters by centrifuge (Table 2-1).

Table 2-1:
Summary of field methods used to collect Mount Nansen porewaters.

Location	Depth (ft)	Field Notes	Sample (Y/N)	Sample Method
B-4	0	Saturated at surface	N	
	1	Saturated; no flow; sticky	N	
	2	Saturated; no flow; sticky	N	
	3	Profile sample; good flow ~4L/hr; low TSS	Y	Profiler
	4	Saturated; no flow; sticky	N	
	5	Profile sample; good flow; ~3L/hr; low TSS	Y	Profiler
	6	Saturated; no flow; sticky	N	
	7	Saturated; no flow; sticky	N	
	8	Saturated; no flow; sticky	N	
	9	Resistance; native ground?	N	
	10	Profile sample; good flow ~2.5 L/hr; low TDS and conductivity	Y	Profiler
B-6	0	Saturated at surface	N	
	1	Saturated; no flow; sticky	N	
	2	Saturated; no flow; sticky	N	
	3	Saturated; no flow; sticky	N	
	4	Saturated; no flow; sticky	N	
	5	Profile sample; low flow ~0.5L/hr; very slow sampling	Y	Profiler
	6	Saturated; no flow; sticky	N	
	6.5	Saturated; no flow; sticky	N	
	7	Profile sample; low flow ~0.25L/hr; flow ceased prior to measuring parameters	Y	Profiler
	7.5	Saturated; no flow; sticky	N	
	8	Saturated; no flow; sticky	N	
	9	Resistance - bottom of impoundment	N	
B-14	0 to 7	Very dry; above water table	N	
	7	Core sample; moist; dewatered from drilling/compaction	Y	Core
	10	No flow; unsaturated; core sample; moist; dewatered from drilling/compaction	Y	Core
	12	No flow; unsaturated; attempted BQ method - no water	N	
	15	No flow; unsaturated; attempted BQ method - no water; core sample moist	Y	Core
	16	Attempted BQ method - no water	N	
B-15	0 to 2.5	Unsaturated; very dry (frozen)	N	
	5 to 7	Water table	N	
	8	Core sample; wet, saturated	Y	Core
	9	Saturated; no flow; sticky; attempted BQ sample - no water	N	
	10	Profile sample; good flow ~1.5L/hr	Y	Profiler
	15	Profile sample; difficult to develop; slow flow ~1L/hr	Y	Profiler
	17	Attempted BQ sample - not enough water	N	
	20	Profile sample; good flow ~1.5L/hr	Y	Profiler
	23.5	Resistance - bottom of impoundment	N	
B-16	2.5 to 5	Water table	N	
	5	Core sample; wet, saturated	Y	Core
	6	Saturated; no flow; sticky	N	
	7	Saturated; no flow; sticky	N	
	8	Saturated; no flow; sticky; core sample - wet, saturated	Y	Core
	9	Saturated; no flow; sticky	N	
	10	Profile sample; good flow ~1.5L/hr	Y	Profiler
	12	Saturated; no flow; sticky; BQ sample - water level at approx 10.5 ft	Y	BQ
	13	Saturated; no flow; sticky	N	
	14	Saturated; no flow; sticky	N	
	15	Resistance - bottom of impoundment	N	

Collection of porewaters using the drive-point profiler was difficult. The profiler screens were particularly susceptible to plugging due to the fine-grained nature of the tailings. Clay-rich tailings were frequently encountered and limited the extraction of porewaters. For example, at sample location B6-7, porewaters were extracted at a rate of approximately 250 mL per hour. Toward the end of the sampling, the suction potential of the pump was exceeded by the suction potential of the clay-rich tails, and porewaters eventually stopped flowing to the surface. Due to the poor productivity of this sampling location, porewater parameters were not measured with the flow-through cell. Low or no-flow conditions were encountered at numerous locations and are a testament to the fine-grained, low permeably nature of the tailings mass.

2.3 Porewater Analysis

Following sample collection, porewaters were pumped through an Horiba U-22 in-line flow-through cell and measured for temperature, conductivity, total dissolved solids, turbidity, salinity, pH, oxidation-reduction potential (ORP), and dissolved oxygen. This methodology allowed for the measurement of physical parameters in the field and under redox-sensitive conditions.

Porewaters were submitted to ALS Environmental Laboratory in Vancouver, British Columbia for analysis of the following parameters: pH, conductivity, hardness, total alkalinity, sulphate, chloride, bromide, ammonia, nitrite, nitrate, total cyanide, weak acid dissociable (WAD) cyanide, thiocyanate, and trace elements by ICP-MS. The full suite of chemical data is provided in Appendix A.

3. Data and Discussions

3. Data and Discussions

The objective of this investigation is to collect and evaluate porewaters from the Mount Nansen tailings impoundment for compatibility with relocation and disposal in the Brown-McDade Pit. In doing so, porewater composition was screened relative to site specific discharge limits and water quality guidelines. The geochemistry of screened parameters was also evaluated for trends and behaviour in the current disposal setting.

3.1 Porewater Data

3.1.1 Overview

Eleven porewater samples were collected from the Mount Nansen tailings facility in September, 2007. A summary of these results is provided in Table 3-1. Data are compared to water quality guidelines for comparison, including site discharge limits and CCME guidelines where applicable. For ammonia, the Yukon Territorial Government Type B Water License Guideline was used for comparison. Parameters that exceed reference guidelines are highlighted. Complete data sets are available in Appendix A.

Table 3-1:
Summary of porewater quality, Mt. Nansen Tailings Pond (all values in mg/L).

Parameter	Maximum	Minimum	**Median**	**Mean**	**Water Quality Guidelines**	
pH	9.3	6.9	7.4	7.8	6.0 to 9.5	YTG
Alkalinity	379	40.2	120	169	NP	NP
Hardness	1550	1010	1260	1261	NP	NP
Sulphate	1750	738	**1525**	**1343**	100	BC
CN	22	0.014	0.037	**2.2**	0.3	YTG
WAD CN	12	<0.014	<0.037	<2.2	0.1	YTG
SCN	100	<0.5	<0.5	11.9		
Ammonia-N	30.5	2.8	**7.6**	**13.3**	2.5	YTG*
Nitrate-N	0.31	<0.005	0.056	0.115	13	CCME
Nitrite	0.15	<0.001	0.0062	0.024	0.06	CCME
Aluminum	0.13	0.0088	0.023	0.040	0.1	CCME
Antimony	0.59	0.00059	0.039	0.13	0.15	YTG
Arsenic	22.9	0.041	**2.06**	**4.39**	0.15	YTG
Cadmium	0.0012	<0.00017	0.00038	0.00044	0.02	YTG
Copper	7.57	0.0011	0.0044	**0.78**	0.2	YTG
Iron	36.6	<0.03	**1.83**	**6.18**	1.0	YTG
Lead	0.014	<0.0005	0.0022	0.0036	0.1	YTG
Molybdenum	0.038	0.002	0.019	0.019	0.073	CCME
Nickel	0.088	0.0041	0.006	0.0152	0.3	YTG
Selenium	0.011	<0.0005	0.00081	0.0025	0.001	CCME
Silver	0.018	<0.00005	0.0001	0.0019	0.1	YTG
Zinc	0.21	<0.01	0.038	0.060	0.3	YTG

Notes: CCME = Canadian Council of Ministers of the Environment
YTG = Yukon Territorial Government - site specific discharge license; *denotes Type B Water License for Ammonia
BC = British Columbia guideline for the protection of aquatic life
NP = “None Proposed”

Mean and median porewater values that exceed reference guidelines are considered parameters of interest and are highlighted in bold. Parameters of interest include sulphate, total cyanide, ammonia, arsenic, copper, and iron. A condensed data set that summarizes all values for these parameters is provided in Table 3-2. Additionally, antimony and zinc have been included. Table 3-2 also includes sample locations, sample depths, pH, dissolved oxygen, and oxidation-redox potential (ORP). Analytical results less than the method detection limit (MDL) are highlighted in red. Note that all samples have dissolved oxygen concentrations of 0.0 mg/L, demonstrating the effectiveness of the sampling methodology at preserving anoxic conditions.

The data presented in Table 3-2 are generally considered to be representative of tailings porewaters. One exception is sample B4-10, which was taken at a depth of 3 metres. Sulphate values at this location were less than the MDL (10 mg/L) and with the exception of iron, metal concentrations were low. These data combined with drilling observations (Table 2-1) suggest that this sample location was collected from below the tailings impoundment in native ground. As a result, the data from this sampling point have not been included in the statistical summaries of tailings porewaters presented within this report, including the tables and figures below and Table 3-1 above.

An important observation to note is the relatively pristine condition of native groundwater at this location, particularly with respect to metals. While B4-10 represents only one sample, the data suggest that tailings are not leaching heavy metals into the groundwater beneath the impoundment. Several contributing factors may be responsible for this, including hydraulic gradient, metal attenuation at depth, and the relatively impermeable nature of the tailings themselves, particularly relative to the native subsurface.

In the following sections, more detailed discussions are provided with respect to the parameters presented in Table 3-2.

Table 3-2:
Porewater parameters of concern (all values in mg/L), Mt. Nansen Tailings Pond.

Sample ID	Depth (ft)	Depth (m)	pH	Dissolved Oxygen (mg/L)	ORP (mV)	Ammonia	Sulfate	Cyanide	SCN	Antimony	Arsenic	Copper	Iron	Lead	Zinc
B4-3	3	0.9	7.02	0.0	-146	5.34	874	0.014	<0.50	0.0035	22.9	0.0012	36.6	0.00091	0.06
B4-5	5	1.5	7.01	0.0	-63	7.58	763	0.017	<0.50	0.0013	0.054	0.00326	4.34	0.00217	0.0923
B4-10	10	3.0	7.15	0.0	-161	28.8	<10	0.020	<0.50	0.0005	0.095	0.00199	18	0.00216	0.0086
B6-5	5	1.5	6.96	0.0	-128	19.4	1610	0.054	5.00	0.0054	6.1	0.0059	14.9	0.00242	0.206
B6-5	5	1.5	6.85	0.0	-53	7.59	738	0.017	<0.50	0.00059	0.041	0.00114	2.12	0.00101	0.0837
B6-7	7	2.1	7.77	0.0	No Data	30.5	1710	0.052	7.75	0.0892	0.31	0.0042	<0.030	0.00213	0.015
B15-10	10	3.0	7.38	0.0	-103	6.13	1500	0.020	<0.50	0.0148	2.13	0.0045	1.56	0.0142	0.098
B15-15	15	4.6	8.16	0.0	32	7.03	1550	0.093	3.65	0.0625	1.99	0.164	0.073	0.00908	0.015
B15-20	20	6.1	9.26	0.0	99	2.83	1380	22	100	0.589	7.57	7.57	2.09	0.00148	<0.01
B16-10	10	3.0	8.44	0.0	166	17.2	1550	0.087	<0.50	0.086	0.42	0.0033	<0.030	<0.00050	<0.01
B16-12	12	3.7	9.2	0.0	33	28.9	1750	0.021	<0.50	0.437	2.35	0.0053	0.04	0.00251	<0.01

3.1.2 pH and Potential for Acid Mine Drainage

Porewater, tailings pond and seepage waters are neutral to slightly basic with most pH values ranging from 7.5 to 8.2 (Figure 3-1). Porewater values exhibit a wider range in pH with values ranging from 6.9 to 9.3. Process waters at this site were initially basic resulting from cyanidation and lime addition. Over time, pH levels have stabilized and have not shown evidence of depression resulting from oxidation of cyanide, ammonia, thiocyanate, or sulphide minerals. This is presumably due to several factors including the buffering reactions associated with carbonate equilibrium. Evidence of these processes is supported by the elevated alkalinity, which is generally in excess of 100 mg/L. Additionally, acid release from sulphide oxidation is presumably limited due to the pervasively saturated nature of the tailings which prevents the ingress of oxygen.

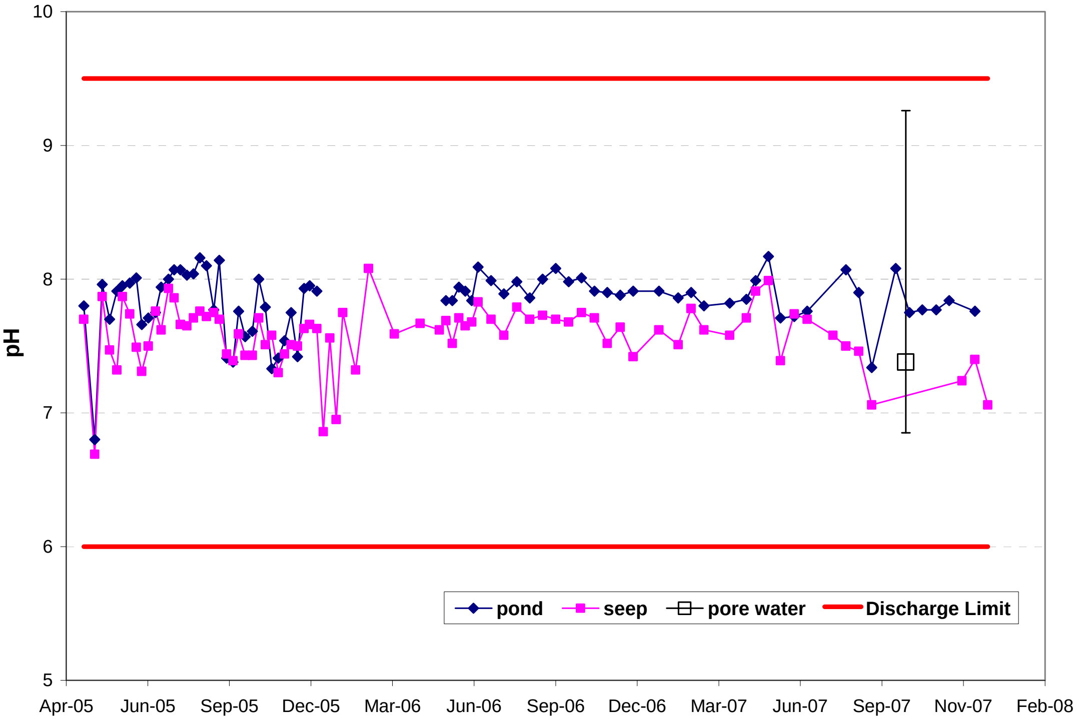

Figure 3-1: pH median (open square), maximum and minimum porewater concentrations compared to time-series of pond and seepage data.

Mount Nansen tailings contain significant amounts of sulphide minerals (Kwong, 2002). The long-term evolution of pH within the tailings is ultimately dependent on the potential for these sulphide minerals to oxidize, release acid, and become neutralized by carbonate bearing minerals within the impoundment. In contrast, acidification by oxidation processes related to cyanide degradation appears to be well-buffered by the tailings and is unlikely. The susceptibility of Mount Nansen tailings to develop acid mine drainage is discussed in greater detail below.

The potential for acid mine drainage to occur within the Mount Nansen tailings was assessed by Kwong (2002) which includes acid base accounting characteristics of 38 samples collected from throughout the tailings impoundment.

Acid-base accounting (ABA) involves a suite of static tests that are utilized as predictors for acid drainage potential. Measures included in ABA are acid potential (AP) and neutralizing potential (NP) of a sample. An accounting technique is used to compare the AP and NP with standard criteria thereby indicating the theoretical acid generation potential of a sample. It is important to note that ABA provides information on whether or not a sample will ultimately generate acidic drainage in the absence of mitigation (*e.g.,* flooding), and not on the rate or timing at which acid drainage will start.

In order to facilitate the accounting technique used, both AP and NP are reported in comparable and consistent units of kg $CaCO_3$/tonne of rock. Typically, the generation of acid is predominantly associated with the oxidation of sulphide minerals (*e.g.,* pyrite). The oxidation of pyrite produces acid, by the following net reaction:

$$FeS_{2(s)} + 15/4\,O_{2(g)} + 7/2\,H_2O \longrightarrow Fe(OH)_{3(s)} + 4H^+ + 2SO_4^{2-} \tag{1}$$

However, as shown by the elemental sulphur humidity cell data, discussed below, elemental sulphur also has the potential to generate acid. In the simplest scenario, the oxidation of elemental sulphur can be represented by the following reaction:

$$2\,S^o_{(s)} + 3O_{2(g)} + 2H_2O \longrightarrow 4H^+ + 2SO_4^{2-} \tag{2}$$

Acid produced by the above reactions is neutralized by calcite following the reaction,

$$CaCO_{3(s)} + 2H^+ \longrightarrow Ca^{2+} + H_2O + CO_2 \tag{3}$$

The two reactions listed above indicate that the two moles of acid generated per mole of sulphur in pyrite or elemental sulphur are neutralized by one mole of calcite. If calculated on a weight basis, the acid produced by 1 g of S is neutralized by 3.125 g of calcite. Therefore, since sulphur concentrations are usually reported as a weight percent, neutralization of a material containing 1% acid generating sulphur is reported as 31.25 kg $CaCO_3$ per tonne of acid generating equivalents. In other words:

AP = [Sulphur content (wt. %)] x [31.25 kg $CaCO_3$/tonne rock]

In sulphide-bearing rock undergoing weathering, ARD will result only if there is insufficient production of neutralizing alkalinity (*i.e.* an imbalance between acid generating and alkalinity-producing reactions). The NP of weathering materials is dependent on the content of minerals that dissolve when exposed to acidic conditions and act to buffer acidity. While many mineral dissolution reactions can be thought of as acid buffering, the minerals most typically responsible for acid neutralization are fast dissolving carbonates.

Both Mend NP and carbonate NP (CaNP) values were determined in Kwong (2002). Mend NP is obtained by titration using the method of Sobek *et al*. (1978), modified with the addition of hydrogen peroxide. This addition oxidizes the Fe(II) liberated from Fe-carbonates prior to titration, which does not occur completely with the Sobek NP determination. Accordingly, MEND NP implicitly accounts for the presence of Fe-carbonates, which show up in the carbonate inventory but do not contribute to NP. Carbonate NP, on the other hand, is obtained by converting the inorganic carbon content of a sample to an equivalent amount of $CaCO_3$ per tonne of rock (CaNP = $\%CO_2 * 16.67$ kg $CaCO_3$/t). This calculation assumes that all the inorganic carbon is present as calcite. It is important to note that Mend NP values provide information on the bulk NP of a sample and are not mineral specific, whereas CaNP values provide information on the specific contribution of carbonate minerals to the neutralization potential of a sample. Comparison of these two values provides useful information on the type of neutralizing mineralization present in a sample.

The net potential ratio (NPR or NP/AP), which is calculated by dividing the NP of a sample by its AP, is often used to assess the likelihood of a sample to generate acidic drainage. Acid-base accounting screening criteria from the British Columbia Ministry of Energy and Mines suggests that a NP/AP value of less than 1 is likely acid generating.

ABA characteristics as measured by Kwong (2002) were separated by tailings type and are illustrated in Figure 3-2. As is clearly demonstrated by the data, Mount Nansen tailings will likely be acid generating in the absence of mitigating factors. Currently, the likelihood of sulphide oxidation and subsequent tailings acidification is limited by two factors: 1) the tailings dam and positive water balance keeps most of the tailings under water cover and away from oxygen; and 2) the clay and silt-rich tailings further maintain high-residual water content and limit the ingress of oxygen. These features of the tailings impoundment have relevance to the selection of final remediation strategies (discussed in Chapter 4).

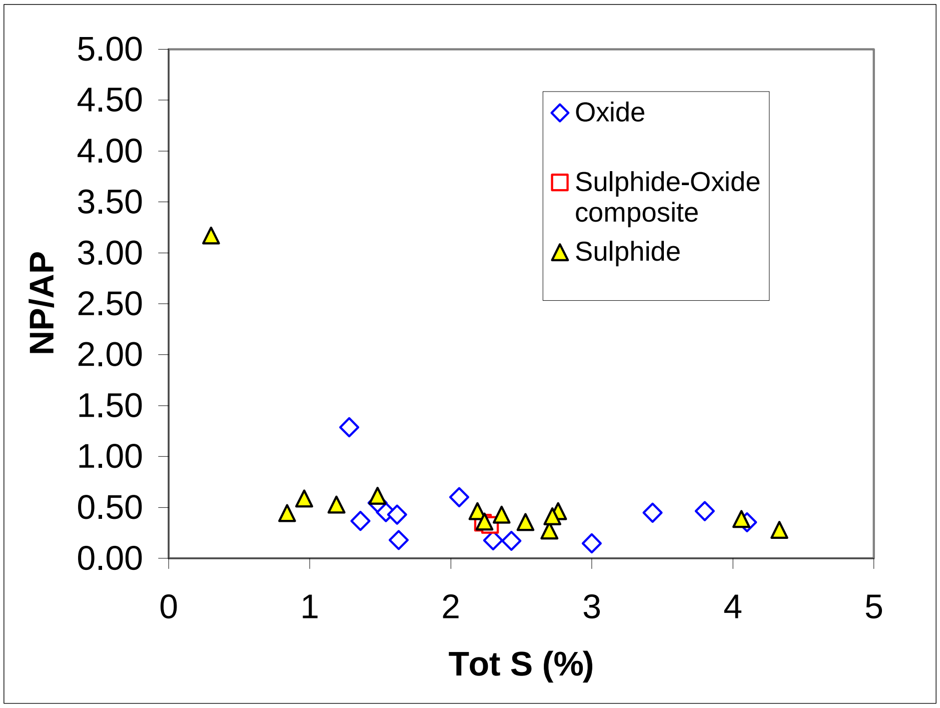

Figure 3-2: ABA characteristics of Mount Nansen Tailings (data from Kwong, 2002).

3.1.3 Sulphate

Sulphate is elevated within the tailings impoundment as a result of sulphide oxidation, which was enhanced by the cyanidation process and buffered by the addition of lime. Sulphate porewater concentrations range from 738 to 1,750 mg/L. Median porewater sulphate concentrations are compared with time-series sulphate measurements of seep and pond waters in Figure 3-3 (Note that the concentration scale is logarithmic).

Seep and pond concentrations demonstrate different behaviour. Pond concentrations vary seasonally, with depressions observed with the input of fresh snowmelt in the spring. Pond concentrations gradually increase over the summer and winter, as porewaters discharge into the pond. Seepage sulphate concentrations are more stable and have steadily decreased over time. Sulphate in seepage appears to be controlled by mineral equilibrium with gypsum ($CaSO_4$), which may be slowly depleting. Long-term solubility control of sulphate by gypsum is dependant upon the availability of calcium, which is released from carbonate minerals upon neutralization of acid produced by sulphide oxidation as demonstrated by the following reaction:

$$Ca^{2+} + SO_4^{2-} + 2H_2O \longrightarrow CaSO_4 2H_2O \qquad (4)$$

In the event carbonate minerals become exhausted, sulphate concentrations may increase beyond the typical seepage concentrations shown in Figure 3-3.

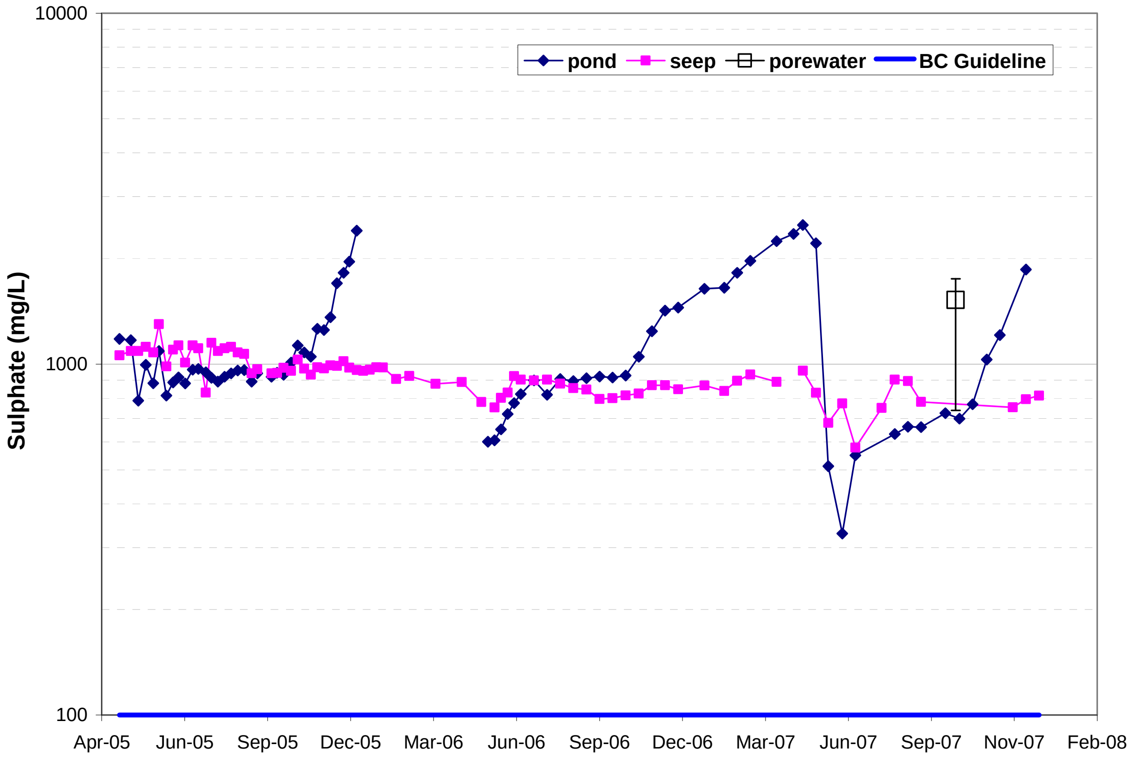

Figure 3-3: Sulphate: median (open square), maximum and minimum porewater concentrations compared to time-series of pond and seepage data.

It is of interest to note that peak pond concentrations for sulphate are in excess of maximum measured porewater. Elevated concentrations of sulphate may be originating from the unsaturated zone or tailings beach due to sulphide oxidation. Porewaters were not collected from the unsaturated zone due to limitations in the field methods employed. Unsaturated porewaters may be collected via centrifuge in the lab, or using in-situ suction lysimeters.

Sulphate concentrations exceed the working BC guideline of 100 mg/L, shown in blue in Figure 3-3. The Yukon Territorial Government has not developed a guideline for sulphate. It is important to note that elevated hardness has been shown to ameliorate sulphate toxicity (Davies, 2003).

3.1.4 Total Cyanide

Cyanide porewater concentrations typically range from 0.014 to 0.093 mg/L (Table 3-3). An anomalous cyanide concentration of 22 mg/L was observed at location B15-20. The range and median porewater concentrations are plotted versus time series of pond and seepage cyanide levels in Figure 3-4. Note that the concentration scale is logarithmic.

Pond and seepage cyanide concentrations have exhibited a gradual decline since 2005, as the porewater source is depleted. Median porewater cyanide corresponds well with recent seepage concentrations. Pond concentrations are typically less than seepage values. The gradual decline in cyanide concentrations suggests that the source of aqueous cyanide is finite and is being depleted.

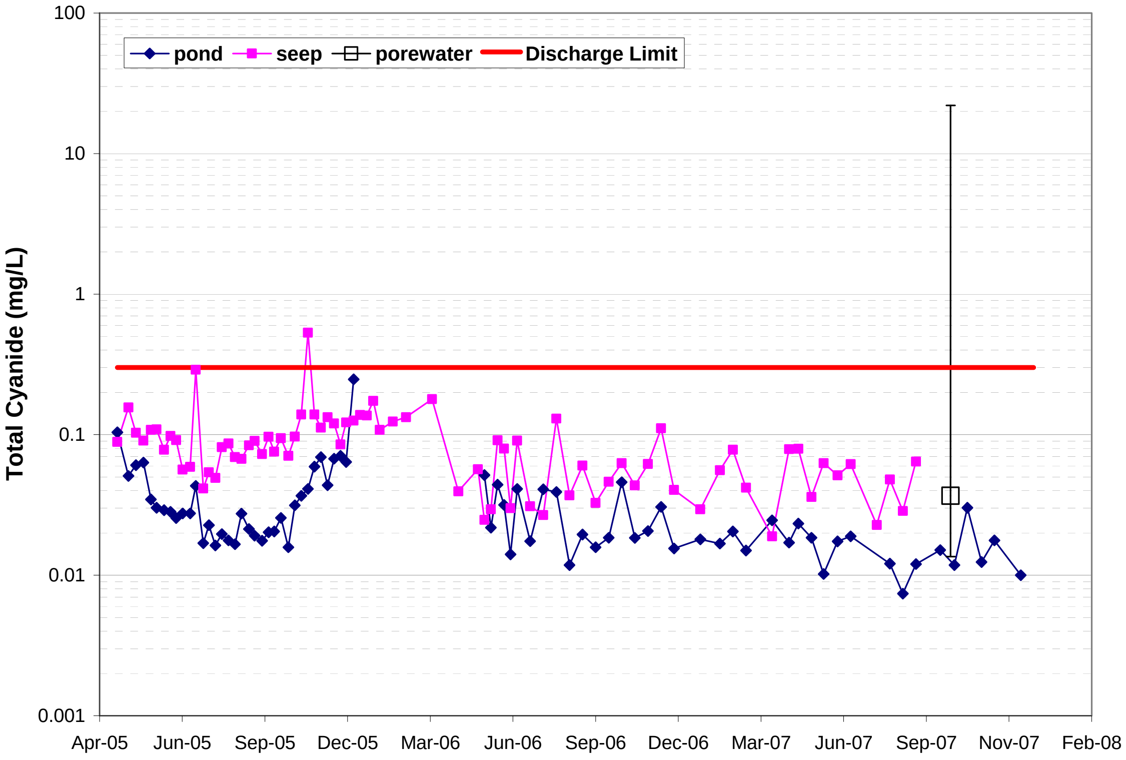

Figure 3-4: Total Cyanide: median (open square), maximum and minimum porewater concentrations compared to time-series of pond and seepage data.

The anomalous cyanide concentration of 22 mg/L (location B15-20 in Table 3-2) may represent isolated porewaters from operations. This premise is supported by the anomalously elevated pH (9.26), sodium concentration (139 mg/L), and thiocyanate (100 mg/L) also measured at this location.

Porewaters may become isolated within the impoundment due to heterogeneity and layering of impermeable clay-rich tails. While elevated pockets of cyanide may be encountered within the impoundment, they appear to be rare and isolated as all other sampled porewaters contained less than 0.1 mg/L cyanide.

Increased dissolved cyanide contributes toward metal solubility. This is evident for porewater collected at B15-20, where concentrations of antimony, arsenic, and in particular, copper were elevated (Table 3-2). Elevated concentrations are presumably due to aqueous complexation with cyanide. WAD cyanide, which provides a measure of the cyanide available for complexation with metals, was 11.8 mg/L at B15-20. WAD cyanide was not measured at the other locations due to the low concentrations of total cyanide.

3.1.5 Thiocyanate

Thiocyanate (SCN) concentrations ranged from below the method detection limit (MDL = 0.5 mg/L) to 100 mg/L in porewaters (Table 3-2). Ten of the eleven samples were between the MDL and 8 mg/L SCN. The maximum SCN concentration (100 mg/L) corresponded with the anomalously elevated cyanide concentration of 22 mg/L in sample B15-20.

Median, maximum and minimum SCN porewater concentrations are plotted in Figure 3-5 and compared to time-series data from the tailings pond and seepage. As with sulphate, pond SCN concentrations are more variable than seepage concentrations, largely due to the influences of spring snowmelt. More recently, pond concentrations have not rebounded over the summer and winter of 2007, suggesting that SCN concentrations are being depleted from the near-surface porewaters.

While pond concentrations have decreased, SCN in seepage has remained consistent since 2005. SCN is an oxidation byproduct of cyanide and sulphide minerals, preferably through chalcopyrite oxidation (McGill, 1984). The majority of SCN formation likely occurred during processing; however tailings degradation, namely cyanide and sulphide oxidation, may contribute toward SCN generation as well. As such, the degradation of SCN is slow compared to that of cyanide.

3.1.6 Ammonia

Ammonia is persistent in the Mount Nansen tailings impoundment as it is a byproduct of cyanide and thiocyanate oxidation/hydrolysis (Lorax, 2006). As pH has stabilized to more neutral levels ($pH<8.5$), ammonia is no longer lost from the system by volatilization, which only occurs on a significant scale above pH 9. Further, ammonia is not susceptible to oxidation to nitrate and nitrate under low oxygen conditions. Since suboxic conditions persist within the tailings subsurface, ammonia is slow to decline (Figure 3-6). Note, however, that since 2005, ammonia concentrations in seepage have slowly but steadily decreased.

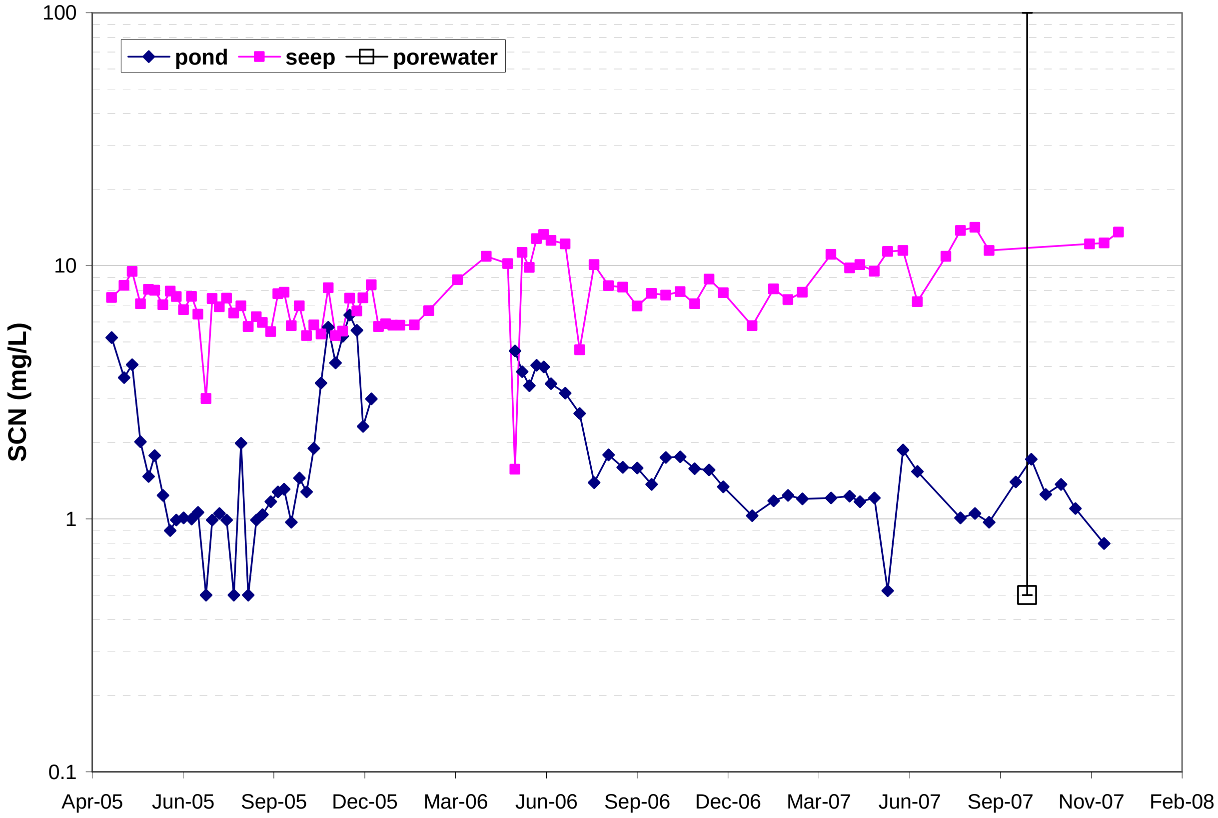

Figure 3-5: Thiocyanate: median (open square), maximum and minimum porewater concentrations compared to time-series of pond and seepage data.

Ammonia concentrations in porewater vary by an order of magnitude and range from 2.8 to 30 mg/L (Table 3-2). Pond concentrations show greater variability, and range from 0.01 to 10 mg/L. Most recently, pond concentrations have shown a dramatic decrease in ammonia over the summer of 2007 from 5 mg/L to 0.2 mg/L. The collective decrease in ammonia sources, namely cyanide and thiocyanate, likely contribute to this sudden decrease. Indeed, ammonia is expected to continue to decrease in pond waters as these sources are depleted.

Seepage and median porewater concentrations of ammonia correspond very well. Seepage concentrations show a subtle decrease over time as ammonia is depleted from the tailings. Seepage concentrations are compared to the Yukon Type B Water License Guideline, as shown in blue if Figure 3-6. While seepage concentrations exceed the guideline (2.5 mg/L), ammonia concentrations are expected to decrease over time as the sources are progressively exhausted.

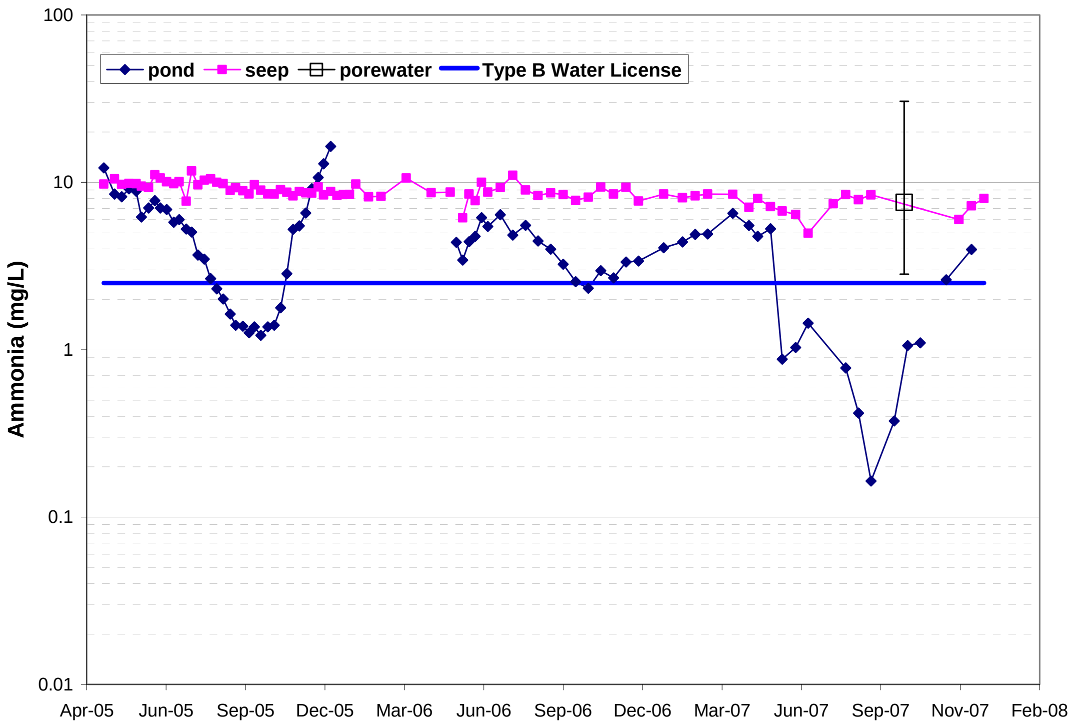

Figure 3-6: **Ammonia: median (open square), maximum and minimum porewater concentrations compared to time-series of pond and seepage data.**

3.1.7 Iron

Iron concentrations measured in tailings porewater vary by nearly three orders of magnitude and range from <0.030 mg/L to 36.6 mg/L (Table 3-2). Iron solubility in near neutral pH waters is controlled by oxidation-reduction processes. Iron hydroxides are abundant within the oxidized tailings. Under reducing conditions, ferrous iron (Fe^{2+}) becomes soluble due to reductive dissolution of iron hydroxide. Figure 3-7 illustrates the negative relationship between oxidation-reduction potential (ORP), measured in millivolts (mV), and iron solubility. As ORP becomes more negative or more reducing, iron becomes more soluble.

Evidence of trends in reductive dissolution processes is evident in Figure 3-8, where iron concentrations in pond and seepage are compared to porewater. Seepage concentrations (~10 mg/L) are typically an order of magnitude higher than pond concentrations (~1 mg/L). These data suggest that reductive dissolution of iron is occurring along the groundwater flow-path from the tailings pond to the seepage collection pond.

The median iron concentration measured in porewaters is approximately 1.8 mg/L and more closely represents pond concentrations. Accordingly, porewater composition is presumably is good metric for redox controls affecting iron solubility in the tailings-pond interface.

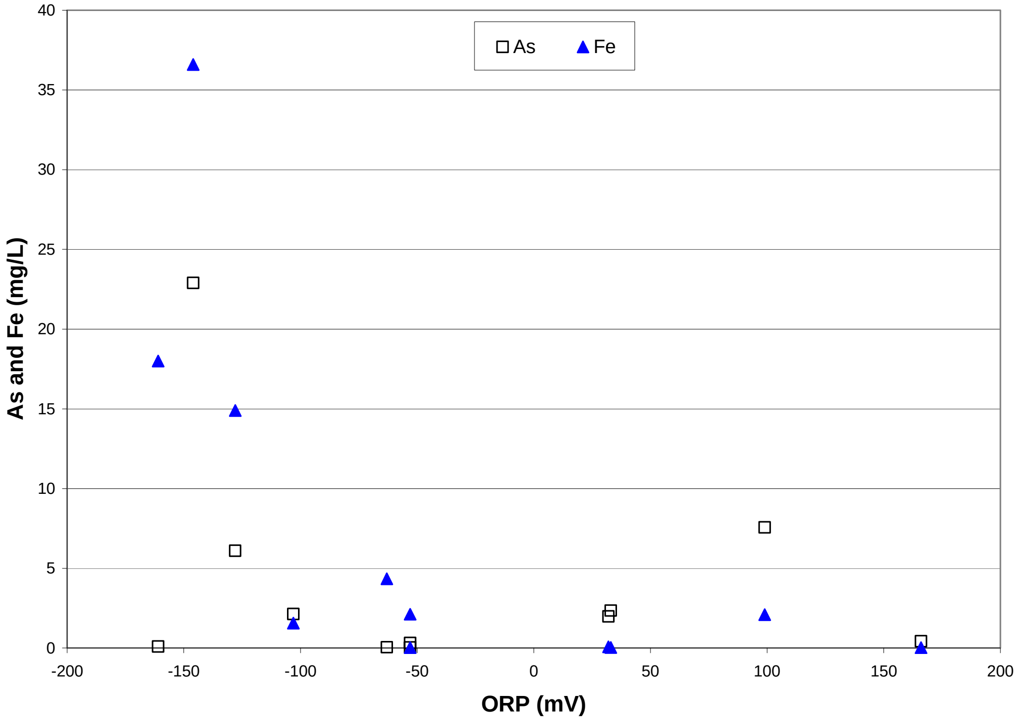

Figure 3-7: **Porewater concentrations of dissolved arsenic (As) and Iron (Fe) compared to oxidation-reduction potential (ORP).**

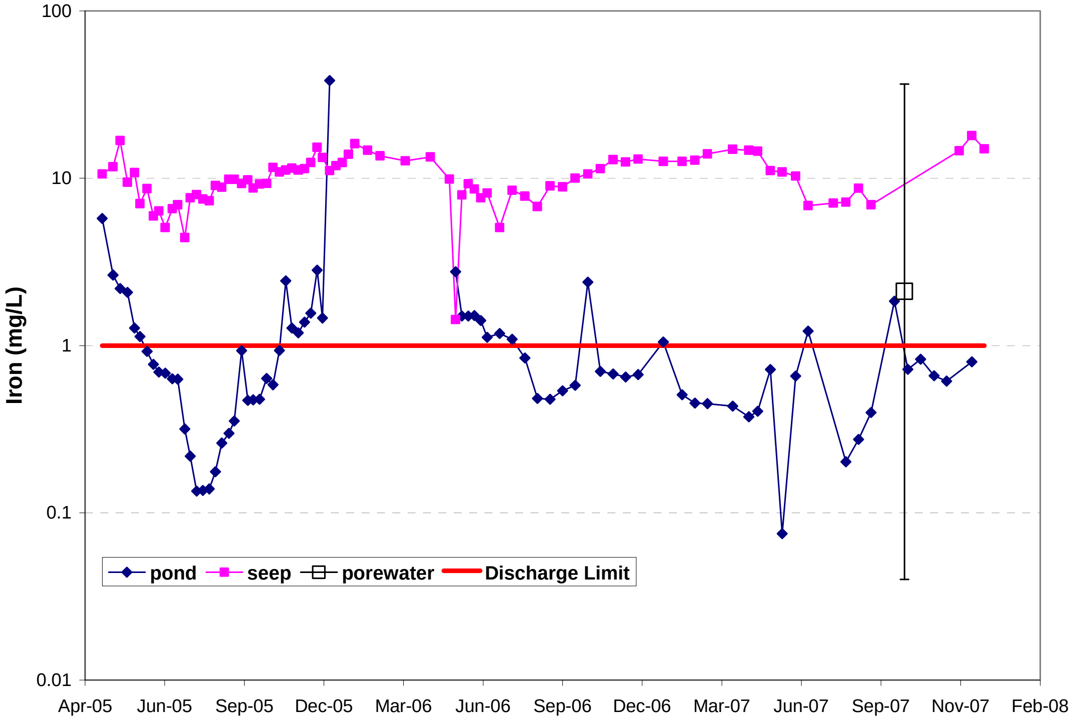

Figure 3-8: **Iron: median (open square), maximum and minimum porewater concentrations compared to time-series of pond and seepage data.**

3.1.8 Arsenic

Of all the parameters examined, only arsenic exhibits median concentrations in tailings porewater which exceed levels in both tailings pond waters and seepages (Figure 3-9). High concentrations in porewater are presumed to reflect remobilization of arsenic-bearing Fe oxyhydroxides which are unstable in the suboxic interior of the saturated tailings (Figure 3-7). Lower arsenic concentrations in seepage waters can be attributed to the removal of arsenic from solution along the seepage flow path. Data for iron and ammonia in seepage waters strongly indicate the presence of porewater suboxia within the tailings at depth, and therefore the attenuation of arsenic is likely related to reductive processes. Possible attenuation mechanisms include the adsorption of arsenite to clay minerals and iron hydroxides and/or the precipitation of arsenic as secondary sulphide phases.

Clay minerals have been shown to provide effective substrates for arsenic removal for both oxidized (arsenate) and reduced (arsenite) species (Violante and Pigna, 2002). Arsenic precipitation as discrete arsenic sulphides (*e.g.*, orpiment) and via co-precipitation with iron sulphides (*e.g.*, pyrite) have also been shown to be important attenuation mechanisms for arsenic in tailings porewaters (Martin and Pedersen, 2002). The abundant clay facies in the underlying deposits in the area certainly suggest that the sorption of arsenic to clay minerals plays a dominant role.

The behaviour of arsenic observed here is similar to that seen for other clay-rich environments hosting tailings in northwestern Ontario and British Columbia. In northwestern Ontario at the Cochenour Wilanour Mine (Red Lake district), arsenic concentrations in porewaters decrease from ~60 mg/L to <0.01 mg/L along a 50 m groundwater flow path, and indicate that arsenic is removed from pore solution within the silt/clay unit which underlies the tailings impoundment (Lorax, 2004a). At another site in British Columbia, dissolved arsenic values in seepage waters (most values <0.010 mg/L) were approximately two orders of magnitude lower than tailings pond values (~2 mg/L). The data suggest that the very low arsenic concentrations in seepages at the B.C. site reflect the attenuation of arsenic through adsorption/co-precipitation mechanisms in a clay-silt stratum underlying the tailings impoundment (Lorax, 2007).

The specific mechanism(s) governing arsenic removal within the tailings environment at Mt. Nansen cannot be accurately determined with the available data. However, given the affinity of both oxidized and reduced forms of arsenic for clay minerals, the removal of arsenic via adsorption mechanisms is certainly plausible. Dissolved sulphide in porewaters was not measured, and therefore the potential for arsenic sulphide precipitation cannot be verified.

With regards to the longevity of the arsenic attenuation process, passive removal through adsorption is finite given the limited number of arsenic adsorption sites. Although the time period to achieve site saturation cannot be quantified with the available information, data for other clay-rich sites have shown that such mechanisms are still active after 60 years (Lorax, 2004a). In contrast, the removal of arsenic through sulphide precipitation is not limited by the availability of adsorption sites. Rather, such mechanisms are typically limited by a labile source of organic matter or reducible sulphate.

Arsenic porewater concentrations are highly variable and range from 0.04 to 23 mg/L (Table 3-2). Arsenic behaviour is intimately related to iron behaviour in Mount Nansen tailings. Arsenic sources include scorodite and arsenic-bearing iron hydroxides. The relationship between iron and arsenic solubility in tailings is most clearly demonstrated in Figure 3-7, which illustrates their redox behaviour.

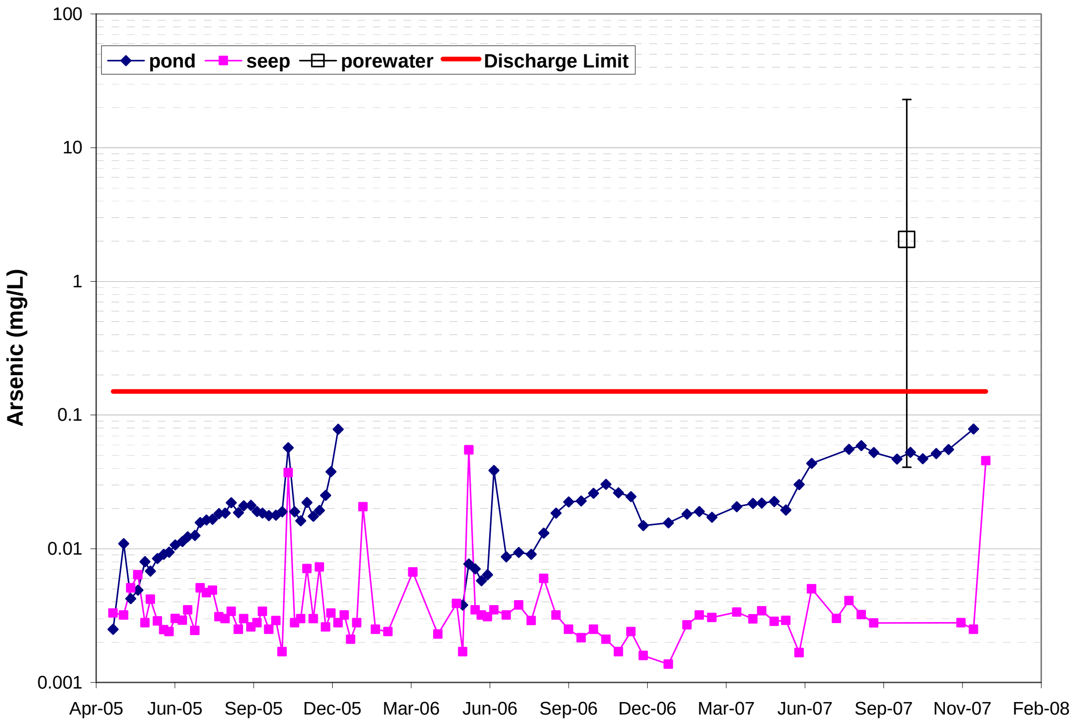

Figure 3-9: Arsenic: median (open square), maximum and minimum porewater concentrations compared to time-series of pond and seepage data.

Trends in arsenic behaviour in the tailings pond and seepage are illustrated in Figure 3-9 and compared to porewater. Pond arsenic concentrations, while seasonally variable, have shown a subtle increase since 2005 from 0.002 mg/L to 0.09 mg/L. Dissimilar to iron, pond arsenic concentrations are higher than in seepage and suggest arsenic is less mobile than iron. Seepage values are more consistent and typically fall below 0.01 mg/L, well below the discharge limit of 0.1 mg/L.

With regards to the arsenic removal mechanism, both adsorption and precipitation mechanisms are possible. The capacity to remove arsenic via adsorption to mineral surfaces (*e.g.,* clays) is finite, and will be dependent on the arsenic loading and on the number of available sorption sites. The latter will be dependent on the path length and composition of subsurface materials. In the context of this study, such adsorption mechanisms can be considered to be irreversible. In reality, there will be a minor degree of exchange over time, with some of the arsenic being displaced with competing ions (carbonate, phosphate, etc.). The effect of such exchange is predicted to be insignificant. A scenario which could result in a pronounced reversibility of arsenic adsorption would be a drop in pH associated with the development of acidic conditions within the impoundment. With regards to arsenic precipitation as As-bearing sulphides, this process is not limited by the availability of sorption sites. If geochemical conditions currently exist for sulphide precipitation, these conditions are unlikely to change. Further, the overwhelming abundance of sulphate in the system relative to arsenic suggests that this removal mechanism would not be limited and could persist indefinitely or until arsenic were removed from solution. The formation of secondary arsenic sulphides can be considered to be irreversible as long as such phases remain in a saturated environment.

Different mechanisms may be responsible for the different behaviour observed in the pond and seepage. It is plausible that oxidation and/or sorption is occurring for porewaters discharging into the tailings pond, while reduction and sulphide precipitation and/or sorption of arsenic is more likely occurring along the groundwater seepage flowpath beneath the tailings impoundment.

3.1.9 Antimony

Antimony is considered relatively mobile in natural environments, particularly in oxic environments (Krupka, 2002). Antimony is known to exist as a sulphide mineral within the tailings impoundment (Jambor, 2005). While meaningful long-term data do not exist for antimony at Mount Nansen, available data support the notion that antimony is mobilized from oxidation processes where tailings are exposed to oxygen. Pond antimony concentrations are nearly two orders of magnitude greater than in the seep (Figure 3-10). While pond and porewater concentrations are elevated, seep concentrations of antimony remain much lower than discharge limits.

Median porewater concentrations are similar to measured pond concentrations and are much higher that typical seepage concentrations. These observations suggest that attenuation mechanisms for antimony are occurring within the tailings mass. Antimony is not particularly susceptible to adsorption mechanisms (Legoux *et al*, 1992). Therefore, attenuation mechanisms are likely limited to precipitation as secondary sulfosalt precipitates or, under reducing conditions, as secondary sulfide phases. Indeed, the sulfosalt jamesonite [$Pb_4FeSb_6S_{14}$] has been identified within the tailings mass (Jambor, 2005).

3.1.10 Copper

Copper is abundant within the tailings solids, and occurs primarily with iron hydroxide with minute amounts of chalcopyrite (Jambor, 2005). The abundance of copper-iron hydroxides demonstrates the affinity copper has for oxidized iron. These precipitates are presumably a by-product of chalcopyrite oxidation and were likely formed during the cyanidation process. Chalcopyrite is particularly susceptible to cyanidation and exhibits among the highest sulphur conversions to thiocyanate of sulphide minerals (McGill, 1984).

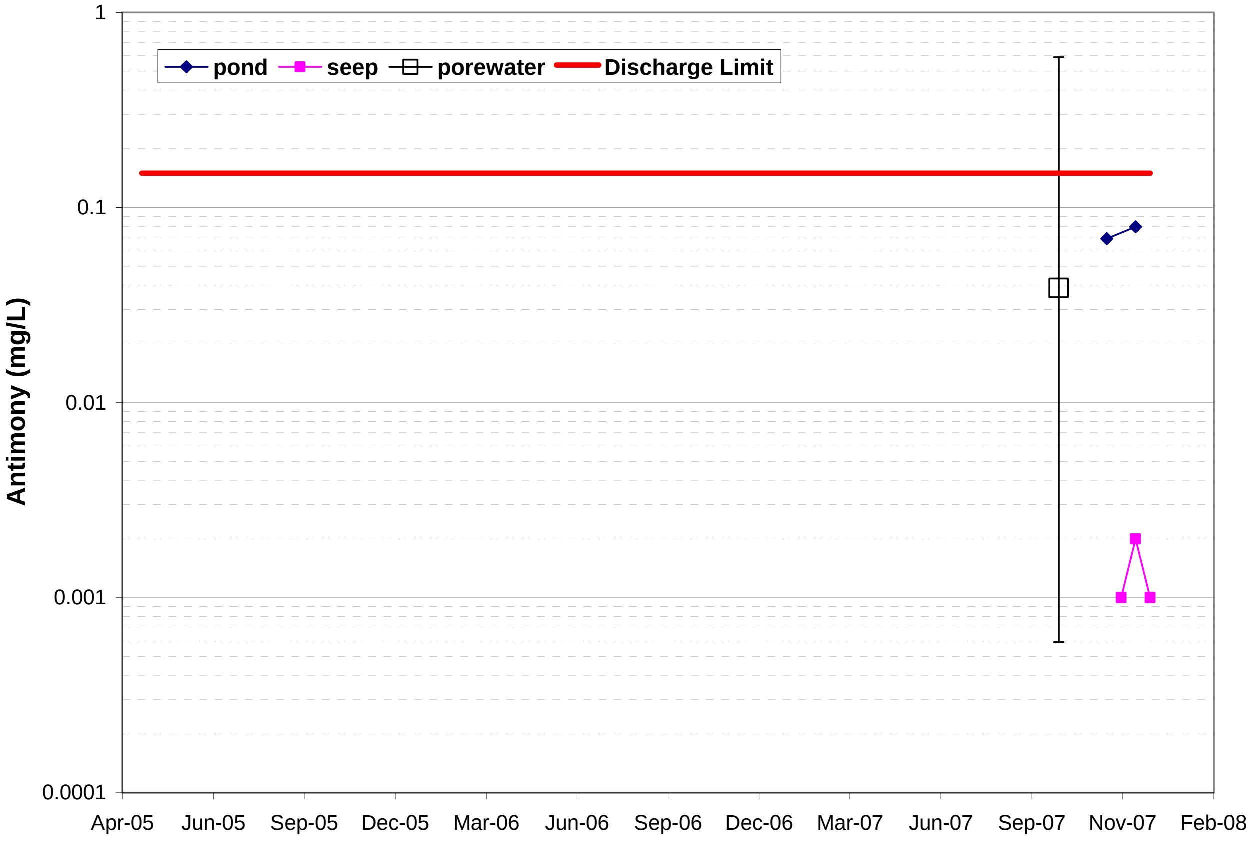

Figure 3-10: Antimony: median (open square), maximum and minimum porewater concentrations compared to time-series of pond and seepage data.

Copper is highly variable within tailings porewater, ranging from 0.0011 to 7.57 mg/L. Local variability of aqueous copper appears to be controlled by aqueous cyanide and the presence of iron hydroxide. Pond copper concentrations are more stable and typically range from 0.01 to 0.1 mg/L (Figure 3-11). Seepage concentrations are typically less than the method detection limit (0.01 mg/L) and are more similar to median porewater concentrations (0.004 mg/L), demonstrating that attenuation is occurring within the tailings mass. Copper concentrations in seepage are typically below 0.01 mg/L, well below the discharge limit of 0.2 mg/L. Possible attenuation mechanisms for Cu are the same as those described for arsenic, including the precipitation of secondary sulphide minerals and/or sorption to clay minerals.

The most abundant phase of copper within the tailings impoundment appears to exist as a co-precipitate within iron hydroxide. The potential for enhanced leaching of copper is balanced by two mechanisms: 1) reductive dissolution of copper-bearing iron hydroxides; and 2) metal leaching induced by acidification and reduction in pH resulting from acid mine drainage. Neither mechanism appears to be at play under the current scenario.

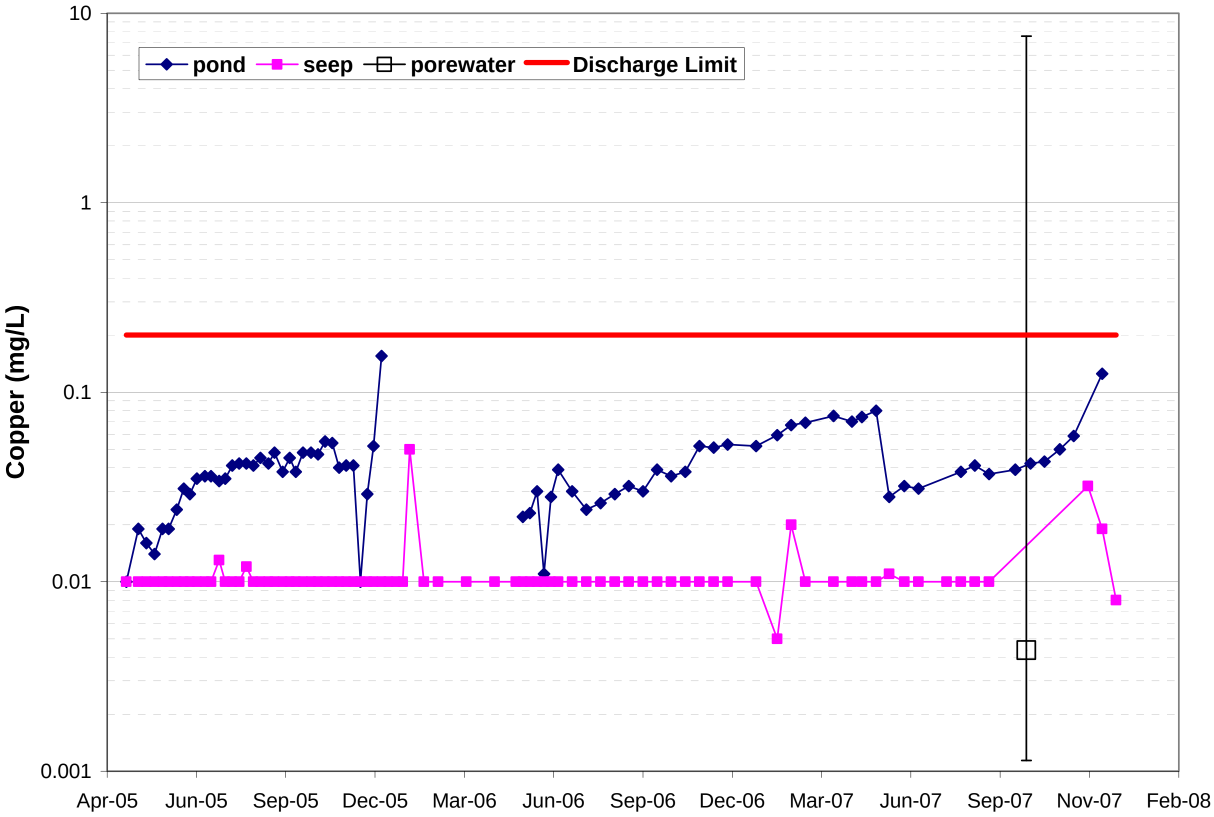

Figure 3-11: Copper: median (open square), maximum and minimum porewater concentrations compared to time-series of pond and seepage data.

3.1.11 Zinc

As with copper, zinc appears to be attenuated within the tailings mass. Seepage concentrations are consistently much lower than in the pond (Figure 3-12). Zinc is more mobile than copper and less abundant within the tailings impoundment, both as a sulphide and as a secondary mineral. Pond water concentrations show high variability similar to sulphate and are reflective of the relatively high-solubility of zinc in oxic environments. Indeed, sulphate release and zinc release may be closely linked by sulphide oxidation. Similar to antimony, median zinc porewater concentrations more closely resemble the pond, which can be attributable to their mobile nature in oxic environments.

As with copper, the long-term susceptibility to leaching is balanced between the potential for reductive dissolution of secondary minerals and the oxidation of primary sulphides. Under the current geochemical regime, zinc seepage concentrations are typically below 0.02 mg/L and well below the discharge limit of 0.3 mg/L.

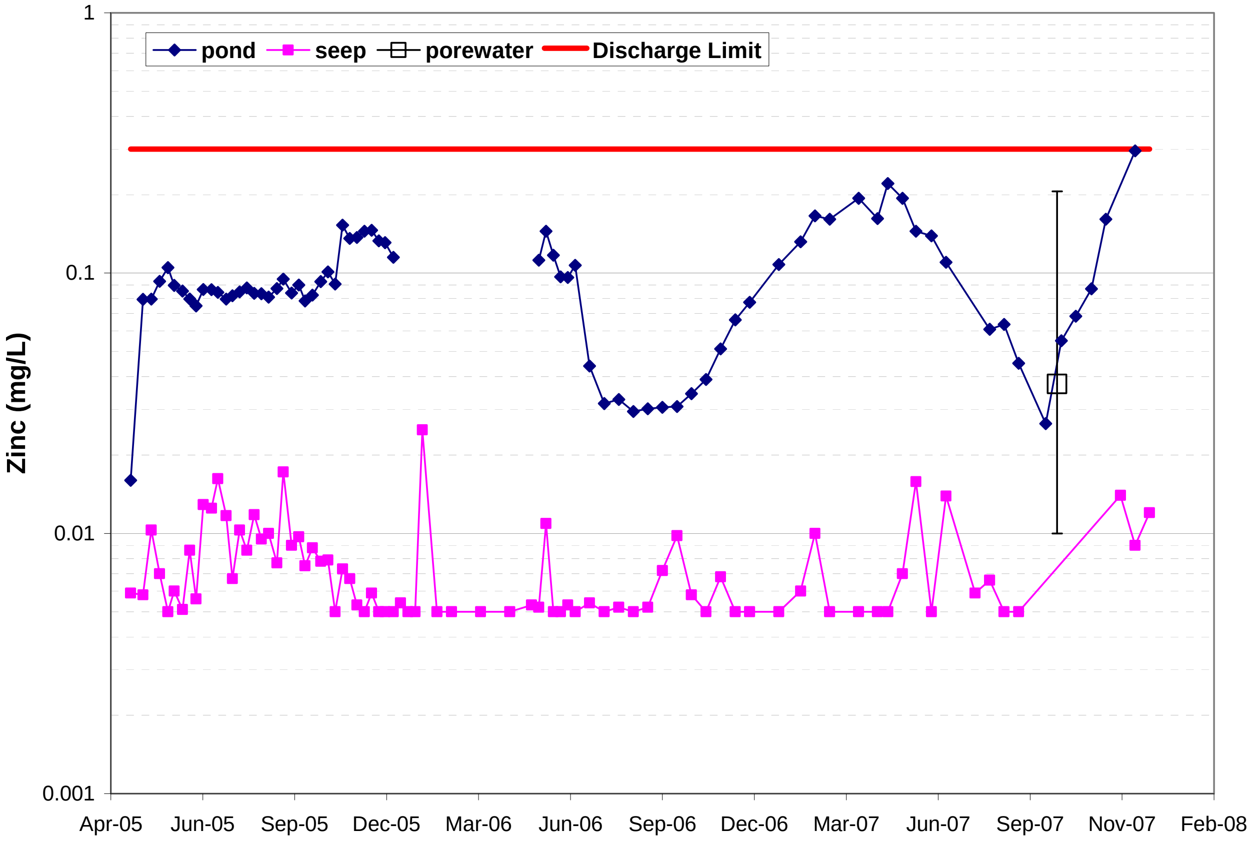

Figure 3-12: Zinc: median (open square), maximum and minimum porewater concentrations compared to time-series of pond and seepage data.

3.2 Comparison to Historic Data – Canmet Porewater Data

In assessing the trends in porewater geochemistry, historical porewater data were compiled and evaluated from Kwong (2002). Average porewater results from the same borehole locations and depths were compared to average porewater results collected for this assessment. Data are compared in Table 3-3 as percent changes. It is interesting to note that all parameters of interest showed a decline in average concentration except for antimony, arsenic, iron, and zinc.

Upon inspection of the Kwong (2002) data, it is apparent that appropriate precautions were not taken to avoid oxidation artifacts during sample collection. Specifically, the porewaters were allowed to oxidize prior to filtration and preservation. As a result, soluble iron and arsenic presumably oxidized and precipitated from solution, providing deceptively low values. Such oxidation artifacts also have the potential influence other parameters which precipitate with iron oxyhydroxides, including Cu. Accordingly, the trace element data in the Kwong (2002) study should be viewed with caution.

Table 3-3:
Increase in porewater concentration from 2002 (Kwong) to 2007 (Lorax), Mt. Nansen Tailings Pond.

Parameter	Median	Mean
pH	-14%	-8%
Ammonia-N	-80%	-59%
Sulphate	-29%	-35%
Total CN	-98%	-78%
SCN	-100%	-93%
Antimony	-17%	**201%**
Arsenic	**1152%**	**1087%**
Copper	-100%	-86%
Iron	**1951%**	**1733%**
Lead	-20%	-17%
Zinc	**103%**	**111%**

Increases in antimony and zinc may reflect the readily mobile nature of these elements as discussed above. Indeed, the increase in their concentration may be the result of sulphide oxidation. This may be supported in part by the decrease in average porewater pH. The decrease in sulphate concentrations may be a relic in sampling methodology, as gypsum solubility could be increased from the sampling of tailings by sonic vibration. Decreases in cyanide and its by-products suggests that the sources of these parameters are finite and becoming progressively exhausted. Additionally, copper has shown a significant decrease in porewater concentration over time.

4. Conclusions and Recommendations

4. Implications and Recommendations

In the following chapter, implications for closure options are discussed based on the results from the tailings porewater analysis, as well as on data from other studies relating to the tailings pond and open pit. The report concludes with discussion of recommendations for tailings management and future study.

4.1 Implications for Closure Options

4.1.1 Overview

The data presented in Chapter 3 show a variation in geochemical behaviours for the main parameters of concern associated with the tailings facility. Comparison of water chemistry for the pond, tailings porewater and seepage shows that for antimony, arsenic, copper and zinc, the lowest concentrations occur in seepage waters. These elements are removed from pore solution along the seepage path length, presumably due to adsorption with clay minerals and/or precipitation as secondary sulphides. In this manner, the tailings facility affords both containment and attenuation of tailings-influenced drainages. Although the tailings show some potential for the development of acidic seepages, pH is currently circumneutral.

In contrast, total-CN, thiocyanate (SCN), ammonia and iron show higher concentrations in seepages and porewaters in comparison to tailings pond values. The presence of residual cyanide compounds is implicitly tied to ammonia levels, whereby the hydrolysis/oxidation of thiocyanate presents a continued source of ammonia to porewaters. In the suboxic porewater environment, ammonia is relatively stable, and therefore ammonia shows elevated values in both porewaters and seepage waters. The high concentrations of dissolved Fe are also consistent with the presence of a strongly suboxic porewater environment. Specifically, at circum-neutral pH, dissolved Fe cannot exist in significant concentrations in the presence of molecular oxygen. The abundance of the former, therefore, is a strong indicator of porewater suboxia.

The suboxic porewater environment also contributes to elevated levels of dissolved arsenic. Of all the parameters examined, only arsenic exhibits concentrations in tailings porewater that exceed levels in both tailings pond waters and seepages. Such observations presumably reflect the addition of arsenic to pore solution via the reductive dissolution of arsenic-bearing Fe oxyhydroxides. Low values for arsenic in tailings pond seepages suggest that arsenic is attenuated at the deeper horizons within the impoundment along the seepage flow path through the sorption mechanisms described above.

The compositional information derived from the porewater study, as well as the behavioral characteristics of tailings-related contaminants inferred from this study and others, have relevance to the potential placement of tailings in the Brown-McDade Pit. The data also have relevance to other potential tailings management options. Possible management scenarios include:

- In-Pit Tailings Disposal: Re-location of tailings to Brown-McDade Pit.
- Status Quo: Maintenance of existing tailings management facility and associated monitoring programs; and
- Tailings Pond Reclamation: Removal of water cover to reduce potential geotechnical instability through materials re-handling, cover application and associated water management.

In the following sections, each of these scenarios are discussed from the perspectives of current and future environmental liability, geotechnical stability and mitigation opportunities.

4.1.2 In-Pit Disposal

The in-pit disposal of tailings to the Brown McDade pit lake offers several potential advantages over the long term. These include: a) geotechnically-sound containment and associated elimination of the potential long-term liability associated with the maintenance and management of a water-retaining dam; b) enhanced stability of sulphide-bearing tailings through the potential for the permanent submergence of tailings materials; c) increased containment of tailings-related drainages, allowing for more control over environmental compliance; and d) potential for natural attenuation of contaminants which migrate out of the pit lake through the groundwater environment.

Disadvantages associated with in-pit tailings placement relate to potential for water quality degradation of surface and groundwater reservoirs. The re-location of tailings to the Brown McDade Pit has the potential to influence pit water quality in three ways: 1) the introduction and mixing of tailings porewater with pit lake waters during the tailings disposal period; 2) the short-term dissolution of soluble tailings components upon submergence; and 3) the long-term diffusion-controlled release of remobilized constituents from the tailings to the overlying water column. The considerations described above are explored in more detail in the following paragraphs.

Given a tailings volume of approximately 225,000 m^3, and an estimated void volume of 35%, the re-location of tailings to the Brown McDade Pit will entail the transfer of ~44,000 m^3 of tailings porewater. Upon tailings placement, a significant portion of this porewater volume will be expected to mix in the water column of the existing pit lake. Accordingly, depending on the relative volumes of the tailings and pit lake and their respective compositions, the process of tailings disposal has the potential to influence pit lake chemistry through this mixing process.

In order to assess the potential influence of tailings porewaters on pit lake chemistry, their compositions were compared (Table 4-1). Tailings porewaters contain elevated levels of several parameters in comparison to recent (2007) water quality values for the Brown McDade Pit. Parameters showing significantly elevated levels in tailings porewaters in comparison to pit data include ammonia, aluminum, antimony, arsenic, copper, iron, lead, molybdenum, nickel, selenium and silver. Of these, ammonia, arsenic and copper exist at levels in porewater which are significant in terms of their potential to negatively affect aquatic communities. Depending on the pit lake volume at the time of tailings transfer, the introduction of tailings porewaters to the pit will have a variable influence on pit lake chemistry. In this regard, draining the pit completely prior to tailings placement should be considered as part of the feasibility assessment. Tailings placement into an empty void would obviate the mixing processes described above, and serve to better isolate, both physically and chemically, the tailings solids and porewaters in the bottom of the pit. Further, if the development of a stratified system is a desired feature at closure, the placement of tailings into a “dry” pit will better facilitate such conditions. The origins and potential benefits of pit lake stratification have been described in detail in Lorax (2006).

The dissolution of soluble oxidation products has the potential to greatly increase the contaminant load to the pit upon tailings placement. Specifically, oxidation products which have accumulated in unsaturated and periodically unsaturated tailings deposits will be expected to exhibit increased solubility in permanently saturated conditions. Such phases include sulphate salts, metal carbonates and metal oxides/hydroxides. The potential loading realized from such mechanisms cannot be quantified with the available data. Testwork, such as large-scale Shake Flask Extractions, could be used to better estimate the significance of this process.

In addition to the short-term release of readily soluble oxidation products, longer-term metal remobilization may be realized through the reductive dissolution of redox-sensitive components. In Lorax (2006), numerous redox-sensitive secondary phases were identified which may become more soluble under permanently saturated conditions, including:

Table 4-1:
Comparison of 2007 mean values for tailings porewater (n=11) with water quality values for Brown McDade Pit (December 2007 data). All units in mg/L unless specified.

	Tailings Porewater	Pit Lake (Dec 2007)		
Parameter	**Mean (2007)**	**Top**	**Middle**	**Bottom**
pH (units)	7.8	7.69	7.59	7.42
Alkalinity	169	158	180	250
Hardness	1261			
Sulphate	1343	733	945	1660
Total CN	2.2			
WAD CN	<2.2			
SCN	11.9	0.8	0.9	0.6
Ammonia-N	13.3	0.1	0.1	0.25
Nitrate-N	0.115	0.82	0.57	<0.05
Nitrite-N	0.024	<0.005	<0.005	<0.02
Aluminum	0.040	<0.005	<0.005	<0.005
Antimony	0.13	0.0095	0.0062	0.0006
Arsenic	4.39	0.0177	0.0147	0.0091
Cadmium	0.00044	0.00241	0.00599	0.00972
Copper	0.78	0.016	0.017	0.012
Iron	6.18	<0.01	<0.01	<0.1
Lead	0.0036	<0.0001	<0.0001	<0.0001
Molybdenum	0.019	<0.001	<0.001	<0.001
Nickel	0.0152	0.002	0.0022	0.0032
Selenium	0.0025	<0.0002	0.0003	0.0002
Silver	0.0019	<0.0001	<0.0001	<0.0001
Zinc	0.060	0.519	1.05	1.43

- Fe oxyhydroxides present as isolated particles;
- Arsenic, copper, lead, and zinc-bearing Fe oxyhydroxides present as alteration rims on sulphide grains; and
- Fe-arsenate ($FeAsO_4$) as oxidation rims on arsenopyrite.

Given the phases present in the tailings, the release of arsenic to pit waters and underlying groundwater is of primary concern. Under pit conditions with a permanent water cover (non free-draining), the release of arsenic from the tailings to the overlying water column will be diffusion controlled, in which both arsenic and iron will be released to porewaters, and subsequently to the water column, upon the reductive dissolution of arsenic-bearing Fe oxyhydroxides. This form of arsenic release has been shown to have a pronounced influence on the water quality in shallow lakes (Martin and Pedersen, 2002). The magnitude of the arsenic flux to the water column has also been shown to be highly sensitive to nutrient inputs (nitrogen and phosphorus) (Martin and Pedersen, 2003, 2004). The considerations described here formed the foundations for recommendations outlined in Lorax (2006), which did not advise fertilization of the tailings pond as a bio-remediation strategy.

Potential measures are available to offset the release of arsenic and other contaminants to the water column of the pit lake, should such processes warrant mitigation. Specifically, locally available overburden (*e.g.*, till sands) could be potentially used as a diffusion barrier to reduce the flux of contaminants across the sediment-water interface. Since the transport of arsenic and other contaminants across the benthic boundary of the lake is predicted to be diffusion controlled, the placement of a barrier of inert material can retard the flux by increasing the diffusive path length. It is likely this form of mitigation could only be effectively achieved in a drained pit, given quality control considerations for the application of this form of cover system.

Under conditions of a non free-draining pit, the various mechanisms of arsenic release described here may not be amendable to the attenuation mechanisms currently observed in the tailings facility. The mode of passive removal currently observed relies on a suboxic seepage flow path through clay-rich materials. Such conditions may not be achieved in a non free-draining system. Conversely, in a free-draining pit, significant attenuation may be afforded in the subsurface environment for contaminants released to tailings porewaters and pit surface waters. The draining properties of the pit will largely depend on how the placement of tailings will affect the permeability of the pit bottom. Given the clay-rich and low permeable nature of the tailings, lower seepage rates out of the pit may occur following tailings placement. More detailed modeling would be required to assess the final water elevation in the pit under contrasting water balance scenarios.

4.1.3 Status Quo

The current management plan for the tailings facility involves the seasonal discharge of tailings pond effluents directly to the Dome Creek diversion ditch as well as ongoing seepage through the dam into the seepage collection pond. The water management scheme also involves the diversion of surface waters through a ditch around the pond and back into Dome Creek immediately below the seepage return pond. Inputs to the pond include direct precipitation, runoff from its own small catchment, and unknown groundwater contributions.

In overview, the advantages of maintaining the current management scheme relate to cost and the current level of passive remediation occurring within the facility for trace elements such as arsenic. In contrast, the existing environmental liability associated with the tailings facility relates to: a) elevated ammonia concentrations in porewater and seepage water associated with the oxidation/hydrolysis of residual cyanide compounds (primarily thiocyanate). Other parameters including WAD cyanide, total cyanide and other trace elements are of less concern; b) un-oxidized sulphide minerals potentially capable of producing neutral drainage and/or acid-drainage problems; c) arsenic-hosting oxide phases which may be capable of release under certain redox conditions; and d) geotechnical/monitoring concerns with regards to the maintenance of a water retaining structure. Each of these are briefly summarized below.

With regards to ammonia, concentrations in seepage waters appear to be decreasing slowly over time as the inventory of residual cyanide compounds is also depleted. Given that there are no other significant sources of ammonia in the system, a continual decline in concentration is predicted to occur concomitantly with thiocyanate. Shorter-term fluctuations in ammonia levels in seepages may also occur in response to water balance variations (*e.g.,* dilution). In the long-term, the potential environmental liability associated with ammonia is predicted to decrease.

The potential for the development of acidic rock drainage (ARD) presents a significant concern for the tailings facility. Static test work conducted on both oxide and sulphide tailings fractions show the majority of Net Potential Ratios to be less than 1. This implies that in the absence of mitigating factors, the tailings deposits are likely to generate acid in the future. The major factor that may limit the development of acidic drainage is the low permeability of the tailings deposits and their tendency to remain saturated conditions in close proximity to the tailings surface. In this manner the depth and associated seasonal fluctuations of the phreatic surface has important relevance to the long-term mitigation of ARD. Of particular relevance, is the potential for ARD to develop in the coarser and largely unsaturated beach deposits adjacent to and within the tailings dam.

Although the porewater data indicate elevated levels of arsenic in comparison to seepage and pond values, attenuation mechanisms occurring along the seepage flow path result in the removal of arsenic to values typically <0.005 mg/L. Evidence for trace element attenuation is also evident for Sb, Cu, and Zn. As outlined in Chapter 3, the form of attenuation seen here may be finite depending on the removal process (adsorption *versus* precipitation), and therefore continual monitoring will be required to verify attenuation is ongoing.

An obvious benefit of tailings relocation to the pit is the removal of the geotechnical liability associated with the maintenance and monitoring a permanent water-retaining dam. This aspect is not discussed in detail here.

4.1.4 Tailings Pond Reclamation

Reclamation of the tailings pond offers potential benefits with regards to water management of the tailings area relative to the current condition. Through removal of the ponded zone and application of a cover system, several advantages are possible including:

- Reduction in geotechnical liability associated with removal of the ponded zone;
- Minimization of unsaturated conditions within the tailings deposits through effective grading and cover placement; and
- Continued exploitation of the passive removal mechanisms which provide effective containment of arsenic, antimony, copper, lead and zinc.

The volume of unsaturated tailings may be minimized via selective grading and placement of the tailings. Conductive tailings masses, such as the tailings beach, may be relocated to the pond and covered with less permeable tailings and/or clay cover to form a saturated or perched cover. Additionally, tailings masses that are currently elevated above the pond could be graded to inhibit drainage.

The disadvantages of such measures relate to the removal of water storage in the tailings pond (contingency for pump back) as well as the uncertainty relating to the potential longevity of the attenuation mechanism(s) and long-term effects of cover material on the stability of redox sensitive parameters such as arsenic, copper, lead, and zinc.

4.1.5 Summary

The preferred closure option for the Mount Nansen tailings is disposal within the Brown-McDade Pit. The chief concern posed by this closure option relates to the long-term geochemical stability of the tailings and effects on pit lake and groundwater seepage quality. Ramifications of deteriorating water quality relate to contaminant loadings to the receiving environment and effects on downstream aquatic receptors (namely fish). Deterioration of water quality associated with the tailings mass may arise from three mechanisms: 1) enhanced metal leaching resulting from the oxidation of sulphide minerals and potential for acid mine drainage; 2) reductive dissolution of redox sensitive phases (Fe oxyhydroxides) and commensurate remobilization of parameters such as arsenic, copper, lead, and zinc; and 3) exhaustion of attenuating mechanisms currently observed within the tailings mass.

Several parameters, including arsenic, copper and zinc, show natural attenuation within the tailings impoundment. While it is uncertain how long these mechanisms will persist, the performance and longevity of these mechanisms are unlikely to change if the tailings are relocated to the pit. Further, the potential for ARD and reductive dissolution of tailings components exists for each closure scenario. Placement of the tails in the pit affords additional advantages by providing a physically stable environment and minimizing the amount of flow the tailings are exposed to (and ultimately minimizing the loading of constituents to the environment).

The chief concerns relating to geochemical stability may be mitigated by taking specific measures when placing the tailings in the pit. The potential for acid generation largely relates as to whether the tailings will remain saturated within the pit. While recent observations have suggested that pit lake levels have slowly decreased since 2006, it is unlikely that the tailings will become completely unsaturated within the pit due to their ability to retain water. To facilitate adequate water coverage, clay-rich tails may be selectively placed on the final lifts within the pit. Additionally, a lime amendment could be added to the tails to offset the potential for acid mine drainage to occur. Conversely, if a pit lake develops above the tailings, ARD will not be a concern. Rather, the dominant loading mechanism under such conditions will be the reductive dissolution of Fe-oxide phases and associated remobilization of arsenic and other trace elements. If a pit lake is predicted to exist over the long term, concerns over the release of contaminants from the tailings to the water cover may be effectively mitigated through the placement of a diffusive cover above the tailings. This could entail the selective placement of clean overburden materials for the final lifts within the pit.

4.2 Recommendations

In order to advance closure planning for the site, and to further assess the potential environmental liabilities associated with in-pit tailings placement, strong consideration should be given to generating a detailed water balance for the pit. This form of exercise would be used to estimate pit-lake water elevations for varying water balance scenarios (wet years, dry years, *etc*.), and help address the fundamental question as to whether or not the tailings will remain permanently saturated (permanent water cover), seasonally saturated (ponding during freshet) or unsaturated. The current understanding of the pit water balance is limited (Lorax, 2004). The pit water balance question has enormous relevance to making scientifically-defensible predictions with regards to the likelihood of

ARD developing in the future. The revised pit lake water balance would also lend itself toward providing pit lake water quality predictions following tailings relocation, as well as providing guidance toward mitigation measures applied to the tailings upon relocation to the pit (*ie*: lime amendment if unsaturated). The types of information required to develop a detailed water balance would include:

- Accurate records of the seasonal and inter-annual changes in the volume of the current lake;
- Applicable meteorological data (precipitation, temperature, pan evaporation);
- Flow measurements for dominant inflows and outflows; and
- Conceptual understanding of the hydrogeologic conditions within the pit (vertical gradients, permeability).

Additionally, shake flask tests should be run on the tailings prior to relocation. These tests should be done on unsaturated beach material and on saturated tailings. Results will provide an indication of water soluble minerals and their potential effects on pit lake water quality.

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Appendix A:
Analytical Results and Field Measurements

Project 844-1 MT. NANSEN
Report To JUSTIN STOCKWELL, LORAX ENVIRONMENTAL SERVICES
ALS File No. L561468
Date Received 02-Oct-07
Date 16-Jan-08

RESULTS OF ANALYSIS

				BH-4-5 Duplicate			BH-6-7 Duplicate					
Sample ID	BH-4-3	BH-4-5	BH4-10	BH5-5	BH-6-5	BH-6-7	BH-6-17	BH-15-10	BH-15-15	BH-15-20	BH-16-10	BQ-16-12
Date Sampled	29-SEP-07	29-SEP-07	29-SEP-07	29-SEP-07	30-SEP-07	30-SEP-07	30-SEP-07	28-SEP-07	28-SEP-07	27-SEP-07	27-SEP-07	28-SEP-07
Time Sampled	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00
ALS Sample ID	L561468-1	L561468-2	L561468-3	L561468-4	L561468-5	L561468-6	L561468-7	L561468-8	L561468-9	L561468-10	L561468-11	L561468-12
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Physical Tests												
Hardness (as CaCO3)	1010	1040	372	1080	1550	1470	1440	1410	1230	1260	1260	1300
pH	7.16	7.5	7.56	7.49	7.47	7.77	-	7.78	8.25	8.8	7.61	8.59
Anions and Nutrients												
Ammonia as N	5.34	7.58	28.8	7.59	19.4	30.5	-	6.13	7.03	2.83	17.2	28.9
Alkalinity, Total (as CaCO3)	212	348	513	379	298	95	-	145	40.2	84.5	41.3	47.7
Bromide (Br)	<1.0	<0.050	<1.0	<0.050	<1.0	<0.50	-	<0.050	<0.050	<0.050	<0.050	<0.25
Chloride (Cl)	<10	1.49	<10	1.41	<10	6.5	-	1.15	2.88	9.33	1.81	4.5
Fluoride (F)	<0.40	0.247	<0.40	0.24	<0.40	0.61	-	0.14	0.542	0.344	0.381	0.94
Sulfate (SO4)	874	763	<10	738	1610	1710	-	1500	1550	1380	1550	1750
Nitrate (as N)	0.31	<0.0050	0.23	<0.0050	0.3	0.105	-	<0.0050	0.0077	0.239	<0.0050	0.167
Nitrite (as N)	0.03	0.0028	0.045	0.0015	<0.020	0.02	-	<0.0010	0.0024	0.149	0.0013	0.0096
Cyanides												
Cyanide, Total	0.0136	0.0165	0.0203	0.0173	0.0537	0.0522	-	0.0203	0.0927	22	0.0872	0.0214
Thiocyanate (SCN)	<0.50	<0.50	<0.50	<0.50	5	7.75	7.88	<0.50	3.65	100	<0.50	<0.50
Total Metals												
Aluminum (Al)-Total	0.023	0.0309	0.0148	0.0088	0.019	0.017	0.017	0.131	0.082	0.014	<0.010	0.033
Antimony (Sb)-Total	0.0035	0.00125	0.00045	0.00059	0.0054	0.0892	0.0858	0.0148	0.0625	0.589	0.086	0.437
Arsenic (As)-Total	22.9	0.054	0.0946	0.0407	6.1	0.31	0.296	2.13	1.99	7.57	0.419	2.35
Barium (Ba)-Total	0.027	0.207	0.435	0.228	0.0195	0.0116	0.0111	0.00539	0.0032	0.00618	0.00712	0.0102
Beryllium (Be)-Total	<0.0050	<0.0025	<0.00050	<0.0025	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total	<0.0050	<0.0025	<0.00050	<0.0025	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Boron (B)-Total	<0.10	0.056	0.038	0.064	0.43	0.17	0.16	0.14	0.23	0.3	<0.10	0.18
Cadmium (Cd)-Total	<0.00017	0.00041	0.000073	0.000302	0.00023	0.00035	0.00076	0.0012	0.0004	0.0004	0.00057	0.00036
Calcium (Ca)-Total	271	268	75.6	282	499	457	448	501	477	500	462	451
Chromium (Cr)-Total	<0.0050	<0.0025	0.00138	<0.0025	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Cobalt (Co)-Total	0.002	0.00189	0.00136	0.00155	0.0138	0.0252	0.0245	0.0081	0.0148	0.052	0.0011	0.0026
Copper (Cu)-Total	0.0012	0.00326	0.00199	0.00114	0.0059	0.0042	0.0038	0.0045	0.164	7.57	0.0033	0.0053
Iron (Fe)-Total	36.6	4.34	18	2.12	14.9	<0.030	<0.030	1.56	0.073	2.09	<0.030	0.04
Lead (Pb)-Total	0.00091	0.00217	0.00216	0.00101	0.00242	0.00213	0.00258	0.0142	0.00908	0.00148	<0.00050	0.00251
Lithium (Li)-Total	<0.050	<0.025	<0.0050	<0.025	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Magnesium (Mg)-Total	81.8	90.3	44.5	92.5	72.7	78.7	77.9	39.7	8.8	3.86	25.9	42.9
Manganese (Mn)-Total	4.84	1.49	0.203	1.54	15.9	3.67	3.57	13.7	1.45	0.0345	3.38	0.719
Molybdenum (Mo)-Total	0.00696	0.0187	0.00166	0.0062	0.00246	0.0143	0.014	0.0249	0.0238	0.0365	0.0196	0.0382
Nickel (Ni)-Total	<0.0050	0.0083	0.00583	0.0041	0.0124	<0.0050	0.0055	0.0072	0.0117	0.0883	<0.0050	<0.0050
Phosphorus (P)-Total	<0.30	<0.30	0.81	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Total	14.1	6.2	7.4	6.4	46.2	39.5	40.3	10.8	23.2	14.1	20	37.4
Selenium (Se)-Total	0.0114	<0.00050	0.00056	<0.00050	0.00191	<0.00050	<0.00050	<0.00050	0.00112	0.00595	<0.00050	0.00171
Silicon (Si)-Total	6.29	8.29	11.7	8.38	7.97	2.18	2.13	9.02	3.65	14.5	2.2	3.07
Silver (Ag)-Total	<0.00010	<0.000050	0.000015	<0.000050	<0.00010	<0.00010	<0.00010	0.00017	0.00025	0.0184	<0.00010	<0.00010
Sodium (Na)-Total	12.9	8.9	13.4	8.9	67.1	74.8	75.4	27.9	70.1	139	37.8	169
Strontium (Sr)-Total	0.852	1.2	0.536	1.21	1.71	1.31	1.27	0.66	0.392	0.747	0.518	0.818
Thallium (Tl)-Total	<0.0010	<0.00050	<0.00010	<0.00050	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Tin (Sn)-Total	<0.0010	<0.00050	0.00062	<0.00050	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)-Total	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Uranium (U)-Total	0.00072	0.000375	0.000099	0.000267	0.00249	0.00172	0.00151	0.00163	0.00127	<0.00010	0.00574	0.0019
Vanadium (V)-Total	<0.010	<0.0050	0.0101	<0.0050	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Zinc (Zn)-Total	0.06	0.0923	0.0086	0.0837	0.206	0.015	0.018	0.098	0.015	<0.010	<0.010	<0.010

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Report To	JUSTIN STOCKWELL, LORAX ENVIRONMENTAL SERVICES
ALS File No.	L561468
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DETECTION LIMITS

				BH-4-5 Duplicate			BH-6-7 Duplicate					
Sample ID	BH-4-3	BH-4-5	BH4-10	BH5-5	BH-6-5	BH-6-7	BH-6-17	BH-15-10	BH-15-15	BH-15-20	BH-16-10	BQ-16-12
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Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Physical Tests												
Hardness (as CaCO3)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
pH	0.01	0.01	0.01	0.01	0.01	0.01	-	0.01	0.01	0.01	0.01	0.01
Anions and Nutrients												
Ammonia as N	0.1	0.25	0.5	0.25	0.5	0.5	-	0.25	0.25	0.05	0.5	0.5
Alkalinity, Total (as CaCO3)	2	2	2	2	2	2	-	2	2	2	2	2
Bromide (Br)	1	0.05	1	0.05	1	0.5	-	0.05	0.05	0.05	0.05	0.25
Chloride (Cl)	10	0.5	10	0.5	10	5	-	0.5	0.5	0.5	0.5	2.5
Fluoride (F)	0.4	0.02	0.4	0.02	0.4	0.2	-	0.02	0.02	0.02	0.02	0.1
Sulfate (SO4)	10	0.5	10	0.5	10	5	-	5	5	5	5	2.5
Nitrate (as N)	0.1	0.005	0.1	0.005	0.1	0.05	-	0.005	0.005	0.005	0.005	0.025
Nitrite (as N)	0.02	0.001	0.02	0.001	0.02	0.01	-	0.001	0.001	0.001	0.001	0.005
Cyanides												
Cyanide, Tota	0.005	0.005	0.005	0.005	0.005	0.005	-	0.005	0.005	0.05	0.005	0.005
Thiocyanate (SCN)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Metals												
Aluminum (Al)-Total	0.01	0.005	0.001	0.005	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Antimony (Sb)-Total	0.001	0.0005	0.0001	0.0005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Arsenic (As)-Total	0.001	0.0005	0.0001	0.0005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Barium (Ba)-Total	0.0005	0.00025	0.00005	0.00025	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Beryllium (Be)-Total	0.005	0.0025	0.0005	0.0025	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Bismuth (Bi)-Total	0.005	0.0025	0.0005	0.0025	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Boron (B)-Total	0.1	0.05	0.01	0.05	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cadmium (Cd)-Total	0.00017	0.000085	0.000017	0.000085	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017
Calcium (Ca)-Total	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Chromium (Cr)-Total	0.005	0.0025	0.0005	0.0025	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Cobalt (Co)-Total	0.001	0.0005	0.0001	0.0005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper (Cu)-Total	0.001	0.0005	0.0001	0.0005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Iron (Fe)-Total	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Lead (Pb)-Total	0.0005	0.00025	0.00005	0.00025	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Lithium (Li)-Total	0.05	0.025	0.005	0.025	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Magnesium (Mg)-Total	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manganese (Mn)-Total	0.0005	0.00025	0.00005	0.00025	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Molybdenum (Mo)-Total	0.0005	0.00025	0.00005	0.00025	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Nickel (Ni)-Total	0.005	0.0025	0.0005	0.0025	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Phosphorus (P)-Total	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Potassium (K)-Total	2	2	2	2	2	2	2	2	2	2	2	2
Selenium (Se)-Total	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Silicon (Si)-Total	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Silver (Ag)-Total	0.0001	0.00005	0.00001	0.00005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sodium (Na)-Total	2	2	2	2	2	2	2	2	2	2	2	2
Strontium (Sr)-Total	0.001	0.0005	0.0001	0.0005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Thallium (Tl)-Total	0.001	0.0005	0.0001	0.0005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Tin (Sn)-Total	0.001	0.0005	0.0001	0.0005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Titanium (Ti)-Total	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Uranium (U)-Total	0.0001	0.00005	0.00001	0.00005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Vanadium (V)-Total	0.01	0.005	0.001	0.005	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zinc (Zn)-Total	0.01	0.005	0.001	0.005	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Appendix A - Lab Results **Units**

Project	844-1 MT. NANSEN
Report To	JUSTIN STOCKWELL, LORAX ENVIRONMENTAL SERVICES
ALS File No.	L561468
Date Received	02-Oct-07
Date	16-Jan-08

UNITS				BH-4-5 Duplicate			BH-6-7 Duplicate					
Sample ID	BH-4-3	BH-4-5	BH4-10	BH5-5	BH-6-5	BH-6-7	BH-6-17	BH-15-10	BH-15-15	BH-15-20	BH-16-10	BQ-16-12
Date Sampled	29-SEP-07	29-SEP-07	29-SEP-07	29-SEP-07	30-SEP-07	30-SEP-07	30-SEP-07	28-SEP-07	28-SEP-07	27-SEP-07	27-SEP-07	28-SEP-07
Time Sampled	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00
ALS Sample ID	L561468-1	L561468-2	L561468-3	L561468-4	L561468-5	L561468-6	L561468-7	L561468-8	L561468-9	L561468-10	L561468-11	L561468-12
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Physical Tests												
Hardness (as CaCO3)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
pH	pH	pH	pH	pH	pH	pH	-	pH	pH	pH	pH	pH
Anions and Nutrients												
Ammonia as N	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L
Alkalinity, Total (as CaCO3)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L
Bromide (Br)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L
Chloride (Cl)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L
Fluoride (F)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L
Sulfate (SO4)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L
Nitrate (as N)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L
Nitrite (as N)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L
Cyanides												
Cyanide, Tota	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L
Thiocyanate (SCN)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Total Metals												
Aluminum (Al)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Antimony (Sb)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Arsenic (As)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Barium (Ba)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Beryllium (Be)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Bismuth (Bi)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Boron (B)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Cadmium (Cd)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Calcium (Ca)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Chromium (Cr)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Cobalt (Co)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Copper (Cu)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Iron (Fe)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Lead (Pb)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Lithium (Li)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Magnesium (Mg)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Manganese (Mn)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Molybdenum (Mo)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Nickel (Ni)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Phosphorus (P)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Potassium (K)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Selenium (Se)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Silicon (Si)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Silver (Ag)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Sodium (Na)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Strontium (Sr)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Thallium (Tl)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Tin (Sn)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Titanium (Ti)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Uranium (U)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Vanadium (V)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Zinc (Zn)-Total	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L

Appendix A - Lab Results **Replicate Results**

Project 844-1 MT. NANSEN
Report To JUSTIN STOCKWELL, LORAX ENVIRONMENTAL SERVICES
ALS File No. L561468
Date Received 02-Oct-07
Date 16-Jan-08

REPLICATE RESULTS

Sample ID	Matrix	ALS ID	Analyte	Replicate 1	Replicate 2	Units	RPD	RPD Limit	Diff	Diff Limit	Qualifier
Anions and Nutrients											
L561468-5	Water	WG669491-6	Ammonia as N	19.4	19.2	mg/L	0.81	20	-	-	-
L561468-8	Water	WG679396-2	Alkalinity, Total (as CaCO3)	145	148	mg/L	1.7	20	-	-	-
L561468-12	Water	WG671038-7	Bromide (Br)	<0.25	<0.25	mg/L	N/A	20	-	-	RPD-NA
L561468-12	Water	WG671038-7	Chloride (Cl)	4.5	4.5	mg/L	-	-	0.0	10	J
L561468-12	Water	WG671038-7	Fluoride (F)	0.94	0.93	mg/L	-	-	0.01	0.4	J
L561468-12	Water	WG671038-7	Sulfate (SO4)	1750	1740	mg/L	0.56	20	-	-	-
L561468-12	Water	WG671038-7	Nitrate (as N)	0.167	0.174	mg/L	-	-	0.007	0.1	J
L561468-12	Water	WG671038-7	Nitrite (as N)	0.0096	0.0100	mg/L	-	-	0.0004	0.02	J
Cyanides											
L561468-12	Water	WG716339-4	Thiocyanate (SCN)	<0.50	<0.50	mg/L	N/A	20	-	-	RPD-NA

Project 844-1 MT. NANSEN
Report To JUSTIN STOCKWELL, LORAX ENVIRONMENTAL SERVICES
ALS File No. L561468
Date Received 02-Oct-07
Date 16-Jan-08

QUALITY CONTROL RESULTS

Matrix	QC Type	Analyte	QC Spl. No.	Reference	Result	Target	Units	%	Limits
Physical Tests									
Water	CRM	pH	WG678917-5	VA-PH7-BUF	7.03	7.00	pH	7.03	6.97-7.03
Anions and Nutrients									
Water	CRM	Bromide (Br)	WG671038-2	VA-ALLT-170088	0.988	1.00	mg/L	99	90-110
Water	CRM	Chloride (Cl)	WG671038-2	VA-ALLT-170088	50.8	50.1	mg/L	101	94-106
Water	CRM	Fluoride (F)	WG671038-2	VA-ALLT-170088	1.02	1.00	mg/L	102	93-107
Water	CRM	Sulfate (SO4)	WG671038-2	VA-ALLT-170088	51.4	50.1	mg/L	103	93-107
Water	CRM	Nitrate (as N)	WG671038-2	VA-ALLT-170088	0.226	0.225	mg/L	100	91-109
Water	CRM	Nitrite (as N)	WG671038-2	VA-ALLT-170088	0.157	0.152	mg/L	103	91-109
Water	CRM	Ammonia as N	WG671500-2	VA-SPXNUT-22-16	3.81	3.84	mg/L	99	85-115
Water	CRM	Sulfate (SO4)	WG671775-2	VA-ALLT-170088	50.8	50.1	mg/L	101	93-107
Water	CRM	Bromide (Br)	WG671038-11	VA-ALLT-170088	0.979	1.00	mg/L	98	90-110
Water	CRM	Chloride (Cl)	WG671038-11	VA-ALLT-170088	49.9	50.1	mg/L	100	94-106
Water	CRM	Fluoride (F)	WG671038-11	VA-ALLT-170088	1.01	1.00	mg/L	101	93-107
Water	CRM	Sulfate (SO4)	WG671038-11	VA-ALLT-170088	50.9	50.1	mg/L	102	93-107
Water	CRM	Nitrate (as N)	WG671038-11	VA-ALLT-170088	0.221	0.225	mg/L	98	91-109
Water	CRM	Nitrite (as N)	WG671038-11	VA-ALLT-170088	0.155	0.152	mg/L	102	91-109
Water	CRM	Sulfate (SO4)	WG671775-10	VA-ALLT-170088	51.0	50.1	mg/L	102	93-107
Water	MB	Bromide (Br)	WG671038-1		<0.050	<0.05	mg/L	-	0.05
Water	MB	Chloride (Cl)	WG671038-1		<0.50	<0.5	mg/L	-	0.5
Water	MB	Fluoride (F)	WG671038-1		<0.020	<0.02	mg/L	-	0.02
Water	MB	Sulfate (SO4)	WG671038-1		<0.50	<0.5	mg/L	-	0.5
Water	MB	Nitrate (as N)	WG671038-1		<0.0050	<0.005	mg/L	-	0.005
Water	MB	Nitrite (as N)	WG671038-1		<0.0010	<0.001	mg/L	-	0.001
Water	MB	Bromide (Br)	WG671038-4		<0.050	<0.05	mg/L	-	0.05
Water	MB	Chloride (Cl)	WG671038-4		<0.50	<0.5	mg/L	-	0.5
Water	MB	Fluoride (F)	WG671038-4		<0.020	<0.02	mg/L	-	0.02
Water	MB	Sulfate (SO4)	WG671038-4		<0.50	<0.5	mg/L	-	0.5
Water	MB	Nitrate (as N)	WG671038-4		<0.0050	<0.005	mg/L	-	0.005
Water	MB	Nitrite (as N)	WG671038-4		<0.0010	<0.001	mg/L	-	0.001
Water	MB	Bromide (Br)	WG671038-6		<0.050	<0.05	mg/L	-	0.05
Water	MB	Chloride (Cl)	WG671038-6		<0.50	<0.5	mg/L	-	0.5
Water	MB	Fluoride (F)	WG671038-6		<0.020	<0.02	mg/L	-	0.02
Water	MB	Bromide (Br)	WG671038-8		<0.050	<0.05	mg/L	-	0.05
Water	MB	Chloride (Cl)	WG671038-8		<0.50	<0.5	mg/L	-	0.5
Water	MB	Fluoride (F)	WG671038-8		<0.020	<0.02	mg/L	-	0.02
Water	MB	Nitrate (as N)	WG671038-8		<0.0050	<0.005	mg/L	-	0.005
Water	MB	Nitrite (as N)	WG671038-8		<0.0010	<0.001	mg/L	-	0.001
Water	MB	Ammonia as N	WG671500-1		<0.0050	<0.005	mg/L	-	0.005
Water	MB	Sulfate (SO4)	WG671775-1		<0.50	<0.5	mg/L	-	0.5
Water	MB	Sulfate (SO4)	WG671775-4		<0.50	<0.5	mg/L	-	0.5
Water	MB	Sulfate (SO4)	WG671775-6		<0.50	<0.5	mg/L	-	0.5
Water	MB	Sulfate (SO4)	WG671775-9		<0.50	<0.5	mg/L	-	0.5
Water	MB	Alkalinity, Total (as CaCO3)	WG679396-1		<2.0	<2	mg/L	-	2
Water	MB	Alkalinity, Total (as CaCO3)	WG679396-3		<2.0	<2	mg/L	-	2
Water	MB	Bromide (Br)	WG671038-10		<0.050	<0.05	mg/L	-	0.05
Water	MB	Chloride (Cl)	WG671038-10		<0.50	<0.5	mg/L	-	0.5
Water	MB	Fluoride (F)	WG671038-10		<0.020	<0.02	mg/L	-	0.02
Water	MB	Sulfate (SO4)	WG671038-10		<0.50	<0.5	mg/L	-	0.5
Water	MB	Nitrate (as N)	WG671038-10		<0.0050	<0.005	mg/L	-	0.005
Water	MB	Nitrite (as N)	WG671038-10		<0.0010	<0.001	mg/L	-	0.001

Project	844-1 MT. NANSEN
Report To	JUSTIN STOCKWELL, LORAX ENVIRONMENTAL SERVICES
ALS File No.	L561468
Date Received	02-Oct-07
Date	16-Jan-08

QUALITY CONTROL RESULTS

Matrix	QC Type	Analyte	QC Spl. No.	Reference	Result	Target	Units	%	Limits
Cyanides									
Water	CRM	Thiocyanate (SCN)	WG716339-2	-SCN-HIGH-CONTR	101	100	mg/L	101	85-115
Water	MB	Cyanide, Total	WG670958-1		<0.0050	<0.005	mg/L	-	0.005
Water	MB	Cyanide, Total	WG672496-1		<0.0050	<0.005	mg/L	-	0.005
Water	MB	Thiocyanate (SCN)	WG716339-1		<0.50	<0.5	mg/L	-	0.5
Total Metals									
Water	CRM	Aluminum (Al)-Total	WG669533-2	VA-HIGH-WATRM	2.08	2.00	mg/L	104	90-110
Water	CRM	Antimony (Sb)-Total	WG669533-2	VA-HIGH-WATRM	1.05	1.00	mg/L	105	90-110
Water	CRM	Arsenic (As)-Total	WG669533-2	VA-HIGH-WATRM	1.03	1.00	mg/L	103	90-110
Water	CRM	Barium (Ba)-Total	WG669533-2	VA-HIGH-WATRM	0.261	0.250	mg/L	104	90-110
Water	CRM	Beryllium (Be)-Total	WG669533-2	VA-HIGH-WATRM	0.105	0.100	mg/L	105	90-110
Water	CRM	Bismuth (Bi)-Total	WG669533-2	VA-HIGH-WATRM	1.00	1.00	mg/L	100	90-110
Water	CRM	Boron (B)-Total	WG669533-2	VA-HIGH-WATRM	0.99	1.00	mg/L	99	85-115
Water	CRM	Cadmium (Cd)-Total	WG669533-2	VA-HIGH-WATRM	0.0970	0.100	mg/L	97	90-110
Water	CRM	Calcium (Ca)-Total	WG669533-2	VA-HIGH-WATRM	48.5	50.0	mg/L	97	85-115
Water	CRM	Chromium (Cr)-Total	WG669533-2	VA-HIGH-WATRM	0.256	0.250	mg/L	103	90-110
Water	CRM	Cobalt (Co)-Total	WG669533-2	VA-HIGH-WATRM	0.253	0.250	mg/L	101	90-110
Water	CRM	Copper (Cu)-Total	WG669533-2	VA-HIGH-WATRM	0.247	0.250	mg/L	99	90-110
Water	CRM	Iron (Fe)-Total	WG669533-2	VA-HIGH-WATRM	0.946	1.00	mg/L	95	90-110
Water	CRM	Lead (Pb)-Total	WG669533-2	VA-HIGH-WATRM	0.506	0.500	mg/L	101	90-110
Water	CRM	Lithium (Li)-Total	WG669533-2	VA-HIGH-WATRM	0.27	0.25	mg/L	107	90-110
Water	CRM	Magnesium (Mg)-Total	WG669533-2	VA-HIGH-WATRM	49.1	50.0	mg/L	98	85-115
Water	CRM	Manganese (Mn)-Total	WG669533-2	VA-HIGH-WATRM	0.246	0.250	mg/L	99	90-110
Water	CRM	Molybdenum (Mo)-Total	WG669533-2	VA-HIGH-WATRM	0.256	0.250	mg/L	102	90-110
Water	CRM	Nickel (Ni)-Total	WG669533-2	VA-HIGH-WATRM	0.500	0.500	mg/L	100	90-110
Water	CRM	Phosphorus (P)-Total	WG669533-2	VA-HIGH-WATRM	2.43	2.50	mg/L	97	90-110
Water	CRM	Potassium (K)-Total	WG669533-2	VA-HIGH-WATRM	49.4	50.0	mg/L	99	85-115
Water	CRM	Selenium (Se)-Total	WG669533-2	VA-HIGH-WATRM	0.997	1.00	mg/L	100	90-110
Water	CRM	Silicon (Si)-Total	WG669533-2	VA-HIGH-WATRM	0.968	1.00	mg/L	97	90-110
Water	CRM	Silver (Ag)-Total	WG669533-2	VA-HIGH-WATRM	0.104	0.100	mg/L	104	90-110
Water	CRM	Sodium (Na)-Total	WG669533-2	VA-HIGH-WATRM	48.3	50.0	mg/L	97	85-115
Water	CRM	Strontium (Sr)-Total	WG669533-2	VA-HIGH-WATRM	0.255	0.250	mg/L	102	90-110
Water	CRM	Thallium (Tl)-Total	WG669533-2	VA-HIGH-WATRM	1.01	1.00	mg/L	101	85-115
Water	CRM	Titanium (Ti)-Total	WG669533-2	VA-HIGH-WATRM	0.254	0.250	mg/L	102	90-110
Water	CRM	Uranium (U)-Total	WG669533-2	VA-HIGH-WATRM	0.00522	0.00500	mg/L	104	90-110
Water	CRM	Vanadium (V)-Total	WG669533-2	VA-HIGH-WATRM	0.518	0.500	mg/L	104	90-110
Water	CRM	Zinc (Zn)-Total	WG669533-2	VA-HIGH-WATRM	0.510	0.500	mg/L	102	85-115
Water	CRM	Aluminum (Al)-Total	WG670086-3	VA-HIGH-WATRM	2.11	2.00	mg/L	105	90-110
Water	CRM	Antimony (Sb)-Total	WG670086-3	VA-HIGH-WATRM	1.05	1.00	mg/L	105	90-110
Water	CRM	Arsenic (As)-Total	WG670086-3	VA-HIGH-WATRM	1.05	1.00	mg/L	105	90-110
Water	CRM	Barium (Ba)-Total	WG670086-3	VA-HIGH-WATRM	0.262	0.250	mg/L	105	90-110
Water	CRM	Beryllium (Be)-Total	WG670086-3	VA-HIGH-WATRM	0.105	0.100	mg/L	105	90-110
Water	CRM	Bismuth (Bi)-Total	WG670086-3	VA-HIGH-WATRM	1.01	1.00	mg/L	101	90-110
Water	CRM	Boron (B)-Total	WG670086-3	VA-HIGH-WATRM	0.99	1.00	mg/L	99	85-115
Water	CRM	Cadmium (Cd)-Total	WG670086-3	VA-HIGH-WATRM	0.101	0.100	mg/L	101	90-110
Water	CRM	Calcium (Ca)-Total	WG670086-3	VA-HIGH-WATRM	50.1	50.0	mg/L	100	85-115
Water	CRM	Chromium (Cr)-Total	WG670086-3	VA-HIGH-WATRM	0.260	0.250	mg/L	104	90-110
Water	CRM	Cobalt (Co)-Total	WG670086-3	VA-HIGH-WATRM	0.256	0.250	mg/L	103	90-110
Water	CRM	Copper (Cu)-Total	WG670086-3	VA-HIGH-WATRM	0.251	0.250	mg/L	101	90-110
Water	CRM	Iron (Fe)-Total	WG670086-3	VA-HIGH-WATRM	0.981	1.00	mg/L	98	90-110
Water	CRM	Lead (Pb)-Total	WG670086-3	VA-HIGH-WATRM	0.516	0.500	mg/L	103	90-110
Water	CRM	Lithium (Li)-Total	WG670086-3	VA-HIGH-WATRM	0.26	0.25	mg/L	105	90-110
Water	CRM	Magnesium (Mg)-Total	WG670086-3	VA-HIGH-WATRM	49.9	50.0	mg/L	100	85-115
Water	CRM	Manganese (Mn)-Total	WG670086-3	VA-HIGH-WATRM	0.253	0.250	mg/L	101	90-110
Water	CRM	Molybdenum (Mo)-Total	WG670086-3	VA-HIGH-WATRM	0.262	0.250	mg/L	105	90-110
Water	CRM	Nickel (Ni)-Total	WG670086-3	VA-HIGH-WATRM	0.503	0.500	mg/L	101	90-110
Water	CRM	Phosphorus (P)-Total	WG670086-3	VA-HIGH-WATRM	2.53	2.50	mg/L	101	90-110
Water	CRM	Potassium (K)-Total	WG670086-3	VA-HIGH-WATRM	50.5	50.0	mg/L	101	85-115
Water	CRM	Selenium (Se)-Total	WG670086-3	VA-HIGH-WATRM	0.995	1.00	mg/L	99	90-110
Water	CRM	Silicon (Si)-Total	WG670086-3	VA-HIGH-WATRM	0.983	1.00	mg/L	98	90-110
Water	CRM	Silver (Ag)-Total	WG670086-3	VA-HIGH-WATRM	0.102	0.100	mg/L	102	90-110
Water	CRM	Sodium (Na)-Total	WG670086-3	VA-HIGH-WATRM	49.2	50.0	mg/L	98	85-115
Water	CRM	Strontium (Sr)-Total	WG670086-3	VA-HIGH-WATRM	0.265	0.250	mg/L	106	90-110
Water	CRM	Thallium (Tl)-Total	WG670086-3	VA-HIGH-WATRM	1.01	1.00	mg/L	101	85-115
Water	CRM	Titanium (Ti)-Total	WG670086-3	VA-HIGH-WATRM	0.261	0.250	mg/L	104	90-110
Water	CRM	Uranium (U)-Total	WG670086-3	VA-HIGH-WATRM	0.00526	0.00500	mg/L	105	90-110
Water	CRM	Vanadium (V)-Total	WG670086-3	VA-HIGH-WATRM	0.510	0.500	mg/L	102	90-110
Water	CRM	Zinc (Zn)-Total	WG670086-3	VA-HIGH-WATRM	0.518	0.500	mg/L	104	85-115

Project 844-1 MT. NANSEN
Report To JUSTIN STOCKWELL, LORAX ENVIRONMENTAL SERVICES
ALS File No. L561468
Date Received 02-Oct-07
Date 16-Jan-08

QUALITY CONTROL RESULTS

Matrix	QC Type	Analyte	QC Spl. No.	Reference	Result	Target	Units	%	Limits
Water	MB	Calcium (Ca)-Total	WG669533-1		<0.050	<0.05	mg/L	-	0.05
Water	MB	Iron (Fe)-Total	WG669533-1		<0.030	<0.03	mg/L	-	0.03
Water	MB	Magnesium (Mg)-Total	WG669533-1		<0.10	<0.1	mg/L	-	0.1
Water	MB	Phosphorus (P)-Total	WG669533-1		<0.30	<0.3	mg/L	-	0.3
Water	MB	Potassium (K)-Total	WG669533-1		<2.0	<2	mg/L	-	2
Water	MB	Silicon (Si)-Total	WG669533-1		<0.050	<0.05	mg/L	-	0.05
Water	MB	Sodium (Na)-Total	WG669533-1		<2.0	<2	mg/L	-	2
Water	MB	Titanium (Ti)-Total	WG669533-1		<0.010	<0.01	mg/L	-	0.01
Water	MB	Aluminum (Al)-Total	WG670086-1		<0.0020	<0.002	mg/L	-	0.002
Water	MB	Antimony (Sb)-Total	WG670086-1		<0.00010	<0.0001	mg/L	-	0.0001
Water	MB	Arsenic (As)-Total	WG670086-1		<0.00010	<0.0001	mg/L	-	0.0001
Water	MB	Barium (Ba)-Total	WG670086-1		<0.000050	<0.00005	mg/L	-	0.00005
Water	MB	Beryllium (Be)-Total	WG670086-1		<0.00050	<0.0005	mg/L	-	0.0005
Water	MB	Bismuth (Bi)-Total	WG670086-1		<0.00050	<0.0005	mg/L	-	0.0005
Water	MB	Boron (B)-Total	WG670086-1		<0.010	<0.01	mg/L	-	0.01
Water	MB	Cadmium (Cd)-Total	WG670086-1		<0.000017	<0.000017	mg/L	-	0.000017
Water	MB	Calcium (Ca)-Total	WG670086-1		<0.050	<0.05	mg/L	-	0.05
Water	MB	Chromium (Cr)-Total	WG670086-1		<0.00050	<0.0005	mg/L	-	0.0005
Water	MB	Cobalt (Co)-Total	WG670086-1		<0.00010	<0.0001	mg/L	-	0.0001
Water	MB	Copper (Cu)-Total	WG670086-1		<0.00010	<0.0001	mg/L	-	0.0001
Water	MB	Iron (Fe)-Total	WG670086-1		<0.030	<0.03	mg/L	-	0.03
Water	MB	Lead (Pb)-Total	WG670086-1		<0.000050	<0.00005	mg/L	-	0.00005
Water	MB	Lithium (Li)-Total	WG670086-1		<0.0050	<0.005	mg/L	-	0.005
Water	MB	Magnesium (Mg)-Total	WG670086-1		<0.10	<0.1	mg/L	-	0.1
Water	MB	Manganese (Mn)-Total	WG670086-1		<0.000050	<0.00005	mg/L	-	0.00005
Water	MB	Molybdenum (Mo)-Total	WG670086-1		<0.000050	<0.00005	mg/L	-	0.00005
Water	MB	Nickel (Ni)-Total	WG670086-1		<0.00050	<0.0005	mg/L	-	0.0005
Water	MB	Phosphorus (P)-Total	WG670086-1		<0.30	<0.3	mg/L	-	0.3
Water	MB	Potassium (K)-Total	WG670086-1		<2.0	<2	mg/L	-	2
Water	MB	Selenium (Se)-Total	WG670086-1		<0.00050	<0.0005	mg/L	-	0.0005
Water	MB	Silicon (Si)-Total	WG670086-1		<0.050	<0.05	mg/L	-	0.05
Water	MB	Silver (Ag)-Total	WG670086-1		<0.000010	<0.00001	mg/L	-	0.00001
Water	MB	Sodium (Na)-Total	WG670086-1		<2.0	<2	mg/L	-	2
Water	MB	Strontium (Sr)-Total	WG670086-1		<0.00010	<0.0001	mg/L	-	0.0001
Water	MB	Thallium (Tl)-Total	WG670086-1		<0.00010	<0.0001	mg/L	-	0.0001
Water	MB	Tin (Sn)-Total	WG670086-1		<0.00010	<0.0001	mg/L	-	0.0001
Water	MB	Titanium (Ti)-Total	WG670086-1		<0.010	<0.01	mg/L	-	0.01
Water	MB	Uranium (U)-Total	WG670086-1		<0.000010	<0.00001	mg/L	-	0.00001
Water	MB	Vanadium (V)-Total	WG670086-1		<0.0010	<0.001	mg/L	-	0.001
Water	MB	Zinc (Zn)-Total	WG670086-1		<0.0010	<0.001	mg/L	-	0.001

Appendix A - Field Data

LORAX FIELD MEASUREMENTS

Sample ID	Depth (ft)	pH	conductivity S/cm	Turbidity NTU	Dissolved Oxygen mg/L	Temp C	Salinity %	TDS g/L	ORP mV
BH-4-3	3	7.02	2.23	50.8	0.0	3.55	0.1	1.4	-146
BH-4-5	5	7.01	2.25	61.2	0.0	4.35	0.1	1.4	-63
BH5-5 (BH4-5 Du	5	6.85	2.23	45	0.0	4.02	0.1	1.4	-53
BH-6-5	5	6.96	3.63	35	0.0	2.56	0.2	2.3	-128
BH-6-7	7	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
BH-15-10	10	7.38	3.04	154	0.0	4.61	0.1	1.9	-103
BH-15-15	15	8.16	3.59	>200	0.0	3.42	0.2	2.3	32
BH-15-20	20	9.26	3.6	121	0.0	3.66	0.2	2.3	99
BH-16-10	10	8.44	3.11	93.2	0.0	3.67	0.1	2	166
BQ-16-12	12	9.2	3.7	202	0.0	5.31	0.2	2.4	33