Fate and Transport of Naphthenic Acids in a Glacial Aquifer

by
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A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Science
in
Earth Sciences

Waterloo, Ontario, Canada, 2004

AUTHOR'S DECLARATION FOR ELECTRONIC SUBMISSION OF A THESIS

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ABSTRACT

Naphthenic acids (NAs) are carboxylated alkanes and cycloalkanes concentrated in wastewater during oil sands processing. The general chemical formula is $C_nH_{n+Z}O_2$, where n represents the number of carbon atoms and Z specifies a homologous family with 0-6 rings (Z=0 to Z=-12). The wastewater is acutely toxic to surface water organisms and is stored in tailings ponds with over 230 million m^3 of fines tailings and free water. The purpose of this thesis was to provide a preliminary evaluation of the potential attenuation of NAs during groundwater flow from the ponds.

Laboratory studies were conducted to evaluate possible attenuation mechanisms. Aerobes from aquifer material degraded 60% of the NAs over 20 weeks in laboratory microcosms. The greatest decrease occurred in the low molecular weight bicyclic homologues with 12 to 16 carbons. The microbial activity confirms that aerobic naphthenate-degrading bacteria occur naturally in the glacial aquifer near Suncor's Pond 2/3. These results support the hypothesis that limited aerobic biodegradation of the smaller components of NAs could occur relatively rapidly under field conditions.

There was no measurable decrease in NA concentration over six months in anaerobic microcosms, although microbial activity did lead to sulfate-reducing and methanogenic conditions.

The theoretical retardation in glacio-fluvial sands was calculated using soil-water partitioning coefficients (K_d) determined by batch equilibration experiments using a mixture of naturally occurring naphthenic acids as well as the nine surrogates. The retardation (porosity of 0.3, bulk density of 1.5 g/mL) ranged from 1.2 to 2.6. However, no measurable sorption was seen at the field sites.

Detailed characterization allows us to examine how the proportions of homologue, or groups of molecules with the same molecular weight and number of cycloalkane rings, vary. Aerobic biodegradation favoured removal of low molecular weight NAs. A 15% mass loss attributed to sorption caused no changes in the 3D signature. Thus, changes in NA "signature" in groundwater systems were then attributed to aerobic biodegradation.

Three plumes were examined for evidence of attenuation of NAs via biodegradation. First, the individual samples were classified as background, possibly process-affected or process-affected using a combination of Piper diagrams, the stable isotopes oxygen-18 and deuterium, dissolved chloride and sodium, as well as the total naphthenic acids concentration. Second, in order to estimate attenuation due to dispersive dilution, a linear correlation line was drawn between various conservative tracers and the naphthenic acids concentration. This allowed the identification of certain samples as possibly having a lower concentration of NAs than could be expected from simple dispersive dilution. Third, the 3D signature of certain samples were examined for the presence of the aerobic biodegradation 3D signature.

One site showed good evidence for aerobic biodegradation of naphthenic acids. A second site showed some evidence for biodegradation under methanogenic conditions but the evidence was not definitive. The evidence at the third site was contradictory and no conclusions could be drawn from it. This research suggests some attenuation of NAs by biodegradation may be possible during groundwater flow.

ACKNOWLEDGEMENTS

This thesis would not have been possible without the logistical and financial help received from the Canadian Water Network and the oil sand mining companies: Albian Sands Energy Inc., Suncor Energy Inc. and Syncrude Canada Ltd. I gratefully acknowledge the help and expertise of Mike Bowron, Noreen Easterbrook, Barry Esford and Grey Kampala.

Thanks to Shirley Chatten and Marianne Vandergriendt of the Organic Geochemistry Laboratory.

Steve Berg, thanks for trekking to northern Alberta in the winter to man a jackhammer for me. And Barrett Elliott, thanks for your willingness to risk being carried off by bugs and bears in the summer. Michelle Fraser, thanks for your work in the basement of the BFG.

Technical help was provided by Bob Ingleton and Ed Cey.

I wanted to thank Barb Butler, Tony Endres and Dave Rudolph for lending their expertise to my thesis. And finally, Jim Barker, for being a great supervisor.

DEDICATION

This thesis is dedicated to Peter. It would have been a lot harder without you.

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Chapter 1

Introduction

1.1 The Oil Sands Industry

The Athabasca oil sands deposit is the world's largest known petroleum resource with an estimated 300 billion barrels of recoverable bitumen within 400 kilometres of Fort McMurray, Alberta (Government of Alberta, 2004). By 2005, oil sands production is expected to represent 50 per cent of Canada's total crude oil output and 10 per cent of North American production.

Oil sands are deposits of bitumen, a heavy, black, thick, sticky form of crude oil, with a viscosity similar to cold molasses at room temperature and a density greater than 960 kilograms per cubic metre. Bitumen makes up about 10-12% of the actual oil sands found in Alberta. The remainder is 80-85% sand and clays and 4-6% water (Government of Alberta, 2004). The bitumen in the oil sand contains naphthenic acids, alkanes and aromatics, resins and asphaltenes.

Unlike conventional crude oil that flows naturally or is pumped from the ground, oil sands must be mined. Bitumen is recovered using open-pit mining techniques, although *in situ* techniques will be brought online in the near future. About two tonnes of oil sands must be dug up, moved and processed to produce one 159-litre barrel of crude oil. Roughly 75-90% of the bitumen can be recovered from sand (PCF, 2002).

Before bitumen can be upgraded into a crude oil for use by refineries to produce gasoline and diesel fuels, it must be separated from the sand. Sodium hydroxide is often added to increase pH. Commercial processing of oil sands includes passing oil

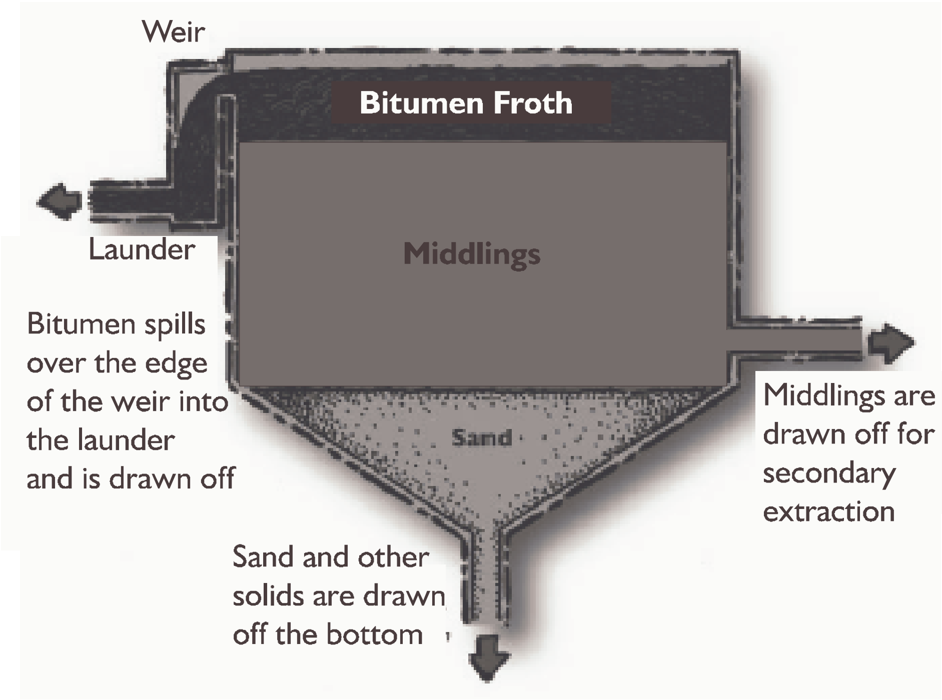


FIGURE 1.1: Primary separation tank showing the three layers formed by the different densities of the main components of oil sands once they have been separated by the Clark Hot Water Process (Center, 2003).

sand slurry through steam to raise the temperature to 80°C and washing the slurry with hot water spray (Schramm et al., 2000). It is then pumped into the primary separation tank (Figure 1.1) to settle out into its various layers. The layer of bitumen froth rises to the top while the tailings sand sinks to the bottom. The water, clay, sand and residual bitumen (tailings) are pumped to holding ponds (Center, 2003).

1.1.1 Holding Ponds

The three active mines in the area, Albian Sands Energy Inc, Syncrude Canada Ltd and Suncor Energy Inc, discharge no tailings water directly to the environment; all tailings are contained within a tailings pond, which must eventually be reclaimed. As the slurry of water, clay, sand, residual bitumen and chemicals enter the pond, it stratifies into three layers.

First, the sand drops out to form sand tailings used to build dams and dykes around the tailings ponds. The fine clay/water mixture forms a stable suspension for a time. The fine clay particles settle to form a zone with <0.1% suspended solids (i.e. a "free-water" zone) and a fine tails zone with 10-60% solids composed mainly of clays, unrecovered bitumen and slightly saline porewater (Schramm et al., 2000). Recently, gypsum is sometimes added to pond tailings to encourage settling. Tailings water from the pond itself may therefore have a high sulfate concentration.

1.2 Naphthenic Acids

Naphthenic acids (NAs) have been identified as the largest component of dissolved organic matter released into water during the digestion of the bitumen and are a major contributor to toxicity (Lai et al., 1996). Once the water used in oil sand processing is separated from the solids, it is not discharged back into the ecosystem, but is re-used in the same processes. The hot-water process causes the naphthenic acids to become solubilized and concentrated in the tailings. This leads to process-affected water with concentrations of organic acids and other naturally occurring chemical components of the McMurray Formation higher than found naturally (up to 4 mg/L) (Schramm et al., 2000). Tailings wastewater may reach concentrations in the range of 40 to 120 mg/L (Evison, 2000a; Herman et al., 1994).

1.2.1 Definition of Naphthenic Acids

Naphthenic acids (NA) are a group of organic acids of varying size and structure (carbon number range of 5–33, with 0–6 rings) with a pKa generally around 5-6 (Brient et al., 1995). The various acids are grouped together because they are all saturated petroleum acids with a carboxylic functional group. Some naphthenic acids are amphiphilic i.e. contain a polar, water-soluble group attached to a nonpolar, water-insoluble hydrocarbon chain. Some of the naphthenic acids with medium to long alkyl chain may be surfactants and will tend to concentrate at the surface and interfaces between an aqueous solution and gases or solids or non-aqueous phases (White & Russell, 1994).

Naphthenic acids are a complex mixture of naturally occurring monocyclic, polycyclic and acyclic carboxylic acids (Figure 1.2), with the general chemical formula

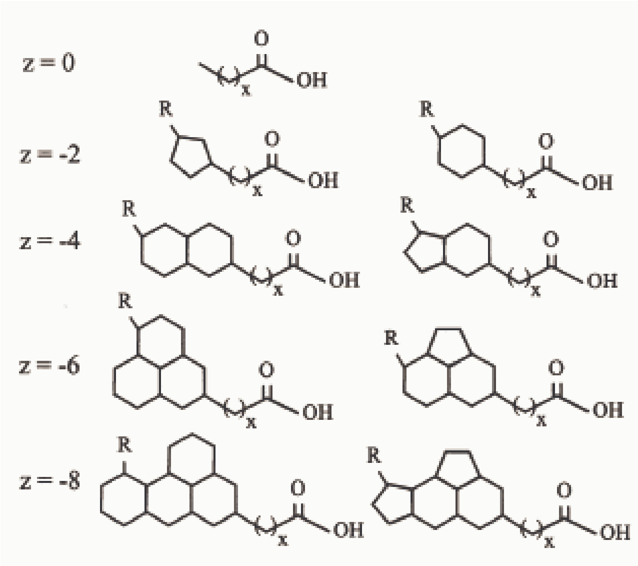


FIGURE 1.2: Naphthenic acid structures, where R is an alkyl group and x is a variable describing the carboxyl sidechain length (carbon number). Adapted from Rogers et al., 2002.

$C_nH_{2n+z}O_2$, where n indicates the carbon number and Z specifies a homologous family with 0-6 rings (Z=0 to Z=-12). The ring structures predominantly contain 5- or 6-carbon atoms in various combinations.

An exact definition of a NA is to some degree arbitrary. Holowenko *et al.* (2002), refined the definition of a NA for oil sands research and made certain assumptions based on the empirical formula for NAs described above:

- if Z<0 then at least one 5-carbon-member ring was present in the molecule (conversely, if Z=0 then the molecule is a carboxylated alkane)
- carbon number ranges from 5 to 33
- there will always be one carbon atom available for the carboxyl group
- there was at least one carbon atom available to the alkyl R group and
- structures with more than 3 rings (Z<-6) could be fused on more than two sides.

The upper right hand corner of a table of carbon number vs Z family (Figure 1.3) will always be empty since these combinations of carbon and Z numbers are deficient

$C_nH_{(2n+Z)}COOH + NaOH \leftrightarrows$	$C_nH_{(2n+Z)}COO^- + Na^+ + H_2O$
-carboxylic acid	-carboxylate
-surfactant	-anionic
-lipophilic	-hydrophilic
-log K_{ow} from <0.3 to >2	-high solubility

TABLE 1.1: Relationship between naphthenic acid and naphthenates.

in carbon or hydrogen atoms to satisfy the $C_nH_{2n+z}O_2$ formula and the assumptions listed above (Figures 1.3 and 1.4).

There are 156 homologues with the same carbon and Z number. Unfortunately, the GC-MS method of Holowenko *et al.* (2002) does not allow differentiation between isomers. The composition and relative proportions of individual isomers are not currently determinable.

Even though it is common to discuss NAs in the literature, including this thesis, at the pH of natural groundwater we are usually referring to naphthenates, not naphthenic acids. Table 1.1 summarizes the differences (Schramm et al., 2000).

1.2.2 Analysis and Classification of Naphthenic Acids

NAs are natural components of most petroleum sources, including the bitumen found in the Athabasca Oil Sands. NAs are known to vary with origin and age of the source, and each source may therefore have its own "signature". Previously, researchers were limited to measuring the total naphthenic acid content of a sample of water, unless they had access to specialized fluoride ion chemical ionization mass spectrometry (St John et al., 1998). Holowenko and Fedorak (2002) evaluated a new method for characterizing naphthenic acids which combines gas chromatography and electron impact mass spectrometry (St John et al., 1998). Derivatization by tert.-butyldimethylsilyl stabilizes the molecules and allows analytical labs to semi-quantitatively describe the distribution of 156 different naphthenic acid molecular formulas.

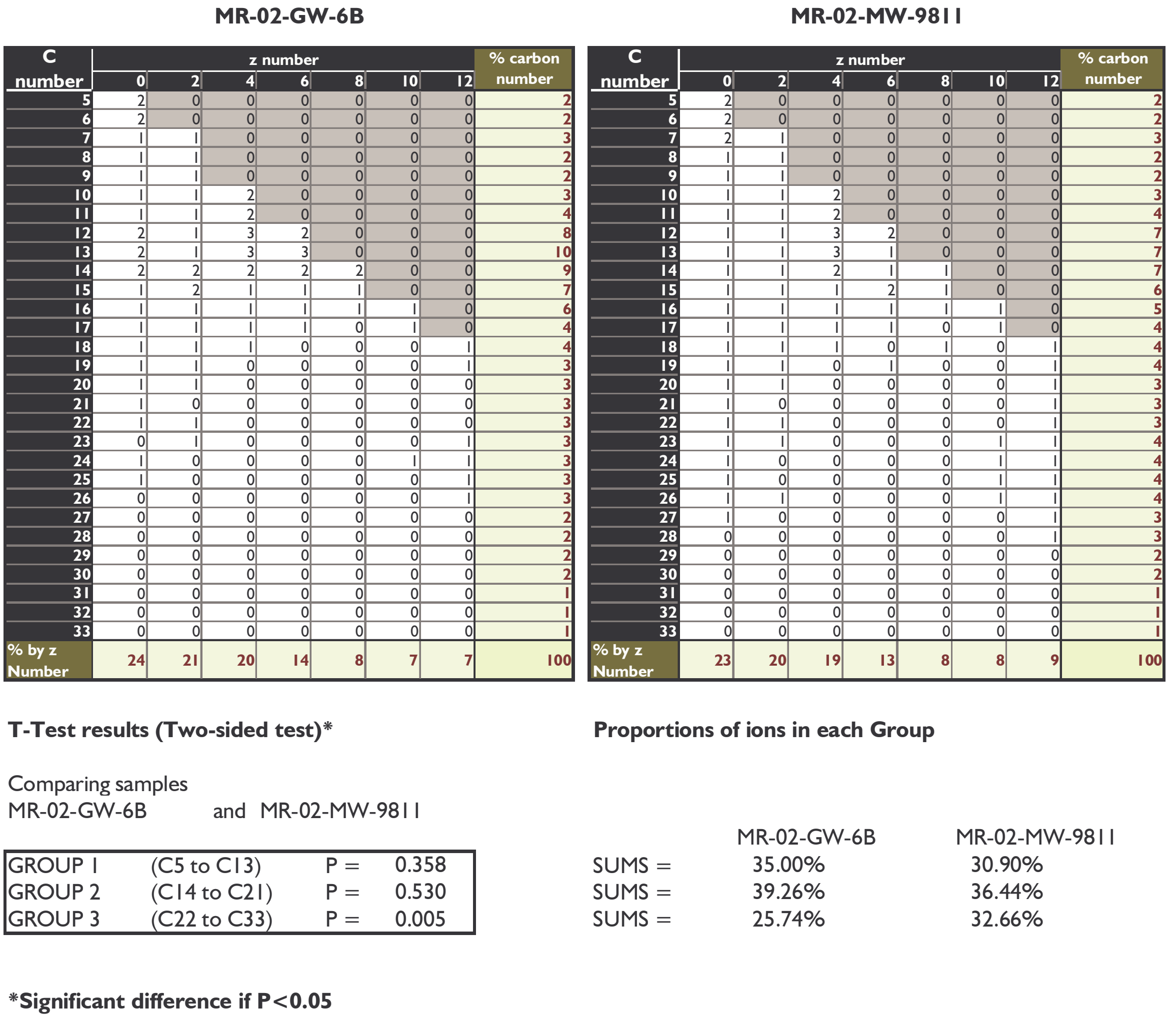
In the course of their evaluation, Holowenko and Fedorak (2002) analyzed 14 NA mixtures from various oil sands related sources and found that they each had a distinctive signature when the data were plotted in three dimensions. First, the data (abundance of specific ions corresponding to naphthenic acids) is organized in a table of Z number versus carbon number (Table 1.3). Second, the data is plotted (Figure 1.4) using the percentage of the total ions as the vertical axis, and the two horizontal axes are carbon number and Z number. The sum of all bars equals 100%.

1.2.2.1 T-Test of Detailed Naphthenic Acid Analysis

A t-test using arcsine-transformed data can be used to compare groups in samples and determine if samples are statistically significantly different. The Students t-test indicates probabilities (P) that the mean found from a finite number of measurements will differ from the "true" mean by a given amount and is useful for comparing data sets of finite number that have random errors characterized by a Gaussian distribution. Three groups were chosen based on carbon number after Clemente *et al.* (2003) examined multiple three dimensional plots: group 1 contains molecules with 5 to 14 carbon atoms, group 2 molecules contain 15 to 21 carbons, and group 3 molecules contain 22 to 33 carbon atoms.

A printout of the program is shown in Figure 1.3. If $P<0.05$, then we can conclude that there is a significant difference between the two groups compared. The printout includes matrices summarizing the percent by number of ions given by the formula $C_nH_{2n+z}O_2$ distributed among carbon numbers and Z families in the two samples. The lower portion shows the results from the t-test comparing the three groups in each sample and the sums of the abundance of the ions in each group. The shaded portion represents cases in which there are insufficient numbers of carbon or hydrogen atoms available to form a naphthenic acid as previously defined.

The t-test is useful for seeing gross changes. Group 3 is more sensitive to being classified as significantly different than the other two groups. Group 1 has 22 homologues, group 2 has 50 and group 3 has 84. Since group 3 contains the majority of homologues and each homologue has a low concentration, minor analytical variations in the first two groups would lead to group 3 being classified as different. This could be an advantage since group 1 and 2 molecules are considered to be more toxic than group 3 (Holowenko et al., 2002); however, it could be a disadvantage if analytical variations are high. The classification must be interpreted in each case.



MR-02-GW-6B

C number	z number							% carbon number
	0	2	4	6	8	10	12	
5	2	0	0	0	0	0	0	2
6	2	0	0	0	0	0	0	2
7	1	1	0	0	0	0	0	3
8	1	1	0	0	0	0	0	2
9	1	1	0	0	0	0	0	2
10	1	1	2	0	0	0	0	3
11	1	1	2	0	0	0	0	4
12	2	1	3	2	0	0	0	8
13	2	1	3	3	0	0	0	10
14	2	2	2	2	2	0	0	9
15	1	2	1	1	1	0	0	7
16	1	1	1	1	1	1	0	6
17	1	1	1	1	0	1	0	4
18	1	1	1	0	0	0	1	4
19	1	1	0	0	0	0	1	3
20	1	1	0	0	0	0	0	3
21	1	0	0	0	0	0	0	3
22	1	1	0	0	0	0	0	3
23	0	1	0	0	0	0	1	3
24	1	0	0	0	0	1	1	3
25	1	0	0	0	0	0	1	3
26	0	0	0	0	0	0	1	3
27	0	0	0	0	0	0	0	2
28	0	0	0	0	0	0	0	2
29	0	0	0	0	0	0	0	2
30	0	0	0	0	0	0	0	2
31	0	0	0	0	0	0	0	1
32	0	0	0	0	0	0	0	1
33	0	0	0	0	0	0	0	1
% by z Number	24	21	20	14	8	7	7	100

MR-02-MW-9811

C number	z number							% carbon number
	0	2	4	6	8	10	12	
5	2	0	0	0	0	0	0	2
6	2	0	0	0	0	0	0	2
7	2	1	0	0	0	0	0	3
8	1	1	0	0	0	0	0	2
9	1	1	0	0	0	0	0	2
10	1	1	2	0	0	0	0	3
11	1	1	2	0	0	0	0	4
12	1	1	3	2	0	0	0	7
13	1	1	3	1	0	0	0	7
14	1	1	2	1	1	0	0	7
15	1	1	1	2	1	0	0	6
16	1	1	1	1	1	1	0	5
17	1	1	1	1	0	1	0	4
18	1	1	1	0	1	0	1	4
19	1	1	0	1	0	0	1	4
20	1	1	0	0	0	0	1	3
21	1	0	0	0	0	0	1	3
22	1	1	0	0	0	0	1	3
23	1	1	0	0	0	1	1	4
24	1	0	0	0	0	1	1	4
25	1	0	0	0	0	1	1	4
26	1	1	0	0	0	1	1	4
27	1	0	0	0	0	0	1	3
28	0	0	0	0	0	0	1	3
29	0	0	0	0	0	0	0	2
30	0	0	0	0	0	0	0	2
31	0	0	0	0	0	0	0	1
32	0	0	0	0	0	0	0	1
33	0	0	0	0	0	0	0	1
% by z Number	23	20	19	13	8	8	9	100

T-Test results (Two-sided test)*

Comparing samples
MR-02-GW-6B and MR-02-MW-9811

GROUP 1	(C5 to C13)	P =	0.358
GROUP 2	(C14 to C21)	P =	0.530
GROUP 3	(C22 to C33)	P =	0.005

Proportions of ions in each Group

	MR-02-GW-6B	MR-02-MW-9811
SUMS =	35.00%	30.90%
SUMS =	39.26%	36.44%
SUMS =	25.74%	32.66%

***Significant difference if P<0.05**

FIGURE 1.3: A printout from the Excel program which compares the naphthenic acids from two groundwater samples collected within the same plume.

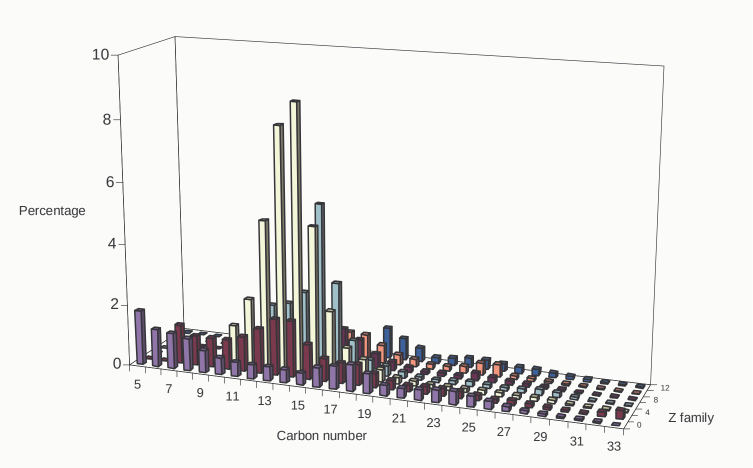


FIGURE 1.4: Example of the 3D graph or "signature" of naphthenic acids in the complex naphthenic acids mixtures extracted and derivatized from both laboratory experiments and field samples.

1.3 Environmental Implications

The level of NAs in process-affected water is acutely toxic to aquatic life (Schramm et al., 2000; Brient et al., 1995; Havre et al., 2003; Herman et al., 1994). The main problem is believed to be osmotic stress and membrane disruption, consistent with the toxic effects of surfactants. Acute toxic responses have been found in bacteria, invertebrates and fish. NAs have been found to be toxic at concentrations down to 1 mg/L. The NA concentration in the Athabasca River both up and downstream of the main oil sand deposits as well as several tributaries in the deposit area did not exceed 1 mg/L and were not considered toxic.

Five ponds at Suncor currently contain about 145 million cubic metres of water and fine tailings, and cover about 870 hectares (Suncor Energy Inc, 2002). The Mildred Lake Settling Basin at Syncrude Canada Ltd contains roughly 880 million m^3 of tailings sand, 200 million m^3 of water and fines tailing and 30 million m^3 of free water with a surface area of 29 km^2(B. Esford, personal communication, April 13, 2004). The combination of high volume and toxicity makes this a significant environmental concern.

1.4 Study Structure

The research program has two principal components.

1. A field component to obtain information on the migration and attenuation of naphthenic acids components of process-affected water.
2. A laboratory study to assess the relative role of sorption and biodegradation as potential mechanisms of naphthenic acids attenuation.

1.5 Objectives.

In general, the environmental mobility of organic contaminants with a polar, water-soluble group attached to a nonpolar, water-insoluble hydrocarbon chain which may be present in groundwater as both ionized and protonated species has been less thoroughly studied than nonpolar organics. Therefore, site-specific investigations may provide the most reliable information for their transport characteristics and possible intrinsic remediation.

Previous work on naphthenic acids has concentrated on analytical method development (St John et al., 1998), corrosive properties (engineering), surfactant properties (petroleum) (Schramm et al., 2000), biodegradation in surface waters (Herman et al., 1994) or the sorption of simple surrogates (Peng et al., 2002). To the best of my knowledge, this is the first published study to investigate field and laboratory biodegradation and retardation of naphthenic acids in glacially deposited sand and gravel and to apply detailed naphthenic acids analysis to sorption studies.

The objectives of the research program are:

1. To evaluate the potential for attenuation of naphthenic acids in surficial sand aquifers as they travel via groundwater to potential surface water receptors, and
2. To identify the principal physical, chemical, or biological processes responsible for attenuation.

Chapter 2

Laboratory Assessment of Biodegradation Potential

This chapter describes a matrix of static microcosms, both aerobic and anaerobic, which was assembled in order to assess the biodegradation potential of naphthenic acids (NAs) in process-water released to aquifers.

2.1 Previous Studies

Results of laboratory studies have been published where the substrate was 1) naphthenic acid surrogates (carboxylated alkanes and cycloalkanes), 2) commercial naphthenic acid mixes or 3) naphthenic acids in process water. The latter may be water directly sampled from a tailings pond or concentrated stock (Rogers et al., 2002). A concentrated stock is created by first collecting tailings pond process-affected water and lettling the solids settle before decanting the clarified tailings. The tailings are acidified to a pH of 2.5. Then, the naphthenic acids are extracted with CH_2Cl_2, the aqueous phase is washed to separate the organic solvent and the solvent is evaporated to leave behind the "organic extract". The extract in acidified to a pH of 13 and filtered to remove the insolubles, leaving behind the organic acids. Finally, the low molecular weight organic acids are isolated, to form the naphthenic acids stock.

There are limitations with each of these sources, other than process water straight from the holding pond. Commercial naphthenic acid mixes may be obtained from different sources and often have a different distribution than tailings pond NAs

(Holowenko et al., 2002). Finally, since we don't know the exact chemistry of NAs, we don't know which surrogates are actually present in NAs or in what concentrations.

2.1.1 Aerobic Biodegradation

Aerobic microbial biodegradation is a significant factor in the fate of naphthenic acids in aerobic surface waters. Natural aging in ponds has decreased the toxicity of process-affected water over time (Mackinnon & Boerger, 1986; Holowenko et al., 2002). Since microbial activity has been observed under laboratory conditions, the decrease in NA concentration and toxicity may be attributed to biodegradation (Herman et al., 1994; Lai et al., 1996; Clemente et al., 2004).

2.1.1.1 Intrinsic Properties of Naphthenic Acids

Several studies have shown that molecular structure has a strong effect on biodegradation potential. The usual metabolic pathway for saturated fatty acids is β oxidation, the metabolic process by which a long-chain fatty acid is shortened by a two-carbon fragment during successive cycles of reactions. The beta refers to the fact that the second carbon of the methyl functional group closest to the carboxylic acid or alkane ring is oxidized. Hammond and Alexander (1972) examined the oxidation of non-cyclic fatty acids to determine the biodegradation potential of surfactants in environments supporting heterogeneous and metabolically active microbial communities. Soil microorganisms rapidly degraded the unsubstituted mono- and dicarboxylic acids, but all dimethyl-substituted compounds tested were relatively resistant to microbial attack. The effect of a single methyl group on the rate of degradation depended on its location relative to the β-carbon. Increasingly complex structures delay microbial destruction, presumably by slowing or preventing reactions with the β-carbon.

An experiment on carboxylated alkanes and single or double ring cycloalkanes yielded further insights into the variability of biodegradation potential. The straight chain palmitic acid degraded more quickly and to a greater degree than bicyclic decahydro-2-naphthoic acid. The rate of biodegradation decreased with increasing number of rings and carbon number, with a marked decrease when there are more than 17 carbons (Lai et al., 1996). Biodegradation potential is decreased by methyl substitution (Herman et al., 1994; Hammond & Alexander, 1972). Geometric isomers (Figure 2.1) also react differently to biodegradation. The *cis* configuration allows a

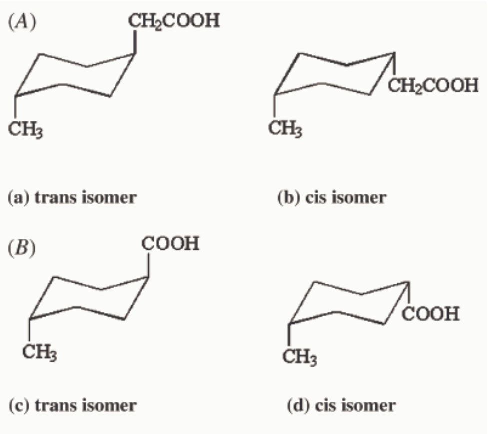


FIGURE 2.1: Molecular structure of the *cis* and *trans* isomers of two cyclic naphthenic acid surrogates: A) 4-methycyclohexaneacetic acid and B) 4-methylcyclohexanecarboxylic (Figure from Peng *et al.*, 2002).

hydrogen bond to form between the methyl and carboxyl groups on the same molecule, making the isomer more resistant (Headley et al., 2002).

The Z=0 family in the process-water naphthenic acids are probably branched rather than linear fatty acids since Holowenko *et al.* (2002) saw no marked decrease in acyclic naphthenic acids in an eleven year period, especially in the carbon number 23 to 26 group. They suggested that Z=0 naphthenic acids are highly branched, since straight chain carboxylated alkanes are readily biodegradable (Lai et al., 1996; Hammond & Alexander, 1972).

2.1.1.2 Chemical Environment

Some compounds did not begin to degrade until nitrogen and phosphorus were added to the aerobic system, implying that microbial activity may be nitrogen- and phosphorus-limited, depending on the environment. A decrease in either oxygen or temperature led to a decrease in biodegradation rate (Lai et al., 1996; Headley et al., 2002).

2.1.1.3 Toxicity

The most toxic NAs have a lower molecular weight (Holowenko et al., 2002; Clemente et al., 2003; Clemente et al., 2004). When examining the 3D signatures, toxicity decreases as the relative abundance of C22+ cluster increases. As well, the relative abundance of C22+ cluster increases as concentration of naphthenic acids decreases. Biodegradation likely removes low molecular weight acids, increasing relative abundance of C22+ cluster (Holowenko et al., 2002). These results were confirmed when Clemente *et al.* (2004) showed commercial preparations of NAs can be degraded under aerobic conditions in enriched cultures from oil sands process-affected waters, with an accompanying reduction of toxicity as measured by the Microtox assay. A 3D graph of the relative abundance of the 156 homologues showed that the overall composition had been changed by biodegradation. The lower molecular weight acids (with carbon number 5-13) were degraded more readily than the high molecular weights acids.

2.1.2 Anaerobic Biodegradation

Methanogens and sulfate-reducing bacteria often compete for the same electron donors in anoxic environments (Table 2.1). Based on available Gibbs free energy and the redox ladder (Stumm & Morgan, 1996), oxygen-reducing bacteria obtain the most energy from hydrogen or acetate (Table 2.1, Equation 1). Sulfate-reducing bacteria (Equations 2, 3 and 4) will obtain more energy than methanogens (Equations 5 and 6) and will therefore out compete the methanogens for that substrate if sulfate is sufficiently abundant. When sulfate is depleted, methanogens will carry out the terminal steps.

Since substantial methanogenesis occurs in tailing ponds (Holowenko et al., 2002), Holowenko, Mackinnon and Fedorak (2001) set up anaerobic microcosms using commercially available NAs, NAs extracted from oil sands process-affected waters, and naphthenic acid surrogates. They hypothesized that if other, non-methanogenic microorganisms are present, the "carboxylated side chains of the naphthenic acids would undergo β-oxidation to provide acetate and H_2 for the methanogens, likely leaving the more recalcitrant cyclic portion unmetabolized" if the carboxylated side chains were of sufficient length. Neither the commercially available NAs nor the process-water derived NAs stimulated methanogenesis in microcosms that contained either oil sands fine tailing or domestic sewage sludge. However, the surrogates added at high concentrations underwent mineralization in the sewage sludge as measured by methane production. As well, when added at 200 mg/L to fine tailings microcosms, 3-cyclohexylpropanoic acid and 4-cyclohexylbutanoic acid gave methane yields that

Reaction mechanisms catalyzed by oxygen reducing bacteria		
$O_2 + 2HCOO^- + 2H^+ \longrightarrow 2CO_2 + 2H_2O$	(1)	ΔG = -125 kJ/eq
Reaction mechanisms catalyzed by sulfate reducing bacteria		
$SO_4^{2-} + 4H_2 + H^+ \longrightarrow HS^- + 4H_20$	(2)	
$SO_4^{2-} + CH_3COO^- \longrightarrow HS^- + 2HCO_3^-$	(3)	
$SO_4^{2-} + 4\ HCOO^- + 5H^+ \longrightarrow HS^- + 4CO_2 + 4H_20$	(4)	ΔG = -25 kJ/eq
Reaction mechanisms involved microbially catalyzed methanogenesis		
$CH_3COO^- + H_20 \longrightarrow CH_4 + HCO_3^-$	(5)	
$4HCOOH \longrightarrow CH_4 + 2H_20$	(6)	ΔG = –23 kJ/eq
Net equation of anoxic methane oxidation		
$CH_4 + SO_4^{2-} \longrightarrow HCO_3^- + HS^- + H_20$	(7)	

Table 2.1: Possible microbially catalyzed reactions (Valentine, 2002; Stumm and Morgan, 1996).

suggested mineralization of the side chain and the ring. The literature suggests that methanogenesis using NAs as substrates is possible under certain circumstances, but not probable.

2.2 Methods

With the exception of the stock NA, all chemicals were purchased from Sigma-Aldrich Canada Ltd (Oakville, Ontario). All water was deionized. A detailed laboratory report may be found in Appendix A.

2.2.1 Soil and Groundwater Collection and Storage

Aquifer material was collected from Fee Lot 2 at the Suncor Energy Inc. site in fall 2002. Cores of the lower semi-confined aquifer were collected in clear Lexan liners inserted into split spoon samplers. After collection, a foil paper cap was immediately placed over the top and bottom of the liner, the foil was taped in place and the ends were dipped in hot wax to seal the ends. Then the entire liner was wrapped in plastic wrap. The soil samples were kept cold in the field using either the ambient air temperature, which hovered around freezing or using freezer packs. In the lab, aquifer material was stored at 4°C.

Groundwater was collected in April 2003 from monitoring well ENV91-7B at Suncor Energy Inc. and shipped to the University of Waterloo in a cooler with freezer packs. The groundwater was stored at 4°C. A subsample was sent for total NA and inorganic ions analysis.

2.2.2 Microcosm Set-Up

All equipment used during the microcosm set-up was sterilized prior to use, and aseptic technique was employed through the experiment.

The core material was allocated 4 days in advance of the experimental set-up and portions used in sterile controls sterilized by autoclaving for 1 hour on 3 successive days (day 1, 2 and 4). Just prior to experimental set-up, the addition of a metabolic poison — either sodium azide (aerobic) or mercuric chloride (anaerobic) — was made to poison microbes in the ground water added to the sterile control microcosms.

Just prior to experimental setup, all pared cores were thoroughly mixed and allocated to sterile, tight sealing mason jars, in an anaerobic glove box. Aquifer material used for anaerobic microcosms was not exposed to oxygen and remained in the glove box at room temperature. Aquifer material for the aerobic microcosm was removed and stored at 4°C. Autoclaved aquifer material from the paring jars were used for control microcosms.

The groundwater was prepared the day before microcosm setup. ENV91-7B groundwater contained approximately 16 mg/L NA and concentrations were increased by adding MLSB-derived NA stock (UW456), to a final NA concentration of 30 mg/L, and then pH adjusted to neutrality. Anaerobic microcosm groundwater was purged overnight with pre-purified nitrogen to a dissolved oxygen concentration of 0.8 mg/L. Positive control microcosms received 10 μl additions of both palmitic (hexadecanoic) acid and cyclohexanepropanoic (CHPA) acid dissolved in methylene chloride (Figure 2.2). The solvent was allowed to evaporate before groundwater addition was made to the microcosm for a final concentration of 10 mg/L of each acid.

Since NA biodegradation is both N and P limited, modified Bushnell Haas medium (MBH) was added. The MBH consisted of: K_2HPO_4, 1.0 L/g; NH_4NO_3, 1.0 L/g; $MgSO_4$*$7H_2O$, 0.2 L/g; $CaCl_2$*$2H_2O$, 0.02 L/g; and $FeCl_3$, 0.005 L/g (modified from Mueller et al., 1991). The following quantities of MBH were added to the groundwater 1-2 hours before dispensing: 506.5 ml of MBH to 19L of groundwater (Aerobic); 493.5

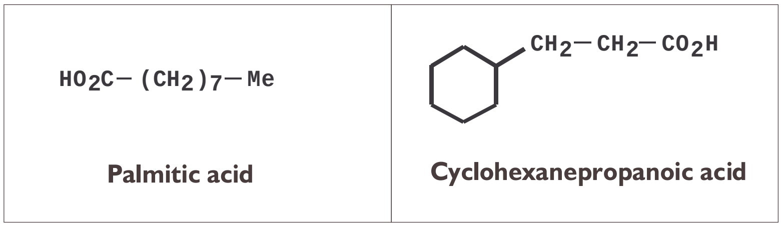


FIGURE 2.2: Chemical structure of the two naphthenic acid surrogates added to the positive control microcosms. “Me” represents a methyl group.

ml of MBH to 18.5L of groundwater (Anaerobic); and 250.5 ml of MBH to 9.4L of groundwater (Aerobic/Anaerobic).

Three hundred and seventy-five milliliters of amended groundwater was added to each of the microcosms. Immediately after groundwater was dispensed, each amber glass bottle was capped with a Teflon septa and screw cap, leaving a headspace containing either air or a mixed gas of nitrogen gas, carbon dioxide and hydrogen. A total of 144 microcosms were created. Microcosms were incubated at room temperature in the dark, either in the anaerobic chamber or in a cardboard box in the laboratory.

Due to the insolubility of palmitic acid and CHPA, 4 extra positive control microcosms (2 aerobic and 2 anaerobic) were prepared in the same way as the other positive controls, but without soil. These microcosms were used to obtain initial total NA concentration of the positive control groundwater. For the NA analysis of these particular bottles, methylene chloride, an extractant, was added directly to the microcosm to enable extraction of palmitic acid and CHPA emulsions.

2.2.3 Sampling and Analysis

Either a 50 mL ground glass syringe fitted with a Teflon tip or a glass pipette was used to draw groundwater out of the microcosms. Care was taken not to disturb the sediment in the microcosm. All microcosms were sampled for total naphthenic acid concentration and detailed naphthenic acid analysis. Aliquots were measured for dissolved oxygen and pH with probes and then returned to the total NA samples for aerobic microcosms or refrigerated/frozen for anion analysis by ion chromatograph (SO_4^{2-}, F^-, Cl^-, Br^-, PO_4^{3-}) for anaerobic microcosms. In addition, anaerobic microcosms were intermittently sampled for methane (15 mL in ground glass syringes) and analyzed by gas chromatograph (Kampbell & Vandergrift, 1998; EPA,).

Fourier transform infrared spectroscopy (FTIR) was used to analyze the total concentration of naphthenic acids (Jivraj et al., 1995). Three hundred milliliters of microcosm water was acidified to a pH of less than 2 with 1:1 sulfuric acid. Then 100 mL was used for total NA and 200 mL saved for detailed NA by gas chromatograph-mass spectrometry (St John et al., 1998). The last aerobic sample and the last 2 anaerobic samples for NA analysis were extracted slightly differently; samples for total NA and detailed NA were acidified separately.

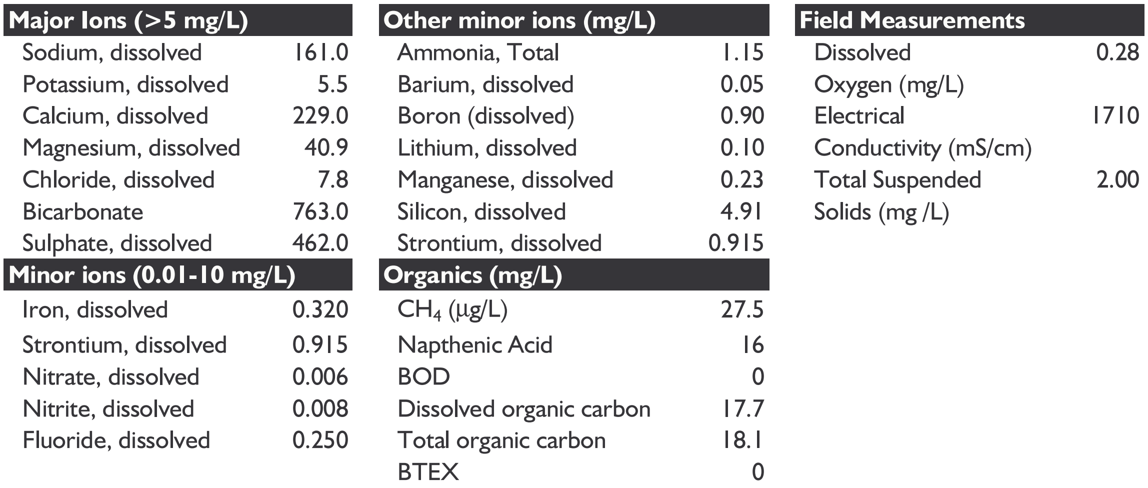
Aerobic microcosms were sacrificed 7 times in triplicate (3 active, 3 positive controls and 3 sterile controls) on days 1, 8, 14, 43, 57, 83 and 140. On day 8, the samples were decanted instead of drawn off. Anaerobic microcosms were sacrificed 7 times in triplicate (3 active, 3 positive controls and 3 sterile controls) on days 1, 7, 37, 63, 91, 140 and 182. On days 91 and 182, the naphthenic acids in the positive control microcosms were extracted from both the aqueous and solid phases (extraction was performed in the bottle including the soil). As well, on day 182 an additional set of positive control microcosms were extracted as usual. One set of aerobic and anaerobic microcosms (minus one set of positive controls) were saved for future analysis.

2.2.4 Groundwater

Laboratory studies of microbial activity and contaminant degradation are of limited value unless the samples are incubated at a redox state representing *in situ* conditions. For this reason, groundwater from a well near the base of Dyke 2W, screened in the semi-confined glaciofluvial sand and gravel aquifer at a depth of approximately 60 feet on the Suncor lease was used as the base groundwater for all microcosms and supplemented by stock NA derived from a Syncrude holding pond. The groundwater chemical characteristics are listed in Table 2.2. Low *in situ* dissolved oxygen (DO) of <0.5 mg/L confirms that the water was initially anaerobic.

The addition of the stock naphthenic acid to the groundwater has increased the relative concentration of the C5-C20 ions with Z=-2 and -4 with the accompanying decrease in all other groups.

Phosphate concentrations have historically been low. Of the common groundwater electron acceptors, nitrate and nitrite are both below the method limit and the his-



Major Ions (>5 mg/L)	
Sodium, dissolved	161.0
Potassium, dissolved	5.5
Calcium, dissolved	229.0
Magnesium, dissolved	40.9
Chloride, dissolved	7.8
Bicarbonate	763.0
Sulphate, dissolved	462.0

Minor ions (0.01-10 mg/L)	
Iron, dissolved	0.320
Strontium, dissolved	0.915
Nitrate, dissolved	0.006
Nitrite, dissolved	0.008
Fluoride, dissolved	0.250

Other minor ions (mg/L)	
Ammonia, Total	1.15
Barium, dissolved	0.05
Boron (dissolved)	0.90
Lithium, dissolved	0.10
Manganese, dissolved	0.23
Silicon, dissolved	4.91
Strontium, dissolved	0.915

Organics (mg/L)	
CH_4 (μg/L)	27.5
Napthenic Acid	16
BOD	0
Dissolved organic carbon	17.7
Total organic carbon	18.1
BTEX	0

Field Measurements	
Dissolved Oxygen (mg/L)	0.28
Electrical Conductivity (mS/cm)	1710
Total Suspended Solids (mg /L)	2.00

Table 2.2: Chemical characteristics of groundwater collected from monitoring piezometer ENV91-7B on Suncor lease in April 2003.

torical presence of ammonia indicates a highly reduced environment. Dissolved iron is 0.32 mg/L. Sulfate levels are high at 442 mg/L and may suppress methanogenesis (Fedorak et al., 2002). In spite of this, methane concentrations are measurable at 27.5 μg/L.

2.2.5 Changes in pH

Since aqueous pH will affect the solubility of organic acids and microbial activity, it is important to keep it stable. Oil-water partitioning coefficients for naphthenic acids can change by half an order of magnitude as pH increases from 7 to 8 (Havre et al., 2003) and individual surrogate solubility can change by a full order of magnitude (Havre et al., 2003). Changes in pH must be monitored in case substantial desorption occurs increasing both aqueous concentrations and, perhaps, bioavailability. Fortunately, pH never went lower than 7. At pH 7 and higher, most of the molecules were already deprotonated. The effect of changing pH on microbial activity is unknown.

Except for the gas present in the headspace, all microcosms were treated the same. All bottles, whether aerobic or anaerobic, had the same headspace, the same water was placed in a capped bottle, used the same homogenized soil and were stored in the dark. The water pH was adjusted to 7 with HCl prior to addition to the microcosms. However, final pH varied in the different microcosms. Two of the possible reasons for the change are the chemicals used to inhibit microbial activity in the controls and the microbially catalyzed reactions. Since the soil was not analyzed, the soil buffering capacity is unknown.

2.2.5.1 Aerobic Microcosms

The pH measurements of each aerobic active and positive control set was somewhat constant (Table 2.3). All bottles showed an increase in pH from 7 from a minimum of 7.2 to a maximum of 8.7. At this pH, most of the NA molecules will be present as ionized molecules and will have a high solubility and bioavailability. Field values were as high as pH 8.4 and therefore, it is probable that microbial activity was not adversely affected.

The aerobic controls had pH ranging from 7.7 to 8.5, a higher minimum than the active or positive control. The soil had been thoroughly autoclaved and the water poisoned with sodium azide. Sodium azide has been known to increase pH from 5.2 to 8.7 over a 30 day period if the soil did not have sufficient buffering capacity (Wolf et al., 1989). The soil buffering capacity is unknown.

2.2.5.2 Anaerobic Microcosms

The increase in pH for the anaerobic active and positive controls are neither as precise nor as small as the controls (Table 2.4). There is a general increase in pH (maximum of 9) with decreasing sulfate concentration, which may due to the consumption of hydrogen during sulfate reduction and methanogenesis (Table 2.1). The active microcosms had maximum pH higher than the maximum field value of 8.4. However, since sulfate reduction was occurring in these microcosms, it may be inferred that not all microbial activity was reduced.

The pH of the anaerobic controls were very similar over the course of the experiment (Table 2.4). The pH increase is approximately 0.4 to 0.5 units above the initial pH of 7. Mercuric chloride ($HgCl_2$) was added as a microbial poison. It was ideal because it causes minimal changes in soil chemical and physical properties. The pH increase is consistent with literature values of pH change due to $HgCl_2$ poisoning (Wolf et al., 1989).

	Set 3 pH	Set 4 pH	Set 5 pH	Set 6 pH	Set 7 pH
Control A	7.91	7.87	8.01	7.71	7.75
Control B	7.92	7.85	8.25	8.39	8.51
Control C	7.96	7.84	8.18	7.9	8.16
Control Average	7.93	7.85	8.15	8.00	8.14
Active A		7.42	7.71	8.43	8.66
Active B		7.48	8.02	7.25	7.33
Active C		7.34	7.59	8.3	7.19
Active Average		7.41	7.77	7.99	7.73
Positive Control A		7.35	8.39	8.48	7.14
Positive Control B		7.36	7.53	8.39	7.21
Positive Control C		7.36	8.21	8.43	7.26
RSD		7.36	8.04	8.43	7.20

Table 2.3: pH in various aerobic microcosms. Each set had three replicate bottles, labelled A, B and C. Set 3, 4, 5, 6 and 7 sampled on days 14, 44, 58, 84 and 141 respectively.

	Set 3 pH	Set 4 pH	Set 5 pH	Set 6 pH	Set 7 pH
Control A	7.46	7.38	7.44	7.46	7.33
Control B	7.47	7.41	7.46	7.54	7.40
Control C	7.48	7.41	7.44	7.48	7.41
Control Average	7.47	7.40	7.45	7.49	7.38
Active A	7.85	7.91	8.33	8.01	7.68
Active B	7.83	7.97	8.16	8.72	8.02
Active C	7.94	7.99	7.96	8.12	8.63
Active Average	7.87	7.96	8.15	8.28	8.11
Positive Control A	8.03	8.41	8.01	8.42	8.63
Positive Control B	8.44	8.61	8.74	8.80	9.04
Positive Control C	7.91	7.82	8.12	7.70	8.84
Positive Control Average	8.13	8.28	8.29	8.31	8.84

Table 2.4: pH in different anaerobic microcosms. Each set had three replicate bottles, labelled A, B and C. Set 3, 4, 5, 6 and 7 sampled on days 37, 63, 91, 140 and 182.

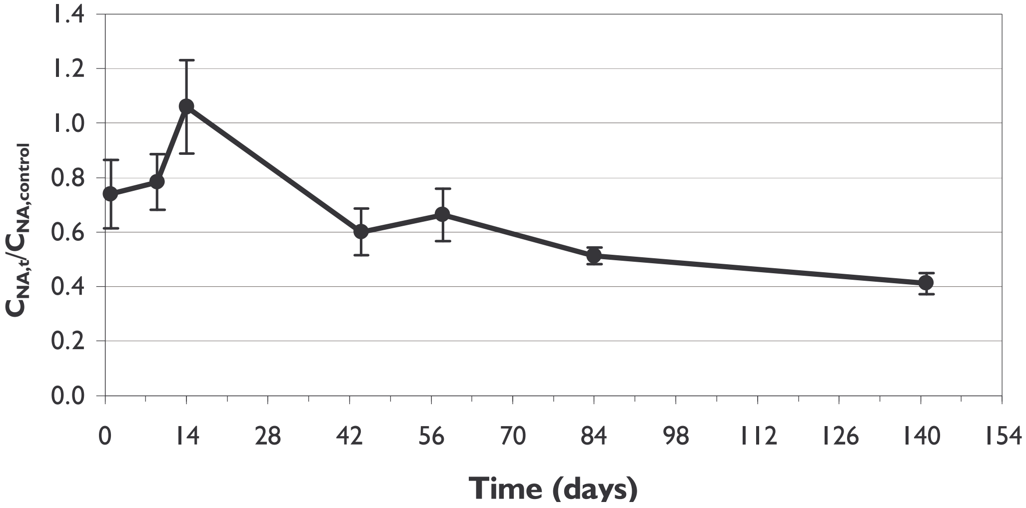


FIGURE 2.3: Change in the total average naphthenic acids concentration in the active aerobic microcosms, normalized by the average concentrations in the control microcosms sampled on the same day.

2.3 Results and Discussion

2.3.1 Aerobic Microcosms

2.3.1.1 Changes in Naphthenic Acid Concentration

The NA concentrations for the active microcosms showed a 60% decrease over 18 weeks, starting from Day 14 (Figure 2.3). There is an apparent lag time of 14 to 42 days before microbial degradation started. The controls showed no decrease overall and, by days 83 and 140, were more than two standard deviations higher than concentrations in the active and positive control bottles. After an initial lag time of several weeks, the greatest rate of change appears to occur between day 14 and 42. Note that the second set of microcosms were decanted instead of drawn off; the inclusion of geological material in the sample water could explain the low concentrations found in all the "Set 2" bottles. See Appendix A.8 for a table containing all data.

In order to confirm that aerobic conditions existed from beginning to end, dissolved oxygen (DO) measurements were taken for Set 4, 5, 6 and 7. In general, the concentrations in the active and positive controls were very similar to the control (around 8 mg/L). Bottles sacrificed on day 44 (Set 4) had DO concentrations that went down to 6.5 and 6.2 mg/L for the active and positive controls and day 141 (set 7) had DO as low as 4.2 mg/L. This is low compared to 8 mg/L for the sterile control, perhaps indicating strong aerobic activity. While low NAs concentration are present at all DO concentrations, DO less than 6 mg/L occur only with low NAs concentration, providing further support that aerobic biodegradation is decreasing NA concentrations. See Appendix A.8 for a table containing all data.

2.3.1.2 Changes in Naphthenic Acid Composition

Microbial biodegradation is expected to change the relative proportions of homologues (Figures 2.4, 2.5 and 2.6). In this presentation, the bars represent the percentage by number of ions of NAs in the mixture that can account for a given carbon number of a given Z family. The sum of all bars equals 100% and so the relative proportion of homologues is displayed (Holowenko et al., 2002). A graph of every microcosm is presented in appendix A.9.

The biodegradation pattern seen by other researchers was an apparent increase in the relative proportions of the C≥22 homologues (Group 3) caused by a decrease in the proportion of lower molecular weight molecules (Clemente et al., 2004; Holowenko et al., 2002). In this experiment, all Z families with C≥22 show a higher relative proportion in NA homologues after 8 and 20 weeks, except for the Z=-10 family which shows no change.

The bicyclic naphthenic acids (Z=-4) with carbon number 12-16 are the only molecules that show a proportional decrease greater than 0.5% (Figure 2.7). The Z=0 family has no decrease>0.4%. Most are probably highly branched, which would interfere with biodegradation (Holowenko et al., 2002; Lai et al., 1996; Hammond & Alexander, 1972).

T-test analysis Table 2.5 shows the results of the t-test of the active aerobic microcosms. Between Set 1 and 5 (day 1 and 58), and Set 1 and 7 (day 1 and 141), the relative proportion in group 3 changed significantly, confirming the visual observations. Group 1 (carbon number from 5 - 14) changed significantly from Set 1 to 7. Group 2 (carbon number 15-21) changed very little.

When compared against themselves, the control microcosms for Set 1 and Set 5 do show some significant difference in Group 3. However, since P>0.6 for the other two

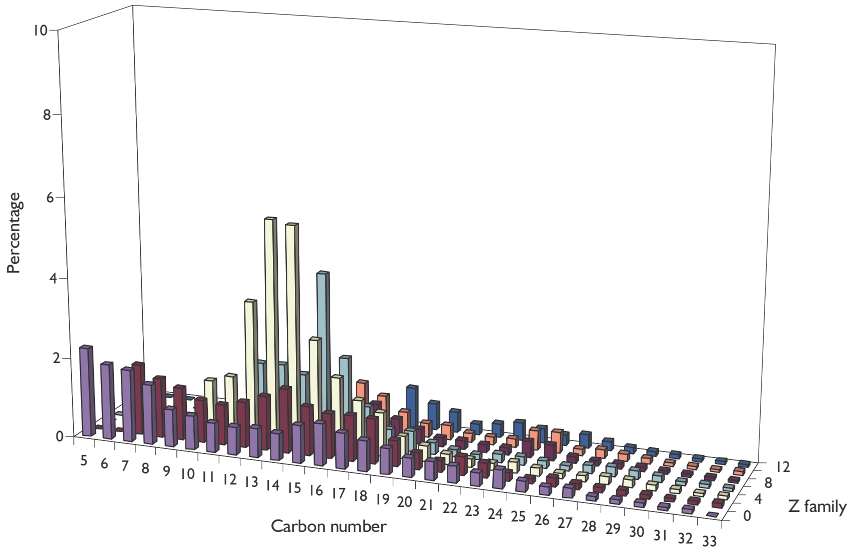


FIGURE 2.4: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from an active aerobic microcosm sampled after one day (Active C, Set 1).

groups in all cases, this is considered to be an analytical variability. When the active microcosms are compared against each other, several of them are statistically different in group 3. Since Group 1 or Group 2 had P<0.5, this difference was considered to be real.

The overall pattern of change in the aerobic microcosms was a decrease in the relative proportions of Group 1, no significant change in Group 2 and an increase in Group 3 (Figure 2.8).

2.3.2 Anaerobic Microcosms

2.3.2.1 Naphthenic Acids, Sulfate and Methane

In the anaerobic microcosms, naphthenic acid concentrations do not change measurably over the course of 6 months (Figure 2.9). The increase in concentration in the active microcosms relative to the controls in the last two set of bottles sacrificed may be due to a slight change in the analytical method (see page 17) or may be attributed to increased solubility due to increased pH, releasing any sorbed naphthenic acids.

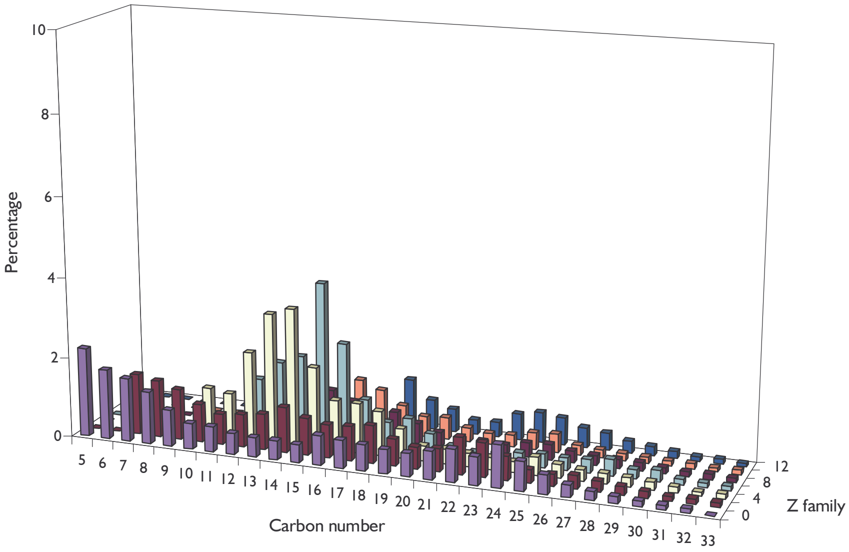


FIGURE 2.5: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from an active aerobic microcosm sampled after 8 weeks (Active C, Set 5).

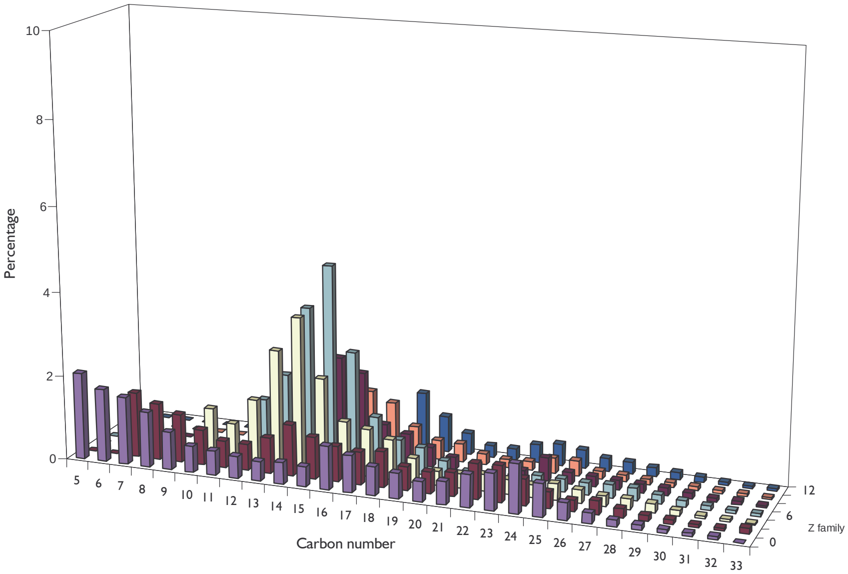


FIGURE 2.6: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from an active aerobic microcosm sampled after 20 weeks (Active C, Set 7).

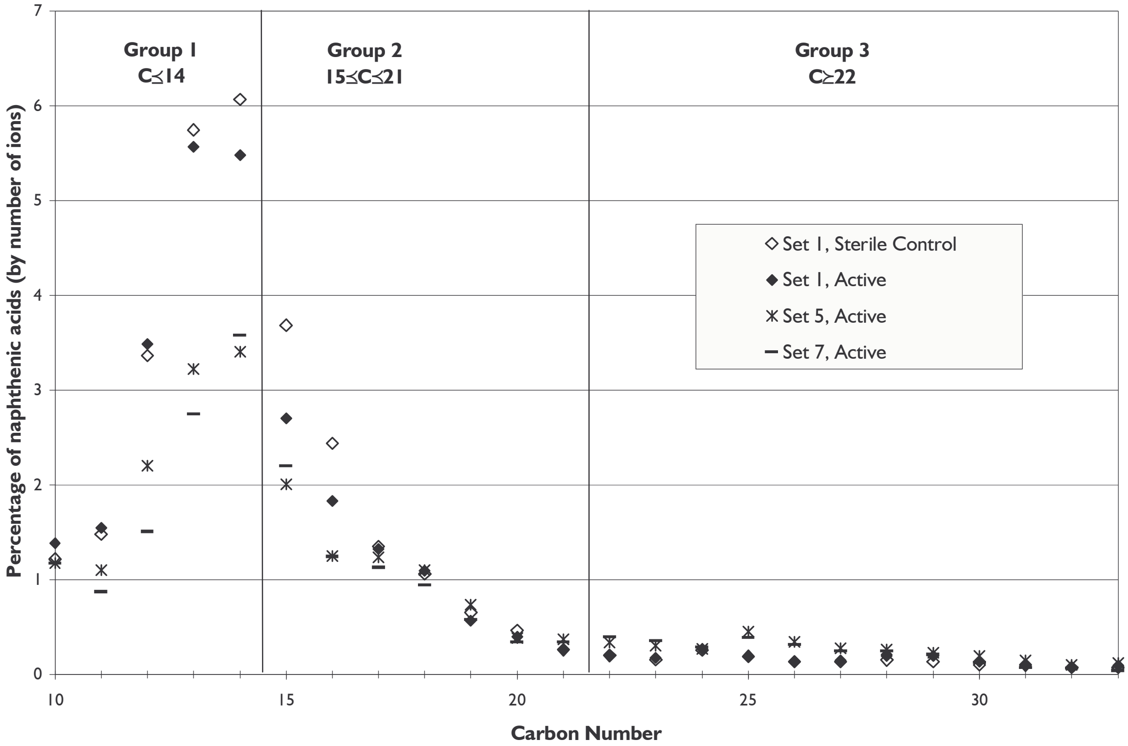
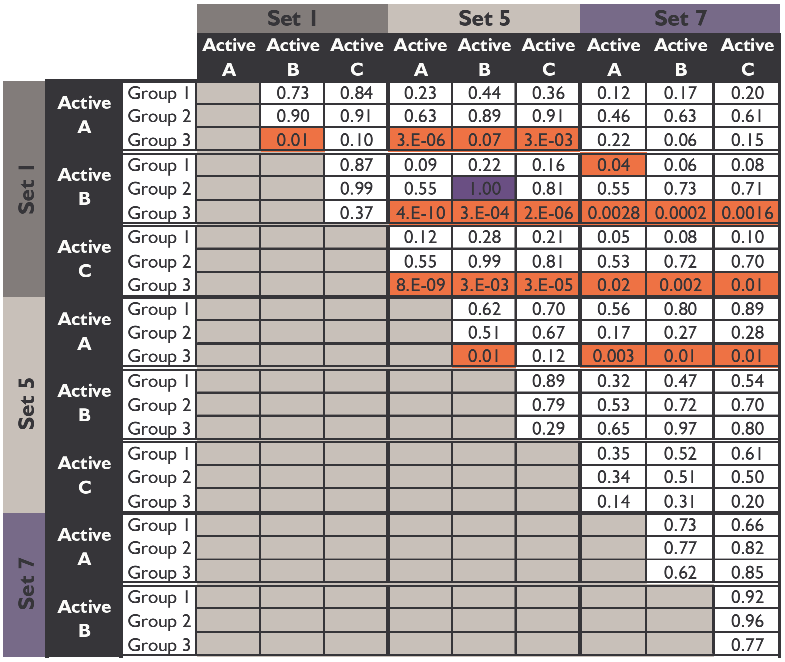
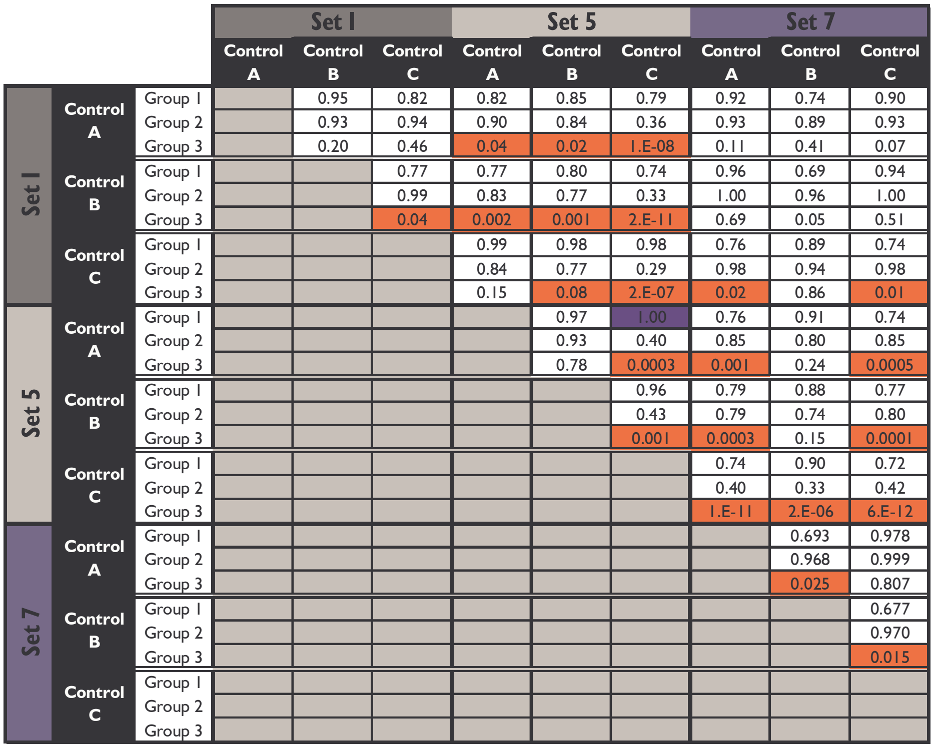


FIGURE 2.7: The distribution of carbon numbers of naphthenic acids in the Z=-4 family from the aerobic microcosms.



A)

			Set 1			Set 5			Set 7		
			Active A	Active B	Active C	Active A	Active B	Active C	Active A	Active B	Active C
Set 1	Active A	Group 1		0.73	0.84	0.23	0.44	0.36	0.12	0.17	0.20
		Group 2		0.90	0.91	0.63	0.89	0.91	0.46	0.63	0.61
		Group 3		0.01	0.10	3.E-06	0.07	3.E-03	0.22	0.06	0.15
	Active B	Group 1			0.87	0.09	0.22	0.16	0.04	0.06	0.08
		Group 2			0.99	0.55	1.00	0.81	0.55	0.73	0.71
		Group 3			0.37	4.E-10	3.E-04	2.E-06	0.0028	0.0002	0.0016
	Active C	Group 1				0.12	0.28	0.21	0.05	0.08	0.10
		Group 2				0.55	0.99	0.81	0.53	0.72	0.70
		Group 3				8.E-09	3.E-03	3.E-05	0.02	0.002	0.01
Set 5	Active A	Group 1					0.62	0.70	0.56	0.80	0.89
		Group 2					0.51	0.67	0.17	0.27	0.28
		Group 3					0.01	0.12	0.003	0.01	0.01
	Active B	Group 1						0.89	0.32	0.47	0.54
		Group 2						0.79	0.53	0.72	0.70
		Group 3						0.29	0.65	0.97	0.80
	Active C	Group 1							0.35	0.52	0.61
		Group 2							0.34	0.51	0.50
		Group 3							0.14	0.31	0.20
Set 7	Active A	Group 1								0.73	0.66
		Group 2								0.77	0.82
		Group 3								0.62	0.85
	Active B	Group 1									0.92
		Group 2									0.96
		Group 3									0.77



B)

			Set 1			Set 5			Set 7		
			Control A	Control B	Control C	Control A	Control B	Control C	Control A	Control B	Control C
Set 1	Control A	Group 1		0.95	0.82	0.82	0.85	0.79	0.92	0.74	0.90
		Group 2		0.93	0.94	0.90	0.84	0.36	0.93	0.89	0.93
		Group 3		0.20	0.46	0.04	0.02	1.E-08	0.11	0.41	0.07
	Control B	Group 1			0.77	0.77	0.80	0.74	0.96	0.69	0.94
		Group 2			0.99	0.83	0.77	0.33	1.00	0.96	1.00
		Group 3			0.04	0.002	0.001	2.E-11	0.69	0.05	0.51
	Control C	Group 1				0.99	0.98	0.98	0.76	0.89	0.74
		Group 2				0.84	0.77	0.29	0.98	0.94	0.98
		Group 3				0.15	0.08	2.E-07	0.02	0.86	0.01
Set 5	Control A	Group 1					0.97	1.00	0.76	0.91	0.74
		Group 2					0.93	0.40	0.85	0.80	0.85
		Group 3					0.78	0.0003	0.001	0.24	0.0005
	Control B	Group 1						0.96	0.79	0.88	0.77
		Group 2						0.43	0.79	0.74	0.80
		Group 3						0.001	0.0003	0.15	0.0001
	Control C	Group 1							0.74	0.90	0.72
		Group 2							0.40	0.33	0.42
		Group 3							1.E-11	2.E-06	6.E-12
Set 7	Control A	Group 1								0.693	0.978
		Group 2								0.968	0.999
		Group 3								0.025	0.807
	Control B	Group 1									0.677
		Group 2									0.970
		Group 3									0.015
	Control C	Group 1									
		Group 2									
		Group 3									

TABLE 2.5: T-test results for the A) active aerobic microcosms and B) sterilized aerobic control microcosms. $P<0.05$ (squares in red) indicates a statistically significant difference between the samples. $P=1$ (dark square) indicates no difference between the samples. Group 1 includes all Z numbers with carbon number 5 to 14. Group 2 includes all Z numbers with carbon numbers 15 to 21. Group 3 includes all Z numbers with carbon number 22 to 33.

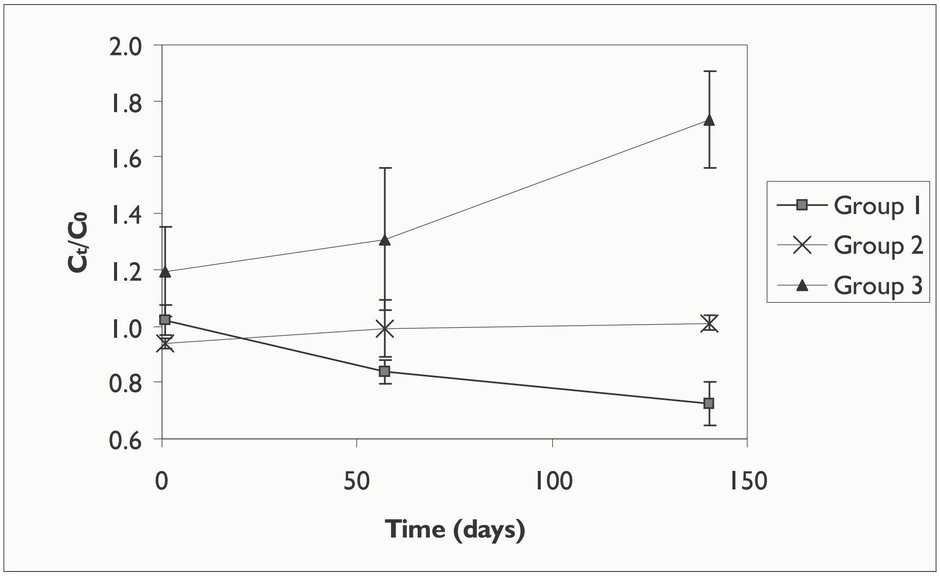


FIGURE 2.8: Changes in the relative abundances of naphthenic acids recovered from aerobic microcosms after different incubation times. The proportions of ions were summed in groups according to carbon numbers and normalized to the control sacrificed on the same day.

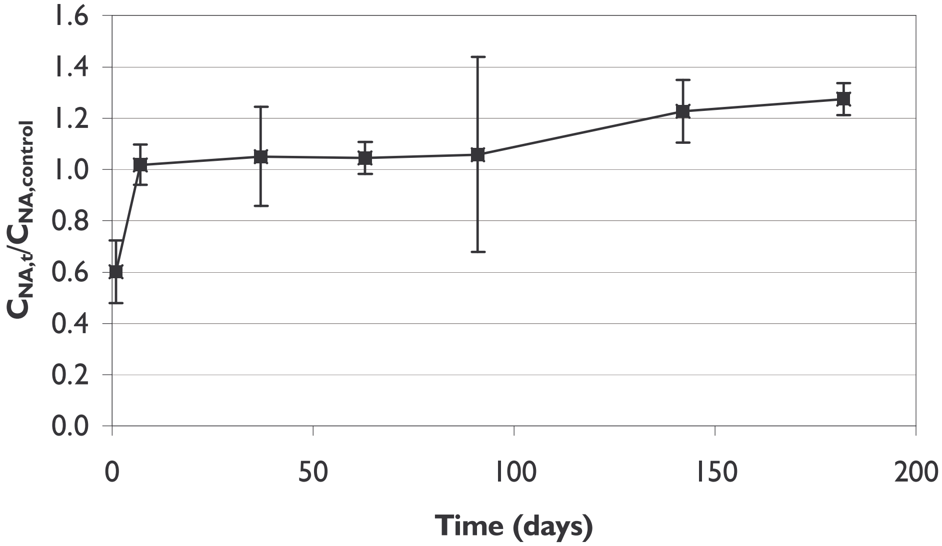


FIGURE 2.9: Changes in the total average concentration of naphthenic acids over the 26 weeks (6 months) of the anaerobic microcosm experiment, normalized by the average concentrations in the control microcosms. NA refers to naphthenic acids.

See Appendix A.8 for tables containing all data.

Sulfate reduction and methanogenesis were highly variable. For example, on day 182, methane concentrations in the three active microcosms ranged from 3 to 1000 μg/L. Where methane is present, its concentration is 2 to 3 orders of magnitude greater in the active and positive controls than in the sterile control, indicating the increase is due to a microbial process, not an abiotic one. Figure 2.10 shows that methane is never present when sulfate concentration is greater than 100 mg/L. Fedorak *et al.* (2002) observed that methane production in microcosms using geological material from holding ponds was not significant until sulfate concentrations were less 20 mg/L and that there was evidence of anaerobic methane oxidation when sulfate concentrations were between 20 and 48 mg/L. The two highest methane concentrations occurred when sulfate concentrations were less than 10 mg/L which may be attributed to a lack of competition by sulfate reducers.

The solubility of methane in water at 25°C is around 20 mg/L (Dean, 1999). The dissolved organic carbon (DOC) in the groundwater was measured at 17.7 mg/L and 14 mg/L of NAs were added. If all DOC and NAs were converted to methane, the simplified reaction pathways for biogenic methane production give a theoretical methane concentration

$$\begin{aligned} 2CH_2O &\rightarrow CO_2 + CH_4 \\ 18 \text{ mg/L } CH_2O &\rightarrow 13 \text{ mg/L } CO_2 + 5 \text{ mg/L } CH_4 \end{aligned}$$

and either/or

$$\begin{aligned} CH_3COOH &\rightarrow CO_2 + CH_4 \\ 14 \text{ mg/L } CH_3COOH &\rightarrow 10 \text{ mg/L } CO_2 + 4 \text{ mg/L } CH_4 \end{aligned}$$

for an approximate maximum methane concentration of 4-5 mg/L. Since the highest concentration measured was 1 mg/L, then methane concentrations are not considered high. It is probable that the other microbes which degrade the organic matter to provide acetate and hydrogen gas for the methanogens did not need to use the naphthenic acids as electron acceptors as yet, which may account for a lack of mass NA mass loss.

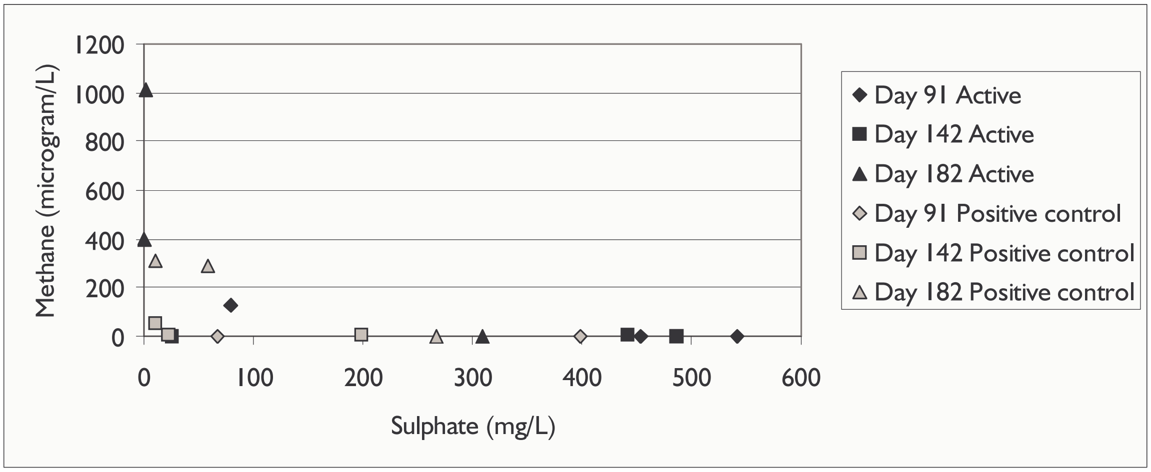


FIGURE 2.10: Variations in sulphate and methane concentrations in the active and positive control microcosms of the anaerobic microcosms.

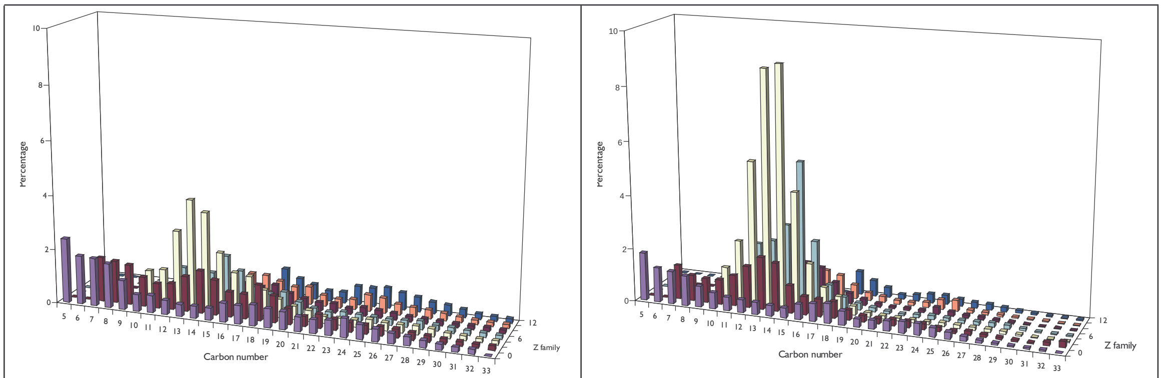
2.3.2.2 Changes in NA composition

Set 2 (Day 7) was used as the initial value for detailed naphthenic analysis instead of set 1 (Day 1) since the NA concentrations were more stable (i.e. all data points within one standard deviation). Also, all active microcosms in set 2 are similar to the controls (Table 2.6). This visual observation was confirmed by t-test analysis (Table 2.5).

When each active sample is compared against all the other microcosms, there is no probability of significant difference less than 0.2 in groups 1 and 2 ($C \leq 21$), although there is often a significant difference in the relative proportion of group 3. However, as discussed in the Introduction, this alone is not a good enough reason to declare that group 3 is significantly different. There is no real change in the naphthenic acid "signature", even in the microcosm with the 1 mg/L of methane (Set 7, Active 4) (Table 2.6).

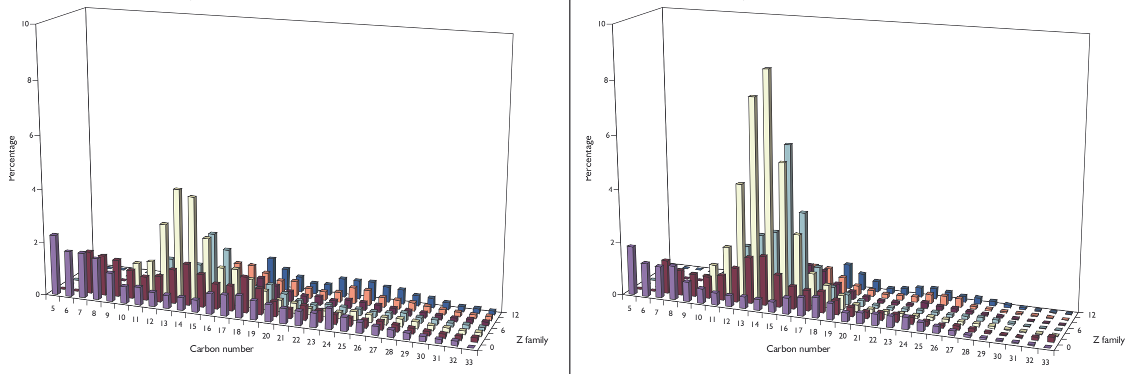
2.3.3 Positive Control Microcosms

The positive control microcosms contained two easily degraded naphthenic acid surrogates: palmitic acid and cyclohexanepropanoic (CHPA) acid (Figure 2.2). Sulfate-reduction and methanogenesis was comparable to the active microcosms. However,



A) Active, Day 7

C) Control, Day 147



B) Control, Day 7

D) Active, Day 147

TABLE 2.6: The distribution of carbon numbers and Z families of naphthenic acids in the complex mixtures extracted and derivatized from anaerobic microcosms sampled after A) 7 days, Active B, Set 2, B) 7 days, Control C, Set 2, C) 26 weeks, Control A, Set 7 and D) 26 weeks, Active A, Set 7.

difficulties with extraction appear to have produced unreliable naphthenic acids concentration data and results are not discussed further.

2.4 Conclusions

2.4.1 Aerobic Microcosms

Just as with aerobic surface waters, aerobic biodegradation may be a significant factor in the fate of naphthenic acids in groundwater. Over 141 days, aerobic microcosms showed a 60% decline in naphthenic acids (NA) concentration (Figure 2.3) as compared to the >90% decrease in 10 days seen when enriched cultures from tailings are used to degrade commercial NAs (Clemente et al., 2004). The rate of degradation was greatest for the first 6 weeks. While less mass loss was seen in the final 100 days of the experiment, analysis of detailed NA indicates that biodegradation continued over the whole period of time. This suggests some potential for limited, rapid (in terms of groundwater flow) biodegradation of NAs under aerobic aquifer conditions.

Selected microcosms samples have been characterized using Holowenko *et al.*'s (2002) technique. A visual appraisal of the data (Figures 2.4, 2.5 and 2.6) found changes in the composition of the NAs over time. The most dramatic change is the 5% decrease in relative proportion of 3 bars, the C12-C14 bicyclic acids.

By week 20, Group 1 along with Group 3 had shown a significant change in relative concentration (Figure 2.8). The relative proportion of Group 1 had decreased, the relative proportion of Group 2 had remained steady while the relative proportion of Group 3 had increased. Since the decrease in Group 1 and 2 has been shown to be accompanied by a decrease in toxicity (Clemente et al., 2004), process-affected water in an aerobic aquifer may show a decrease in toxicity as well as NA concentration. No toxicity testing was done in the current experiment.

This pattern is believed to indicate a decrease in Group 1 acids and not an increase in the concentration of Group 3. Aerobic naphthenate-degrading bacteria occur naturally in most of the active water bodies at the Syncrude site (Schramm et al., 2000). The microcosms confirm their presence in the glacial aquifer near Suncor's Pond 2/3. These results support the hypothesis that limited aerobic biodegradation of the smaller components of NAs could occur relatively rapidly under field conditions.

2.4.2 Anaerobic Microcosms

The anaerobic microcosm showed no significant decrease in naphthenic acid concentration but microbial activity led to sulfate reduction and trace amounts of methane were detected, up to 1000 μg/L. There is no strong evidence over the 26 week period that NAs were significantly utilized. However, surrogate anaerobic biodegradation has been measured and it is possible that a substantial lag time delays degradation.

Chapter 3

Laboratory Assessment of Retardation

3.1 Introduction

Sorption may retard the transport of a compound through groundwater and affect the volatility of organic pollutants, their bioavailability and bioactivity, phytotoxicity, and chemical or microbial transformations (Delle Site, 2001). In this text, "sorption" refers to a reversible sorption-desorption reaction as a chemical distributes itself between the solution and solid phases. The primary liquid phase from which sorption occurs is the solution or solvent. Solute is the free chemical in solution, sorbate is the sorbed chemical on the solid and sorbent is sorbing phase. The term "partition" will be used for the distribution of a chemical between the organic fraction of the sorbent and the solvent, while "adsorption" will be used for the interaction of the chemical with the sorbent mineral fraction (Chiou et al., 1983).

Armed with a sorption coefficient (K_d), we may estimate the retardation (i.e. the diminished chemical transport speed relative to groundwater flow). Since sorption is a significant process in the fate, distribution and transport of a compound, numerous methods have been developed to determine K_d (Delle Site, 2001).

Probably the most extensively used tool is the batch equilibration method. Geological material is added to a bottle along with solute and solvent and kept at constant temperature; the weight, volume and concentration are all known. For organic acids, accurate K_d determination also requires reproduction of the pH and ionic strength

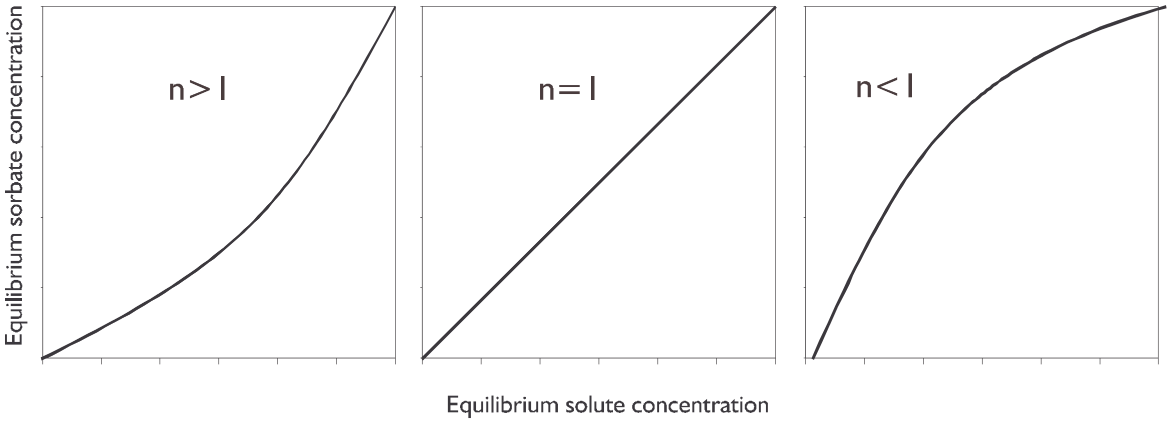


FIGURE 3.1: Typical Freundlich isotherms describing sorption of organic compounds in water by natural sorbents.

of site groundwater. The bottle is shaken until sorption equilibrium is reached. The aqueous phase is sampled to determine the equilibrium solute concentration and the difference between the initial and final aqueous concentration is assumed to be sorbate. Since sorption behaviour may change as concentration changes, batch reactors should be set up using a minimum of three concentrations.

The sorption isotherm is a graphical expression of the equilibrium distribution of a chemical between solid and aqueous phases at different solute concentrations but same temperature and, usually, same pH and ionic strength. An isotherm shows an empirical relationship. It is constructed by plotting the sorbate adsorbed per unit dry mass of solid versus the solute concentrations at equilibrium and fitting a line through the data (Figure 3.1).

Linear isotherms, which have been used to describe the sorption of naphthenic acids surrogates (Peng et al., 2002), are a special case of the Freundlich isotherm:

$$C_{i,s} = K_{i,F} \cdot C_{i,w}^{n_i} \tag{3.1}$$

where i is the chemical of interest, $C_{i,s}$ is the sorbate concentration, $C_{i,w}$ is the solute concentration, $K_{i,F}$ is the Freundlich constant or capacity factor and n_i is the Freundlich exponent. If n_i=1, the graphical representation of the Freundlich isotherm will be linear with an intercept of zero; and we infer constant sorption free energies at all sorbate concentrations. If n<1, the isotherm is concave down; and the inference is that added sorbate concentration decreases the likelihood of further sorption. At n>1, the isotherm is concave up; it is probable that increasing sorbate concentration enhances the likelihood of further sorption (Schwarzenbach et al., 2002; Delle Site, 2001).

The empirical solid-water distribution or sorption coefficient is calculated using the following equation:

$$K_{i,d} = \frac{C_{i,s}}{C_{i,w}} \tag{3.2}$$

Except in the case of linear isotherms, $K_{i,d}$ is concentration dependent. Inserting equation 3.1 into 3.2, we get

$$K_{i,d} = K_{i,F} \times C_{i,w}^{n_i - 1} \tag{3.3}$$

which calculates K_d at any solute concentration based upon empirical results.

The velocity of a chemical (V_i) relative to groundwater velocity (V) is calculated using the retardation equation

$$R = 1 + (\frac{\rho_b}{\eta})K_d \tag{3.4}$$

$$\text{so that } V_i = \frac{V}{R} \tag{3.5}$$

where ρ_b=bulk density of the sediment and η=porosity (Apello & Postma, 1999).

The experimental methods for the determination of environmental properties such as water solubility and solid sorption are expensive and time consuming. Correlations based on measured octanol/water partition coefficient (K_{ow}) and organic carbon partition coefficient (K_{oc}) are often inaccurate for compounds whose solubility is below 1 ppm since the measurement error may be larger than solubility (Delle Site, 2001). Therefore, alternative methods have been developed to predict K_d and other properties.

The values of K_{oc} used in this study were calculated and not measured. The data sets obtained through the American Chemical Society database — CAS Registry File — are calculated by Advanced Chemistry Development (ACD) for a mixture of the neutral and ionic forms of a compound at different pH (ACD, 2002) (Table 3.1 and

3.5). ACD calculates the apparent K$_{oc}$ of compounds using a “unique structure-fragment approach”. An additive-constitutive algorithm takes into account the separate atoms, structural fragments and intramolecular interactions between different fragments.

The pKa of NAs in a crude oil from the Norwegian continental shelf was 4.9 (Havre et al., 2003). The pKa of surrogates varied from 4.71 to 5.1 (Havre et al., 2003; ACS, 2002). When the pH of the batch reactors were greater than pKa+2 (Delle Site, 2001), it can be assumed that the majority of the NAs are ionized. Theories of simple hydrophobic sorption do not apply since part of the molecule is now hydrophilic.

The equation to calculate K$_d$ based on the fraction of sediment which is organic carbon (f$_{oc}$) (Delle Site, 2001) for pH 7 and pKa of 5.1 is developed as follows:

$$\begin{aligned}
K_{oc} &= K_{oc,neutral} \cdot Q + K_{oc,ion}(1-Q) && \text{(3.6a)}\\
\text{where } Q &= \text{degree of protonation} && \text{(3.6b)}\\
&= \frac{[AH]}{[AH]+[A^-]} && \text{(3.6c)}\\
&= (1+10^{pH-pKa})^{-1} && \text{(3.6d)}\\
&= (1+10^{7-5.1})^{-1} && \text{(3.6e)}\\
&= 0.012432735 && \text{(3.6f)}\\
\text{so that } \mathrm{K_{oc}} &= 0.0124 \cdot \mathrm{K_{oc,neutral}} + 0.9876 \cdot \mathrm{K_{oc,ion}} && \text{(3.6g)}\\
\mathrm{K_{oc}} &= 0.0124 \cdot \frac{K_{d,neutral}}{f_{oc}} + 0.9876 \cdot \frac{K_{d,ion}}{f_{oc}} && \text{(3.6h)}\\
\mathrm{K_{oc}} &\approx 0.9876 \cdot \frac{K_{d,ion}}{f_{oc}} && \text{(3.6i)}\\
K_{oc} \cdot f_{oc} &= 0.9876 \cdot K_{d,ion} && \text{(3.6j)}\\
K_{i,d} &= 1.0126 \cdot K_{oc} \cdot f_{oc} \text{ at pH 7, pKa 5.1} && \text{(3.6k)}
\end{aligned}$$

The assumption is that organic carbon is the primary sorbent (i.e. the formation of a neutral ion pair or by sorption of the hydrophobic part of the NA (Delle Site, 2001)).

Not only must two species of the same chemical be considered, but soil can be considered a dual sorbent where organic matter functions as a partitioning medium and mineral fractions as adsorbents. There are three general types of surface-solute sorption mechanisms: physical, chemical and electrostatic (Weber Jr. et al., 1991; Delle Site, 2001). The physical sorption processes involve interactions between dipole moments of sorbate and sorbent. Dipole moments arise from charge separation within a molecule. The dipole moments may be temporary (London forces) or permanent (polar molecules). These are relatively weak bonding forces that can be amplified in the case of hydrophobic molecules due to repulsion by substantial thermodynamic gradients from the solution in which they are dissolved. Usually, the higher the ionic strength of the aqueous phase, the higher the thermodynamic gradient. The combination of physical sorption mechanism and expulsion from aqueous solvent are responsible for "hydrophobic bonding". Chemical sorption involves covalent bonding between solute molecules and specific surface chemical groups. While Weber *et al.* (1991) do not specifically categorize hydrogen bonding, Delle Site (2001) groups it with chemical sorption (note that some people consider hydrogen bonding to be a physical process). Electrostatic interactions involve ion-ion and ion-dipole forces. They may be attractive for oppositely charge species or repulsive between those of like charge i.e. cation exchange reactions in clays. All of these mechanisms occur at the same time to a greater or lesser degree; the exact process will depend on the solvent, the sorbate and the sorbent and whether partitioning or adsorption dominates (Schwarzenbach et al., 2002).

3.2 Previous Studies

While Peng *et al.* (2002) do not specifically mention hydrogen bonding as one of the possible sorption processes in their batch reactors, Zou *et al.* (2003) do. Both Peng *et al.* and Zou *et al.* agree that physical and electrostatic sorption processes dominate, whether hydrophobic bonding in their systems is likely (Peng et al., 2002) or not (Zou et al., 1997). Zou *et al.* removed hydrophobic sorption as a possible mechanism by using toluene — an organic solvent — as the liquid phase. In this case, sorption of commercial NAs onto clays was a two-step process. The first sorption step is mainly hydrogen bonding between the hydroxyl in the carboxyl group and the oxygen atom in the Si-O tetrahedron, with some contribution from electrostatic-dipole and London forces. The second step is predominantly due to London forces between large hydrophobic groups of NA adsorbed on surface and that in solution. The magnitude of partitioning by London forces would depend on adsorption during the first step. Peng *et al.* (2002) set up batch equilibration reactors using two Z=-2 surrogates in aqueous solution, the homologues 4-methylcyclohexaneacetic acid and 4-methylcyclohexanecarboxylic acid (MCCA) (Figure 2.1). The probable sorption mechanisms are London and/or ion-dipole and ion-induced dipole forces.

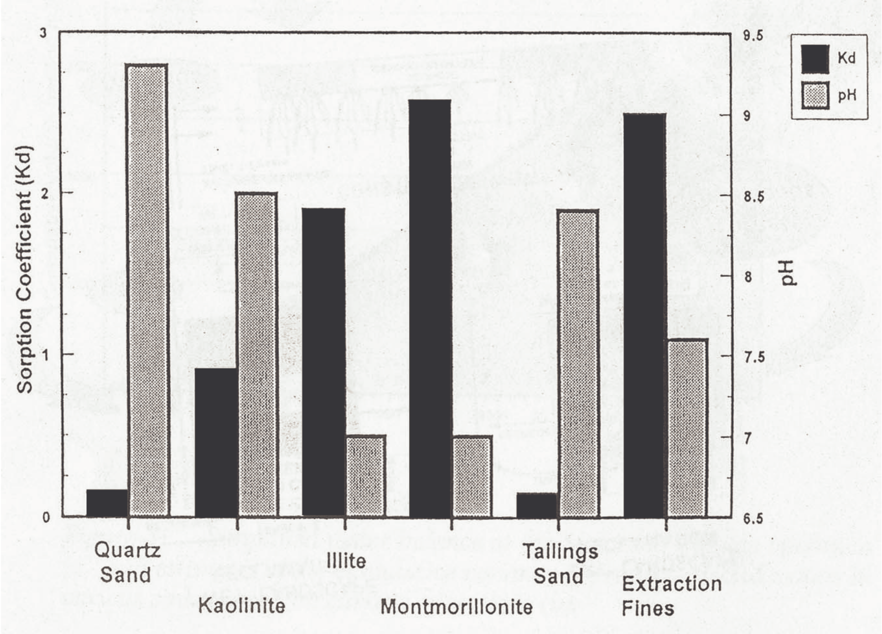


FIGURE 3.2: Adsorption coefficients of naphthenic acids on various mineral surfaces (Schramm et al., 2000). Units are mL/g.

The first efforts to quantify sorption of NAs occurred not due to environmental concerns but to enhance the production of natural surfactants from the bitumen, primarily carboxylic salts of NAs. Tests on crude oil from the Norwegian continental shelf (Havre et al., 2003) have shown that aqueous concentrations increase as pH increases, with a plateau at around pH 9. Schramm *et al.* (2000) also determined that the $K_{NA,ow}$ decreases from near 1000 to about 1 as aqueous pH increases from 5 to 9. Since the pKa of NA is 4.9 and surrogates tend to have pKa around 5 (Peng et al., 2002; Havre et al., 2003; Tables 3.1 and 3.5), the increasing aqueous solubility as pH increases is due to increasing ionization until almost no non-ionized species exists at pH = pKa + 2 (Delle Site, 2001).

Schramm *et al.* (2000) report the K_d of NAs on several mineral substrates (Figure 3.2). At pH 8.5, the K_d in the tailings sand is around 0.125. Assuming a bulk density of 1.5 and a porosity of 0.3, the resulting retardation value of 1.625 would mean NAs migrate at about 60% of the groundwater velocity, providing little attenuation due to sorption in sand tailings dykes. Zou *et al.* (1997) confirmed that sorption will be greater on Na-montmorillonite than Na-illite, and both are larger than on Na-kaolinite.

3.3 Purpose

To evaluate these issues, three sets of batch sorption reactors were constructed using the following naphthenic acids:

1. four carboxylated alkane and monocycloalkane surrogates in a low ionic strength solution at pH 7 to 8 to provide an initial confirmation of sorption by simple NA surrogates and initial data for isotherms.
2. stock naphthenic acid derived from holding pond process-water. Since the exact structure of NAs are not known, it is not possible to know with certainty that the chosen NA surrogates are present in naturally occurring NA mixes. Using stock NA allows us to verify if sorption may occur under field conditions. As well, if sorption causes any detectable and reproducible change of homologue distribution within the mixture, it may be possible to see a change in the NA "signature" in field data and use the data to tentatively confirm the effect of sorption of the transport of NAs.
3. eight surrogates with carbon numbers 7 to 24, and Z numbers 0 to -8 at an ionic strength comparable to field conditions. It is believed that the low molecular weight NAs constitute the most toxic fraction of the NA mixture (Holowenko et al., 2002; Clemente et al., 2004). Are they retarded more in an aqueous environment as compared to high molecular weight NAs? Are higher Z numbers more likely to sorb to the organic phase?

3.4 Method

The stock NA was derived from process-affected water collected at the Mildred Lake Settling Basin. Unless otherwise indicated, all other chemicals were purchased from Sigma-Aldrich Canada Ltd (Oakville, Ontario) and all water was deionized. All chemicals were used as supplied. A detailed laboratory report may be found in Appendix B.

3.4.1 Equilibration Time

Sorption of naphthalene, a possible surrogate for naphthenic acids, is a relatively fast process where equilibrium is reached within hours (Anthony, 1998). Peng *et al.* (2002) determined that single ring NA surrogates achieved equilibrium within 48 hours. As well, Zou *et al.* (1997) showed that adsorption of NAs onto clays equilibrated within 12 hours. Havre *et al.* (2003) used a 24 h equilibration time. Therefore, isotherms were given a minimum of 48 hours on a shaker or rotator to equilibrate before being sampled.

3.4.2 Simple Surrogates at Lower Ionic Strength

3.4.2.1 Solid Sample

Monitoring wells at the Suncor site were installed by Klohn-Crippen in 2001 using drilling methods that allowed coring with minimum contamination. Eleven samples were wrapped in plastic, shipped to the University of Waterloo in a sealed container and stored at room temperature. All solid subsampling was done in the laboratory under a positive air pressure hood to minimize bacterial contamination. Each soil core supplied by Suncor was sampled 3 times, the subsamples homogenized and crushed for f_{oc} analysis using combustion methods.

Eleven samples of Suncor geological material were sent to be analyzed for fraction of organic carbon (f_{oc}) in the soil and one sample, G-01-245, was chosen for the initial batch sorption reactors with low ionic strength aqueous solution. The soil was chosen for batch sorption isotherms based on low naphthenic acid concentrations in groundwater and had f_{oc} of 0.01.

3.4.2.2 Batch Reactor Setup

Laboratory batch equilibration reactors were setup using soil sample G-01-245 from Suncor property at pH 7 for a mix of the naphthenic acid surrogates — undecanoic acid (UA), 3-cyclohexanepropionic acid (CHPA), stearic acid (SA) and 1-methyl-1-cyclohexanecarboxylic acid (MCCA) — which represent acyclic and single ring NAs of different carbon numbers (Table 3.1 and Figure 3.3). Fifty grams of air-dried aquifer material was equilibrated with varying sorbate concentrations in 60 mL hypovials

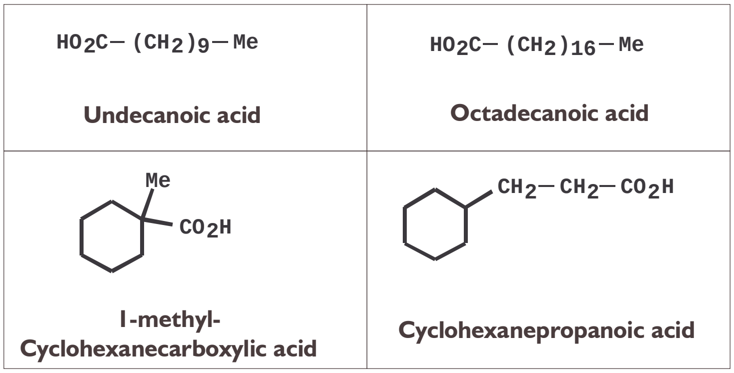


FIGURE 3.3: Molecular structure of the four naphthenic acid surrogates used in the first batch reactors. Me refers to a single methyl group (-CH3).

Property	Undecanoic acid	Octadecanoic acid (Stearic acid)	1-methyl-1-cyclohexane-carboxylic acid	3-cyclohexane-propionic acid
CAS #	112-37-8	57-11-4	1123-25-7	701-97 -3
Formula	$C_{11}H_{22}O_2$, Z=0	$C_{18}H_{36}O_2$, Z=0	$C_8H_{14}O_2$, Z=-2	$C_9H_{16}O_2$, Z=-2
MW	186.30 [3]	284.48 [1]	142.1	156.2
pKa	4.79±0.20 [5]	5 [2]	4.95±0.20 [5]	4.91at 25°C
Solubility (20°C)	9.3 mg/100 g[3]	0.3 mg/100 mL[2]		
Aqueous solubility[4]				
at pH 1	Sparingly Soluble	Sparingly Soluble	Sparingly Soluble	Sparingly Soluble
at pH 4	Sparingly Soluble	Sparingly Soluble	Sparingly Soluble	Sparingly Soluble
at pH 7	Sparingly Soluble	Sparingly Soluble	Soluble	Soluble
at pH 8	Slightly Solube	Sparingly Soluble	Very Soluble	Very Soluble
at pH 10	Soluble	Sparingly Soluble	Very Soluble	Very Soluble
K_{oc**} at pH 1	6650	701000	432	831
at pH 4	5710	601000	389	716
at pH 7	41	4250	3.88	5.19
at pH 8	4.6	477	1	1
at pH 10	1	60	1	1
$\log K_{OW,mix}$: * [4] at pH 1	4.5	8.21	2.31	2.84
at pH 4	4.43	8.15	2.27	2.77
at pH 7	2.29	6	0.27	0.63
at pH 8	1.34	5.05	-0.7	-0.32
at pH 10	0.43	4.15	-1.74	-1.23

**Calculated partition coefficient between organic matter and water at a given pH for the mixture of the neutral and ionic forms of a compound

*Calculated partition coefficient between octanol and water at a given pH for the mixture of the neutral and ionic forms of a compound

[1] Budavari, 1996; [2] Katz, 1994; [3] Bagby, 1995; [4] ACS, 2002

TABLE 3.1: Properties of four naphthenic acid surrogates used in the initial batch isotherm.

sealed with Teflon® faced silicon septa and aluminium crimp caps for a solid:water ratio of 1.3 to 1.4 g/cm^3. The aqueous phase was poisoned with the addition of sodium azide (10 mL of a 10% w/v NaN_3 stock solution per 1 L aqueous phase). The aqueous phase of water, sodium azide and equal amounts of naphthenic acid surrogates were mixed to a final concentration 10 mg/L naphthenic acid mix. Low concentrations were used to remain within the detection limits of the analytical method (GC-MS). This aqueous phase was then serially diluted to 5 mg/L and 2.5 mg/L of naphthenic acid mix. Two series of controls (no solids or "water only", and solid and water but no chemical surrogate) were also set up using similar vials and septa. Triplicate samples and controls were used for each sorbate concentration.

3.4.2.3 pH and Ionic Strength of the Aqueous Phase

The bottles were quickly capped to prevent changes in pH. By the end of the equilibration time, the aqueous phase had a pH of 7 to 7.5, as measured by pH paper. While ionic strength was not measured, the concentration of NaN_3 was 1000 mg/L before dilution, so that the minimum ionic strength of the 10 mg/L reactors had was 15 mM, 5 mg/L reactors had 7.5 mM and the 2.5 mg/L reactors had 4.25 mM. The naphthenic acids contributed less than 0.1 mM to the ionic strength. The final ionic strength is higher since the effect of the HCl added to adjust pH is not included in the calculations.

3.4.2.4 Sampling

After a 2-day equilibration time in a slowly rotating tumbler at room temperature, the aqueous phase was sampled for GC-MS analysis. pH paper strips were used to estimate equilibrium pH.

3.4.3 MLSB-derived Stock Naphthenic Acids

3.4.3.1 Water Preparation

Deionized water (DIW) in four containers was doped to mimic site groundwater with an ionic strength of about 20 mM (Table 3.2). Stock NA (MLSB-derived UW456) was added to achieve the following concentrations: Type 1 (10 mg/L concentration);

Species	**Concentrations (mg/L)**
$NaHCO_3$	1315.0
$CaCl_2$	82.5
$NaSO_4$	135.0
$MgSO_4$	30.0
NaCl	148.0

TABLE 3.2: List of inorganic ions added to artificial groundwater to adjust the ionic strength to field values.

Type 2 (30 mg/L concentration); Type 3 (100 mg/L concentration); and Type 4 (0 mg/L concentration used as a de-sorption control). Triplicate or quadruplicate samples and controls were used for each sorbate concentration. After the addition of inorganic ions and naphthenates, HCl was added to adjust pH to 7. See appendix B for mass calculations of salts and stock added to each bottle.

3.4.3.2 Solid Preparation

Geological material was collected from an active sand pit on Syncrude property in July 2003. The material was air dried in a fume hood, passed through a 2.00 mm sieve and thoroughly mixed. A sample was taken for soil analysis and f_{oc} analysis. A known volume of dry solid was weighed and the bulk density (ρ_b) was calculated.

3.4.3.3 Set up

Doped water and, where appropriate, solid was added to bottles for a solid:water ratio of 1.1 to 1.2 g/cm^3. A minimum of headspace was left to avoid losses of solute into the vapour phase. The larger 1 L and 500 mL bottles were placed on their sides on a shaker at 50 rpm. The smaller 100ml bottles were placed on a rotating wheel.

3.4.3.4 Sampling

The bottles were sampled after 84 hours (3.5 days) of equilibration at room temperature. After four hours of resting on the counter, the fines content of the solid would not settle, so the bottles were centrifuged at 2000 rpm for 45 min. Water was removed from the bottles with a 60 mL ground glass syringe fitted with a wide bore Teflon tip.

The supernatant was allocated for total and dissolved NA analysis, ion analysis and pH and EC measurement by probe. Any difference in aqueous concentration between the control vials and the vials containing the solids was attributed to sorption onto the solids.

Electrical conductivity and total dissolved solids were measured by meter two days later and the aqueous solution was subsampled by single-use plastic syringe. The samples for anion analysis by IC were refrigerated but no other preservation was implemented. Water for cation analysis by ICP-AES was filtered with a .45 micrometer filter and acidified to pH<2 with 70% nitric acid. Samples for alkalinity were filtered, refrigerated and shipped to the analytical laboratory within 7 days.

3.4.3.5 pH and Ionic Strength of the Aqueous Phase

The "water + solid, no NA" controls for the batch reactors containing MLSB-derived stock naphthenic acid had an average final pH of 7.40±0.6% (Table 3.3) while the "water + NA, no solid" controls had an aggregate average pH of 7.25±0.5%. The batch reactors with aquifer materials tended to have a slightly higher pH, with the 100 mg/L reactor attaining a pH of 7.99±1.1% . The ionic strength based on ion concentrations varied from 21 mM for the desorption control with no NA to 38 mM for the batch reactors with 130 mg/L NAs (Appendix B.4). The variation occurred because the stock NA was very basic; the greater the final NA concentration, the greater the amount of HCl required to change the pH to 7. The ion balance was within acceptable limits since the largest charge balance error was less than 8%. Tables containing the major ions and the ionic strength calculation for individual reactors can be found in Appendix B.4.

3.4.3.6 Problems and Comments

The desorption controls had total NA concentrations below the detection limit, so it may be assumed that the solid was "clean".

There were 4 active bottles with initial solute concentration of 130 mg/L. However, only 3 are used in the calculations since one bottle had a concentration of 165 mg/L, 35 mg/L higher than the measured initial concentration. A Q-test showed that there was less than 10% chance that that measurement belonged to the group of the other 130 mg/L reactors.

	pH	RSD*
Soil and doped water control (no NA)	7.40	0.55%
10 mg/L batch reactor	7.58	0.48%
10 mg/L control	7.25	0.32%
30 mg/L batch reactor	7.51	1.81%
30 mg/L control	7.22	0.08%
100 mg/L batch reactor	7.99	1.10%
100 mg/L control	7.29	0.69%

*residual standard deviation

Table 3.3: Final pH of the batch equilibriation reactors containing stock NA and their controls.

Chemical name	Acronym	CAS #	Molecular Formula	Z #
Heptanoic acid	HA	111-14-8	$C_7H_{14}O_2$	0
4-Methylcyclohexaneacetic acid	MCAA	6603-71-0	$C_9H_{16}O_2$	-2
1-Methyl-1-cyclohexanecarboxylic acid	MCCA	1123-25-7	$C_8H_{14}O_2$	-2
Cycloheptanecarboxylic acid	CHCA	1460-16-8	$C_8H_{14}O_2$	-2
4-Pentylbicyclo[2.2.2]octane-1-carboxylic acid	POCA	73152-70-2	$C_{14}H_{24}O_2$	-4
3-Methyl-octahydro-pentalene-1-carboxylic acid	MOPCA	87-30-9	$C_{10}H_{16}O_2$	-4
3-Methyl-adamantane-1-carboxylic acid	MACA	33649-73-9	$C_{12}H_{18}O_2$	-6
Cholanoic acid	CA	546-18-9	$C_{24}H_{40}O_2$	-8

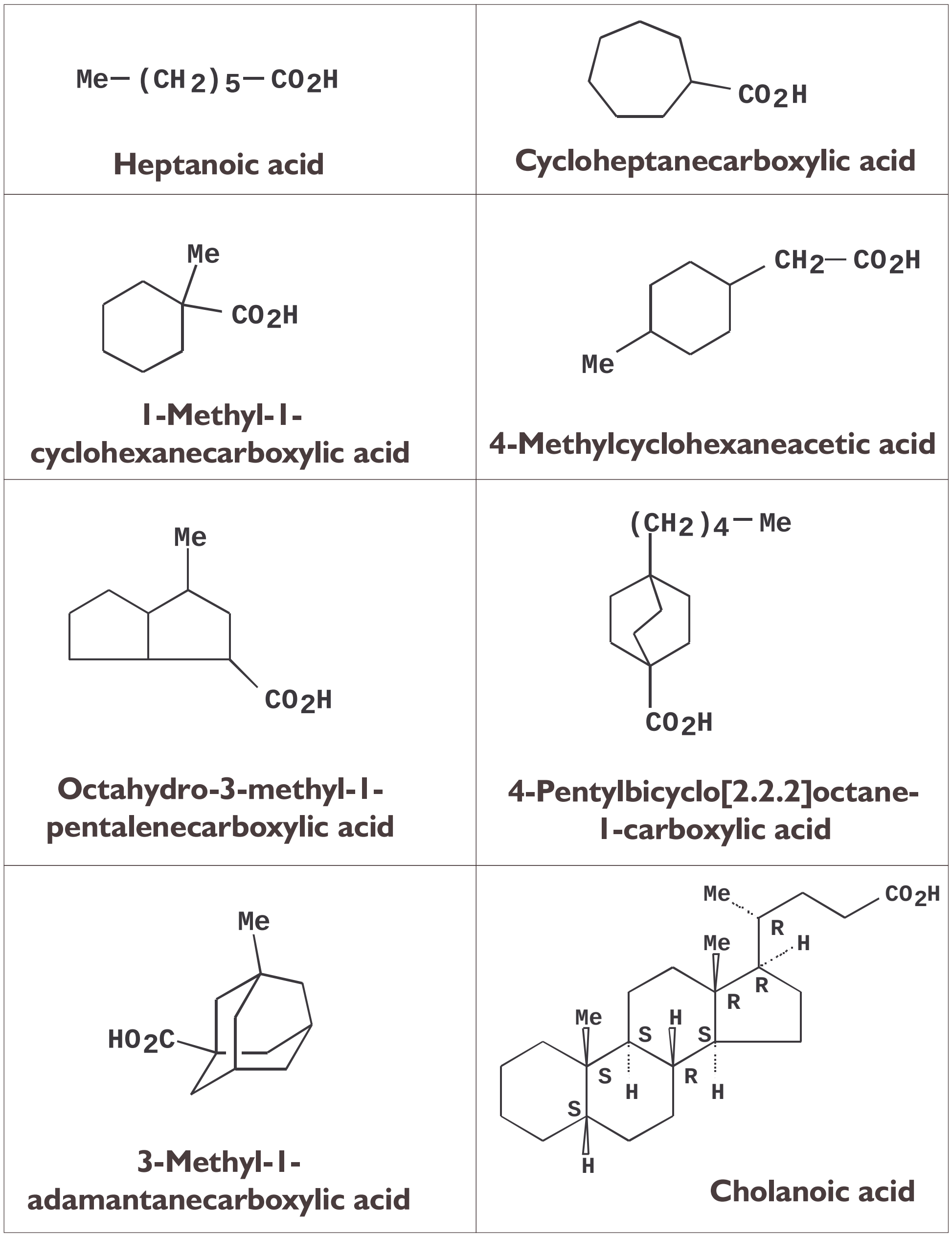
Table 3.4: List of naphthenic acid surrogates chosen for the batch sorption experiment with a high ionic strength aqueous phase.

3.4.4 Naphthenic Acid Surrogates at High Ionic Strength

The sorption of eight surrogates was determined using artificial groundwater with an ionic strength of approximately 37 mM and fresh (unweathered) aquifer material from an active sand pit at Syncrude Canada Ltd.

3.4.4.1 Solid Sampling and Preparation

Geological material was collected from an active sand pit on Syncrude property in July 2003. The material was air dried in a fume hood, passed through a 2.00 mm sieve and thoroughly mixed. A sample was taken for analysis, including f_{oc}. A known



Heptanoic acid

Cycloheptanecarboxylic acid

1-Methyl-1-cyclohexanecarboxylic acid

4-Methylcyclohexaneacetic acid

Octahydro-3-methyl-1-pentalenecarboxylic acid

4-Pentylbicyclo[2.2.2]octane-1-carboxylic acid

3-Methyl-1-adamantanecarboxylic acid

Cholanoic acid

FIGURE 3.4: Molecular structure of the eight naphthenic acid surrogates used in the final batch sorption isotherms at site groundwater ionic strength. “Me” refers to a single methyl group (-CH3).

Name	Molecular weight	Molar solubility*	Boiling point**	Vapour pressure (torr)	K_{ow} at pH7	K_{oc} at pH7
Heptanoic acid	130.18	Very	223	5.8E-02	1.4	2.8
4-Methylcyclohexaneacetic acid	156.20	Soluble	254	5.6E-03	3.4	4.3
1-Methyl-1-cyclohexanecarboxylic acid	142.20	Soluble	234	1.9E-02	1.9	3.9
Cycloheptanecarboxylic acid	142.20	Soluble	263	3.2E-03	1.4	2.9
4-Pentylbicyclo[2.2.2]octane-1-carboxylic acid	224.34	Sparingly	345	1.1E-05	7.6E+02	1.2E+02
Octahydro-3-methyl-1-pentalenecarboxylic acid	168.23	Soluble	269	9.2E-04	3.4	4.8
3-Methyl-adamantane-1-carboxylic acid	194.27	Slightly	314	1.0E-04	8.9	8.4
Cholanic Acid	360.57	Sparingly	474	2.8E-10	3.2E+06	7.9E+03

*The number of moles of a compound that dissolve in pure water at 25°C to produce a liter of saturated solution.

ACD does not calculate absolute solubility but gives a range:

Very soluble	>=	1 mol/L	
Soluble (default)	between	1 and	0.1 mol/L
Slightly soluble	between	0.1 and	0.01 mol/L
Sparingly soluble	<	0.01 mol/L	

** Celsius at 1 atmosphere

Table 3.5: Physical properties of naphthenic acid surrogates.

volume of dry solid was weighed and the bulk density (ρ_b) was calculated.

Two batches of the geological material collected from the active sand pit at Syncrude Canada Ltd were sent to Enviro-Test Laboratories (Saskatoon, Saskatchewan) to be analyzed with standard procedures and the results are summarized in Table 3.6. The percent fractional organic carbon by weight (w/w) was also analyzed at the Organic Geochemistry Lab at the University of Waterloo, and the f_{oc} was almost twice the ETL results. Interlaboratory variation is common and may be due to different analytical method used by both labs (Tiessen & Moir, 1993 at ETL vs Churcher & Dickhout, 1987). K_d calculations based upon f_{oc} will therefore use both values.

3.4.4.2 Surrogate selection

Naphthenic acids surrogates were selected based on commercial availability. Furthermore, surrogates were chosen to attain a good sampling of different ring and carbon numbers (Tables 3.4 and 3.5). Two isomers (MCCA and CHCA) and one surrogate that was approximately 50/50 mix of *cis*- and *trans*- isomers (4MCAA) were included.

Properties	**Solid used with Stock NA**	**Solid used with Surrogate NA**	**Units**
Cation Exchange Capacity	0.9	0.6	meq/100g
Organic Carbon (ETL)	0.6	0.4	%
Organic Matter (ETL)	1.0	0.7	%
Organic Carbon (UW)	1.5		%
Inorganic Carbon	0.14	0.11	%
$CaCO_3$ Equivalent	1.1	0.9	%
% Saturation	22	23	%
pH in Saturated Paste	7.6	7.7	pH
Conductivity in Sat. Paste	0.2	0.3	dS/m
Calcium	27.3	33.5	mg/L
Potassium	4.3	4.7	mg/L
Magnesium	10.7	7.4	mg/L
Sodium	4	4	mg/L
SAR	0.2	0.2	SAR
ρ_b (bulk density)	1.50	1.51	g/mL

Note: SAR = sodium adsorption ratio

% Saturation = ratio of water (mL) to soil (g)when the soil is saturated

Table 3.6: Properties of the tested soils

Since CHCA does not have a methyl group, it does not fit the strict NA definition (Holowenko et al., 2002). However, its role as an isomer still makes it a valuable addition. Solubility data on these compounds are scarce, and confidence in the calculated solubility is not good for organic acids (Ran et al., 2002). Therefore, the solubility of the compounds at the concentrations required for the sorption isotherms (10, 5 and 1.5 mg/L) were verified in the laboratory using DIW. Compounds with expected error on the same order of magnitude as the solubility were excluded.

3.4.4.3 Batch Reactor Setup

Deionized water (DIW) was doped as for the stock NA isotherms (Table 3.2) and then the aqueous phase was poisoned with the addition of sodium azide (10 mL of a 10% w/v NaN_3 stock solution per 1 L aqueous phase). The doped water was separated into four containers and organic acids added to attain the three concentrations shown in Table 3.7 and one control of doped water with no organic acids (Type 4). Acid (HCl) was added to adjust the pH to neutrality. Triplicate or quadruplicate samples and controls were used for each sorbate concentration. Appendix D contains the laboratory report and appendix C details the analytical method development.

The organic acids were dissolved in methylene chloride (dichloromethane) to aid solubilization into doped water. Cosolvents such as methanol will have a significant effect (greater than a factor of 2) on solubility only when cosolvent volume fractions are greater than 5-10%. At volume fractions less than 1%, the effects can "more or less be neglected" (Schwarzenbach et al., 2002). Since methylene chloride concentration was less than 0.1% of the final solution, cosolvent effects can be ignored.

Doped water and, where appropriate, air dried solid were added to 250 mL amber glass bottles for a solid:water ratio of 1.13 to 1.23 g/cm^3. A minimum of headspace was left to avoid losses of solute into the vapour phase. While HA may be slightly volatile, both active and control reactors were treated the same; so this should not be a major source of difference. The bottles were placed on their sides on a shaker at 75 rpm.

3.4.4.4 Sampling

The bottles were sampled after 70 hours of equilibration at room temperature. Water was filtered through a 0.45 micron Millipore HVLP (Durapore - Polyvinylidene Fluo-

	Type 1		Type 2		Type 3	
	Conc. (mg/L)	+/- RSD	Conc. (mg/L)	+/- RSD	Conc. (mg/L)	+/- RSD
Heptanoic acid	10	7%	5	n/a	1.5	8%
4-Methylcyclohexaneacetic acid	10	6%	5	n/a	1.5	4%
1-Methyl-1-cyclohexanecarboxylic acid	10	8%	5	n/a	1.5	9%
Cycloheptanecarboxylic acid	10	7%	5	14%	1.5	3%
4-Pentylbicyclo [2.2.2]octane-1-carboxylic acid	10	6%	5	1%	1.5	4%
3-Methyl-octahydro-pentalene-1-carboxylic acid	10	7%	5	7%	1.5	13%
3-Methyl-adamantane-1-carboxylic acid	10	3%	5	22%	1.5	8%
Cholanic Acid	0.3	12%	0.15	n/a	0.045	n/a

Table 3.7: Surrogate concentrations used in the high ionic strength batch sorption reactors. The residual standard deviation (RSD) of the standards analyzed during method development closest in concentration to the surrogate concentrations are shown.

ride) filter and allocated (using a 60 mL ground glass syringe fitted with a wide bore stainless steel tip) to a 60 ml hypovial for gas chromatographic analytical analysis (both the derivatized method and the Nukol method). Filtered samples were also allocated for ion analysis and pH measurement by probe. The samples for anion analysis by IC were filtered but no preservation was implemented. Water for cation analysis by ICP-AES was filtered and acidified to pH<2 with 70% nitric acid.

3.4.4.5 pH and Ionic Strength of the Aqueous Phase

The pH of the doped DIW was adjusted to 7 prior to setting up the batch reactors. After equilibration, the average pH of all "water only" controls (Con Type) was 7.44±0.8% (Table 3.8). Reactors with solid and NA had an average pH of 7.82±1.7% (Type 1, Type 2 and Type 3) while the bottles with solid but no NA (Type 4) had an average pH of 7.74±0.4%. The increase in pH above that experienced by the controls is probably due to solid buffering, since the pH of the saturated solid paste was 7.7 (Table 3.6).

The second set of surrogate batch reactors were run after the stock NA reactors. Since the largest charge balance error in the stock NA reactors was 8%, it was decided not to measure alkalinity but to assume 0-5% charge balance error and estimate bicarbonate. The ionic strength in the surrogate batch NA reactors (including the effect of the naphthenic acids themselves) was more consistent from bottle to bottle, with an average of 37 mM. Ionic strength was higher than the expected 20 mM since

ID	pH
Type 1A	7.98
Type 1B	7.66
Type 1C	8.14
Type 1D	8.05
Average	**7.96**
StdDev	0.21
RSD	3%
Con Type1 A	7.51
Con Type1 B	7.39
Con Type1 C	7.39
Average	**7.43**
StdDev	0.07
RSD	0.9%

ID	pH
Type 2A	7.73
Type 2B	7.73
Type 2C	7.8
Type 2D	7.78
Average	**7.76**
StdDev	0.04
RSD	0.5%
Con Type 2A	7.41
Con Type 2B	7.39
Con Type 2C	7.38
Average	**7.39**
StdDev	0.02
RSD	0.2%

ID	pH
Type 3 A	7.9
Type 3 B	7.82
Type 3 C	7.82
Type 3 D	7.74
Average	**7.82**
StdDev	0.07
RSD	0.8%
Con Type 3 A	7.5
Con Type 3 B	7.47
Con Type 3 C	7.5
Average	**7.49**
StdDev	0.02
RSD	0.2%

ID	pH
Type 4A	7.71
Type 4B	7.74
Type 4C	7.77
Average	**7.74**
StdDev	0.03
RSD	0.4%

TABLE 3.8: Final pH of the batch equilibration reactors containing surrogate NAs and their controls.

the mass of ion added was not adjusted for the 1000 mg/L of sodium azide added to inhibit microbial growth.

Problems and Comments The reactors with solid and water but no surrogates had no measurable concentration of the surrogates. No desorption from solid was seen.

It was assumed that the 4MCAA standard was half *cis*-4MCAA and half *trans*-4MCAA; the areas on the GC chromatogram were similar so this assumption is probably valid.

The surrogates show a difference between reactor Type 2A and the other three reactors of the same type. The Q-test declares Type 2A MACA an outlier. Therefore, the batch reactor Type 2A results are shown in the tables, but not included in the calculations.

If the calculations for sorbate concentrations had a negative result, the value was reported as 0 mg/L.

Cholanic acid (CA) had the lowest solubility. Though this chemical had fully dissolved for the solubility test, there were problems during the batch equilibration. Even after the doped water was stirred for 24 hour, it is doubtful that the organic acid dissolved properly, perhaps because of the high ionic strength. The water concentrations varied by an order of magnitude and the cholanoic acid data are not usable (Table 3.16).

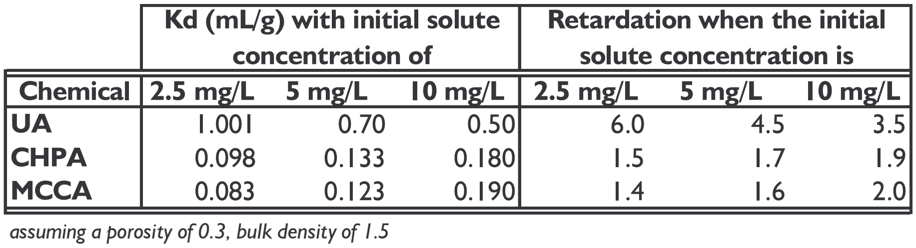
3.5 Results

3.5.1 pH and Ionic Strength of the Aqueous Phase

The pH of all batch reactors was adjusted to pH 7 and quickly capped to prevent changes in pH. The average pH of the batch reactors containing surrogate NAs and the stock varied between 7 and 8; therefore, calculations of theoretical K_d and retardation will be done for both of these pH values. The pH of the bottles containing the stock NAs was more variable, due to the double buffering by the solid (saturated solid pH of 7.7) and the stock NA itself which had an initial pH of 13 due to the addition of NaOH.

The average ionic strength in the batch reactors with 8 surrogate NAs was 37 mM. For the batch equilibration with 4 surrogates and the stock NA, ionic strength varied with concentration. The microbial inhibitor NaN_3 was added to the DIW used in the first batch experiment for a minimum ionic strength of 15 mM and then serially diluted to 7.5 and 4.25 mM. For the stock NA, ionic strength based on ion concentrations varied from 21 mM for the desorption control with no NA to 38 mM for the batch reactors with 100 mg/L (Appendix B.4). The variation occurred because the stock NA was very basic. The greater the final NA concentration, the greater the concentration of NaOH and the greater the amount of HCl required to decrease pH to 7.

This batch sorption isotherm and $K_{NA,d}$ for the mixture of naphthenic acids must be considered with caution since the components and concentration of the homologues will vary from source to source. Even though the ionic strength does not remain constant as NA concentration increases, Peng *et al.* (2002) showed little change in K_d as the ionic strength varied from 10 to 20 mM.



	Kd (mL/g) with initial solute concentration of			Retardation when the initial solute concentration is		
Chemical	**2.5 mg/L**	**5 mg/L**	**10 mg/L**	**2.5 mg/L**	**5 mg/L**	**10 mg/L**
UA	1.001	0.70	0.50	6.0	4.5	3.5
CHPA	0.098	0.133	0.180	1.5	1.7	1.9
MCCA	0.083	0.123	0.190	1.4	1.6	2.0

assuming a porosity of 0.3, bulk density of 1.5

Table 3.9: Retardation values based on the results of the batch equilibration for the UA, CHPA and MCCA.

3.5.2 Isotherms

3.5.2.1 Surrogates in Low Ionic Strength Water

The Freundlich isotherm of naphthenic acid surrogates MCCA, CHPA and undecanoic acid adsorption onto solid sample G-01-245 are shown in Figure 3.5. The "goodness of fit" of the function represented by the line is described by the R^2 term. A good fit of the data is seen, with $R^2>0.95$. Two of the isotherms are concave up ($n>1$) indicating that sorption increases with increasing sorbate concentration of organic acids. Undecanoic acid is concave down ($n<1$), suggesting a different sorption mechanism. The Freundlich exponent for UA is less than 0.75, so that a linear isotherm would probably be inaccurate (Delle Site, 2001). No such guidelines were given for Freundlich exponents greater than 1. The data and calculated K_d values can be found in Tables 3.10, 3.11 and 3.12.

The sorption of stearic acid was so strong that the solute concentration was below the method detection limit. This may be due to electrostatic attraction and binding between ionized organic matter, mineral surfaces and the surrogate's —OO^- functional group. It may also be due to the fact that it has the longest hydrocarbon tail and can therefore be expected to be hydrophobic, in spite of the polar moiety (Schwarzenbach et al., 1993).

Undecanoic acid has the highest K_d of the three chemicals with measurable solutes. While it has a similar structure to stearic acid, UA has seven less carbons in its tail; this seems to be enough to make the molecule more hydrophilic. UA has the highest measurable K_d, ≈ 1 mL/g, and retardation varies from 3.5 to 6 depending, on solute concentration (Table 3.9).

K_d for CHPA and MCCA are an order of magnitude smaller than UA's largest

MCCA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (ml/g)	Average	Kd using $K_{i,F}$	+/-	RSD
1 (10mg/L) A	7.1	8.7	0.0381	50380	1.2E-06	0.17				
1 (10mg/L) B	6.7	8.7	0.0381	50380	1.5E-06	0.23				
2 (10mg/L) A	6.7	8.7	0.0364	52020	1.4E-06	0.21				
2 (10mg/L) B	7.0	8.7	0.0364	52020	1.2E-06	0.17				
3 (10mg/L) A	6.7	8.7	0.0369	50640	1.5E-06	0.22				
3 (10mg/L) B	6.8	8.7	0.0369	50640	1.4E-06	0.21	0.200	0.190	+/-	2%
7(5mg/L)-1A	3.1	3.8	0.0367	49390	5.3E-07	0.17				
7(5mg/L)-1B	3.3	3.8	0.0367	49390	3.5E-07	0.11				
8(5mg/L)-1A	3.2	3.8	0.0375	51070	4.2E-07	0.13				
8(5mg/L)-1B	3.4	3.8	0.0375	51070	3.2E-07	0.09				
9(5mg/L)-1A	3.3	3.8	0.0366	50570	3.4E-07	0.10				
9-(5mg/L)1B	3.5	3.8	0.0366	50570	2.5E-07	0.07	0.111	0.123	+/-	2%
13(2.5mg/L)-1A	1.6	2.0	0.0375	49780	2.5E-07	0.15				
13(2.5mg/L)-1B	1.6	2.0	0.0375	49780	2.4E-07	0.14				
14(2.5mg/L)-1A	1.7	2.0	0.0374	50700	1.7E-07	0.10				
14(2.5mg/L)-1B	1.6	2.0	0.0374	50700	2.4E-07	0.15				
15(2.5mg/L)-1A	1.9	2.0	0.0379	51340	5.1E-08	0.03				
15(2.5mg/L)-1B	1.8	2.0	0.0379	51340	8.3E-08	0.05	0.099	0.083	+/-	4%

C_w = Measured concentration in aqueous solution (mg/L)
C_0 = Average concentration "water only" vials (mg/L)
V_w = Water added to "soils" vial (L)
M = Soil (mg)
C_s = Sorbate concentration (mg/mg of soil)
Kd = solid-water partition coefficient = Cs/Cw

TABLE 3.10: Sorption calculations for MCCA at low ionic strength. Kd is calculated using equation 3.2 and 3.3.

value, although at higher concentrations they are comparable. They have retardation of 2 or less. Both CHPA and MCCA have one ring and either no methyl groups or a methyl group located near the polar carboxyl group.

With an f_{oc} of 1.1%, reactions with organic matter will dominate in this solid for UA. It appears as if the partitioning sites are becoming saturated for UA, although not CHPA and MCCA.

3.5.2.2 Surrogates in High Ionic Strength Water

The sorbate concentration at an aqueous ionic strength of 37 mM and pH 7.4 to 7.8 was very low. Only three surrogates had sufficiently high sorption and good quality data to construct Freundlich isotherms: MOPCA, MACA and POCA (Table 3.14). For the other five NA surrogates, the average K_d (Equation 3.2) had a residual stan-

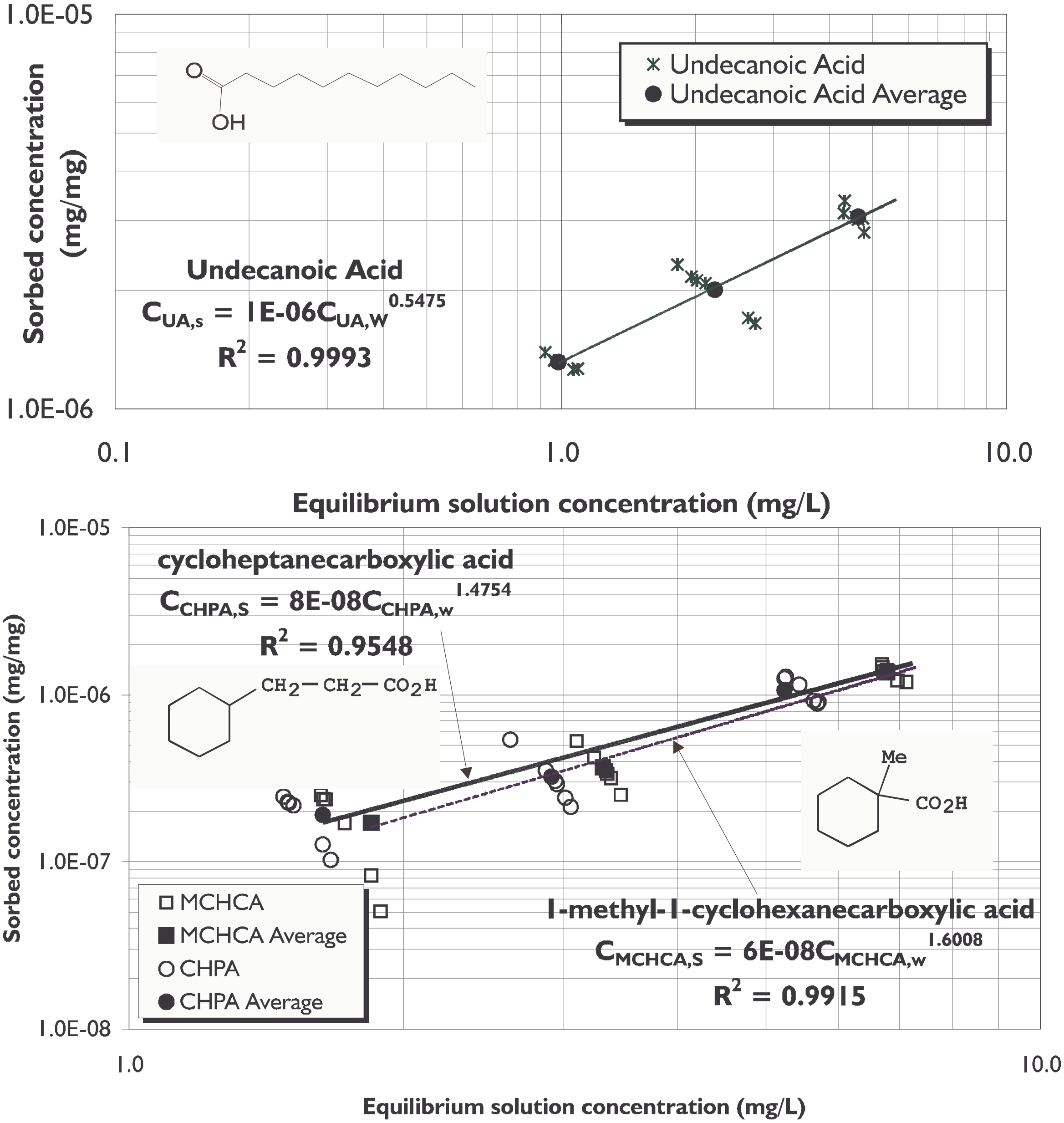
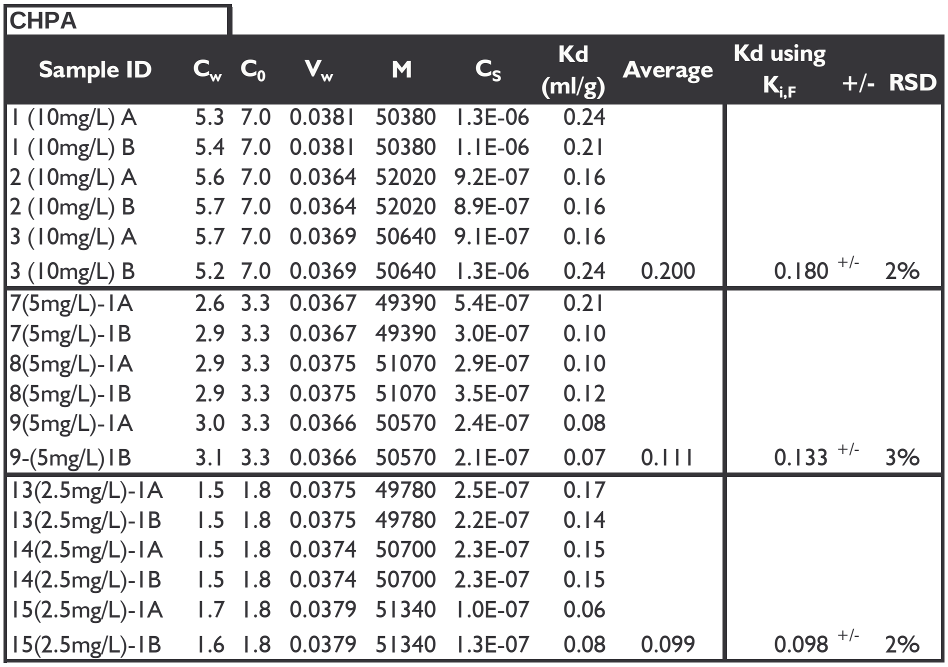


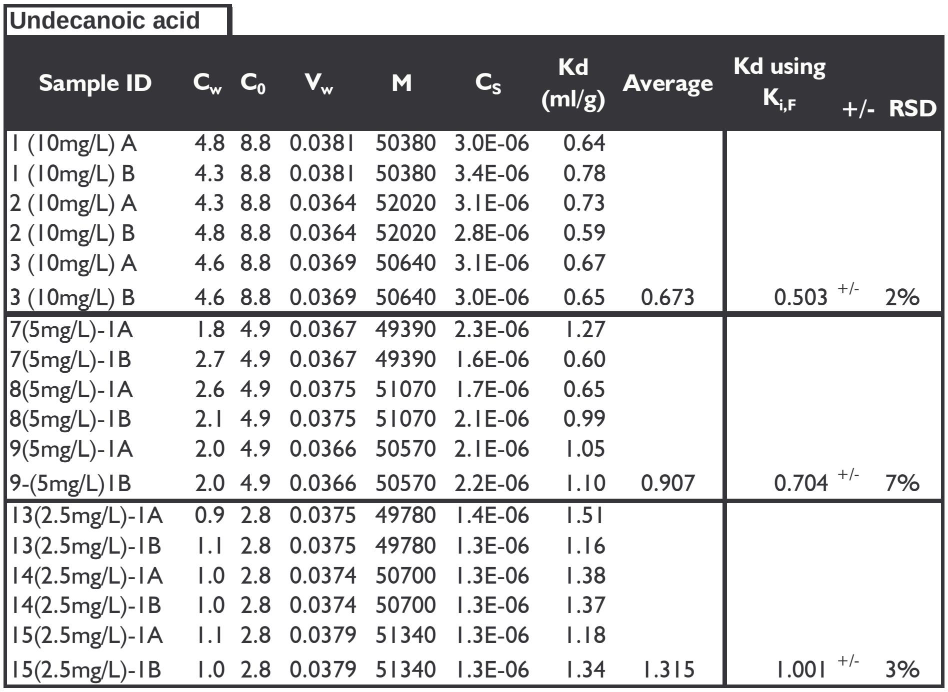
FIGURE 3.5: Freundlich isotherms for undecanoic acid (UA), 1-methylcyclohexanecarboxylic acid (MCHCA) and 3-cyclohexanepropionic acid (CHPA) and soil sample G-01-245. Isotherm is for the arithmetic mean.



CHPA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (ml/g)	Average	Kd using $K_{i,F}$	+/-	RSD
1 (10mg/L) A	5.3	7.0	0.0381	50380	1.3E-06	0.24				
1 (10mg/L) B	5.4	7.0	0.0381	50380	1.1E-06	0.21				
2 (10mg/L) A	5.6	7.0	0.0364	52020	9.2E-07	0.16				
2 (10mg/L) B	5.7	7.0	0.0364	52020	8.9E-07	0.16				
3 (10mg/L) A	5.7	7.0	0.0369	50640	9.1E-07	0.16				
3 (10mg/L) B	5.2	7.0	0.0369	50640	1.3E-06	0.24	0.200	0.180	+/-	2%
7(5mg/L)-1A	2.6	3.3	0.0367	49390	5.4E-07	0.21				
7(5mg/L)-1B	2.9	3.3	0.0367	49390	3.0E-07	0.10				
8(5mg/L)-1A	2.9	3.3	0.0375	51070	2.9E-07	0.10				
8(5mg/L)-1B	2.9	3.3	0.0375	51070	3.5E-07	0.12				
9(5mg/L)-1A	3.0	3.3	0.0366	50570	2.4E-07	0.08				
9-(5mg/L)1B	3.1	3.3	0.0366	50570	2.1E-07	0.07	0.111	0.133	+/-	3%
13(2.5mg/L)-1A	1.5	1.8	0.0375	49780	2.5E-07	0.17				
13(2.5mg/L)-1B	1.5	1.8	0.0375	49780	2.2E-07	0.14				
14(2.5mg/L)-1A	1.5	1.8	0.0374	50700	2.3E-07	0.15				
14(2.5mg/L)-1B	1.5	1.8	0.0374	50700	2.3E-07	0.15				
15(2.5mg/L)-1A	1.7	1.8	0.0379	51340	1.0E-07	0.06				
15(2.5mg/L)-1B	1.6	1.8	0.0379	51340	1.3E-07	0.08	0.099	0.098	+/-	2%

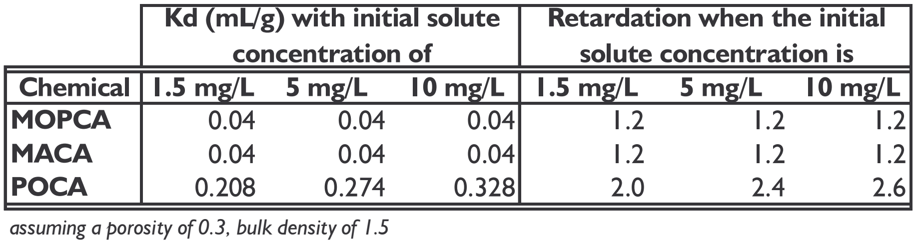
Table 3.11: Sorption calculations for CHPA at low ionic strength. Kd is calculated using equation 3.2 and 3.3. See table 3.9 for legend.



Undecanoic acid

Sample ID	C_w	C_0	V_w	M	C_S	Kd (ml/g)	Average	Kd using $K_{i,F}$	+/-	RSD
1 (10mg/L) A	4.8	8.8	0.0381	50380	3.0E-06	0.64				
1 (10mg/L) B	4.3	8.8	0.0381	50380	3.4E-06	0.78				
2 (10mg/L) A	4.3	8.8	0.0364	52020	3.1E-06	0.73				
2 (10mg/L) B	4.8	8.8	0.0364	52020	2.8E-06	0.59				
3 (10mg/L) A	4.6	8.8	0.0369	50640	3.1E-06	0.67				
3 (10mg/L) B	4.6	8.8	0.0369	50640	3.0E-06	0.65	0.673	0.503	+/-	2%
7(5mg/L)-1A	1.8	4.9	0.0367	49390	2.3E-06	1.27				
7(5mg/L)-1B	2.7	4.9	0.0367	49390	1.6E-06	0.60				
8(5mg/L)-1A	2.6	4.9	0.0375	51070	1.7E-06	0.65				
8(5mg/L)-1B	2.1	4.9	0.0375	51070	2.1E-06	0.99				
9(5mg/L)-1A	2.0	4.9	0.0366	50570	2.1E-06	1.05				
9-(5mg/L)1B	2.0	4.9	0.0366	50570	2.2E-06	1.10	0.907	0.704	+/-	7%
13(2.5mg/L)-1A	0.9	2.8	0.0375	49780	1.4E-06	1.51				
13(2.5mg/L)-1B	1.1	2.8	0.0375	49780	1.3E-06	1.16				
14(2.5mg/L)-1A	1.0	2.8	0.0374	50700	1.3E-06	1.38				
14(2.5mg/L)-1B	1.0	2.8	0.0374	50700	1.3E-06	1.37				
15(2.5mg/L)-1A	1.1	2.8	0.0379	51340	1.3E-06	1.18				
15(2.5mg/L)-1B	1.0	2.8	0.0379	51340	1.3E-06	1.34	1.315	1.001	+/-	3%

Table 3.12: Sorption calculations for undecanoic acid at low ionic strength. Kd is calculated using equations 3.2 and 3.3. See table 3.10 for legend.



	Kd (mL/g) with initial solute concentration of			Retardation when the initial solute concentration is		
Chemical	**1.5 mg/L**	**5 mg/L**	**10 mg/L**	**1.5 mg/L**	**5 mg/L**	**10 mg/L**
MOPCA	0.04	0.04	0.04	1.2	1.2	1.2
MACA	0.04	0.04	0.04	1.2	1.2	1.2
POCA	0.208	0.274	0.328	2.0	2.4	2.6

assuming a porosity of 0.3, bulk density of 1.5

Table 3.13: Retardation values based on the results of the batch equilibration for MOPCA, MACA and POCA. The linear Kd was calculated using equation 3.3.

dard deviation (RSD) greater than 100%; and no isotherm was plotted (Tables 3.16 and 3.15). These five surrogates had either no measurable solubility (CA) or insignificant concentration changes attributable to sorption. However, the data quality for HA, *cis*-MCAA, *trans*-MCAA, MCCA and CHCA are sufficient to estimate that the K_d's for these five chemicals fall within the range of 10^{-2} to 10^{-3} mL/g.

The K_d range of the three chemicals for which isotherms were constructed was 10^{-1} to 10^{-2} mL/g, consistent with the two single-ring surrogates in the first batch equilibration. The sole Z=-6 example (MACA) with measurable sorption had the lowest K_d (equation 3.2), consistent with the assertion that the Z=-6 compounds are more hydrophilic than Z=-4 (Havre et al., 2003). POCA has the highest K_d of the Z=-2, Z=-4 and Z=-6 chemicals, and it has the longest methyl side chain suggesting that hydrophobic bonding is one the sorption mechanisms. POCA's isotherm had $n_{POCA}>1$, but the other two chemicals had linear isotherms i.e. $n_{MACA}=n_{MOPCA}=1$ (Figure 3.6). The data was fit to a Freundlich isotherm even though the fit was poor at $R^2=0.6443$. The Type 3 reactors (lowest solute concentration) had no measurable sorbate; therefore, it was not possible to fit the data to the Freundlich model in log form to generate a non-linear curve.

Generally, the agreement between the K_d calculated using the two equations 3.2 and 3.3 was good for POCA and MOPCA. For MACA, the measured K_d is three orders of magnitude less than calculated $K_{MACA,F}$. Because of low initial concentration, data quality was not good; and there is not a good fit in the isotherm ($R^2=0.6443$). The R^2 for the other two isotherms is greater than 0.9.

The empirical K_d's result in retardation values that may be considered to be negligible for MOPCA and MACA (Table 3.13). POCA has retardation values from 2 to 2.6 so that in theory, it would travel at half the groundwater velocity.

Under slightly basic conditions and an ionic strength of 37 mM, the range of K_d

for the 8 surrogates varied from 10^{-1} to 10^{-3} mL/g. The longer, straight chain hydrocarbons UA and SA sorbed more strongly than heptanoic acid. This may be because of a pattern of decreasing sorption with decreasing molecular weight. Alternatively, the difference in geological material (i.e. f_{oc}) and ionic strength between the two batch reactors may be responsible. The single ring molecules did not sorb well either. Measurable sorption was not seen until the ring number reached Z=-4 and -6.

3.5.2.3 Stock Naphthenic Acids in High Ionic Strength Water

A sorption isotherm was plotted for the mixture of organic acids found in the stock NA, with the understanding that this is the sum of sorption isotherms for hundreds of homologues and isomers. A Freundlich isotherm fits the data with an R^2 value of 0.9964 (Figure 3.7). The resulting isotherm is concave up (n>1). The $K_{NA,F}$ at 5E-8 and the $n_{NA,F}$ at 1.2456 are very similar to POCA, MCCA and CHPA.

It is possible to predict the $K_{NA,d}$ of the stock naphthenic acid solution at any concentration by substituting the Freundlich equation into $K_{NA,d}=C_{NA,s}/C_{NA,w}$. Table 3.18 shows the sorption coefficients calculated using equations 3.2 and 3.3. K_d is low at 10^{-1} mL/g and again falls within the range of the surrogates. However, K_d is large enough to slow the velocity of NAs by almost half compared to the groundwater velocity if the initial concentration is greater than 30 mg/L (Table 3.17).

3.5.3 Sorption Coefficients Based on the Fraction of Organic Carbon

The K_d-f_{oc} relationships are reported to be useful if $f_{oc}>0.001$ for non-ionic compounds and sorption is wholly attributed to organic carbon. Only if there is less than 0.1% organic carbon may sorption on non-organic solids become relatively important (Apello & Postma, 1999). However, naphthenic acids are considered to be surfactants. They are amphiphilic chemicals whose non-linear sorption can be dominated by mineral sorption/cation exchange up to f_{oc} of 0.01 or 1% and a pH>pKa+2 (Schwarzenbach et al., 2002).

Sorption coefficients (Equation 3.6a) and retardation (Equation 3.4) for the geological material used in the reactors were calculated for both pH 7 and 8, the pH range of the batch reactors (Table 3.19). K_{oc} for NA surrogates in the second experiment

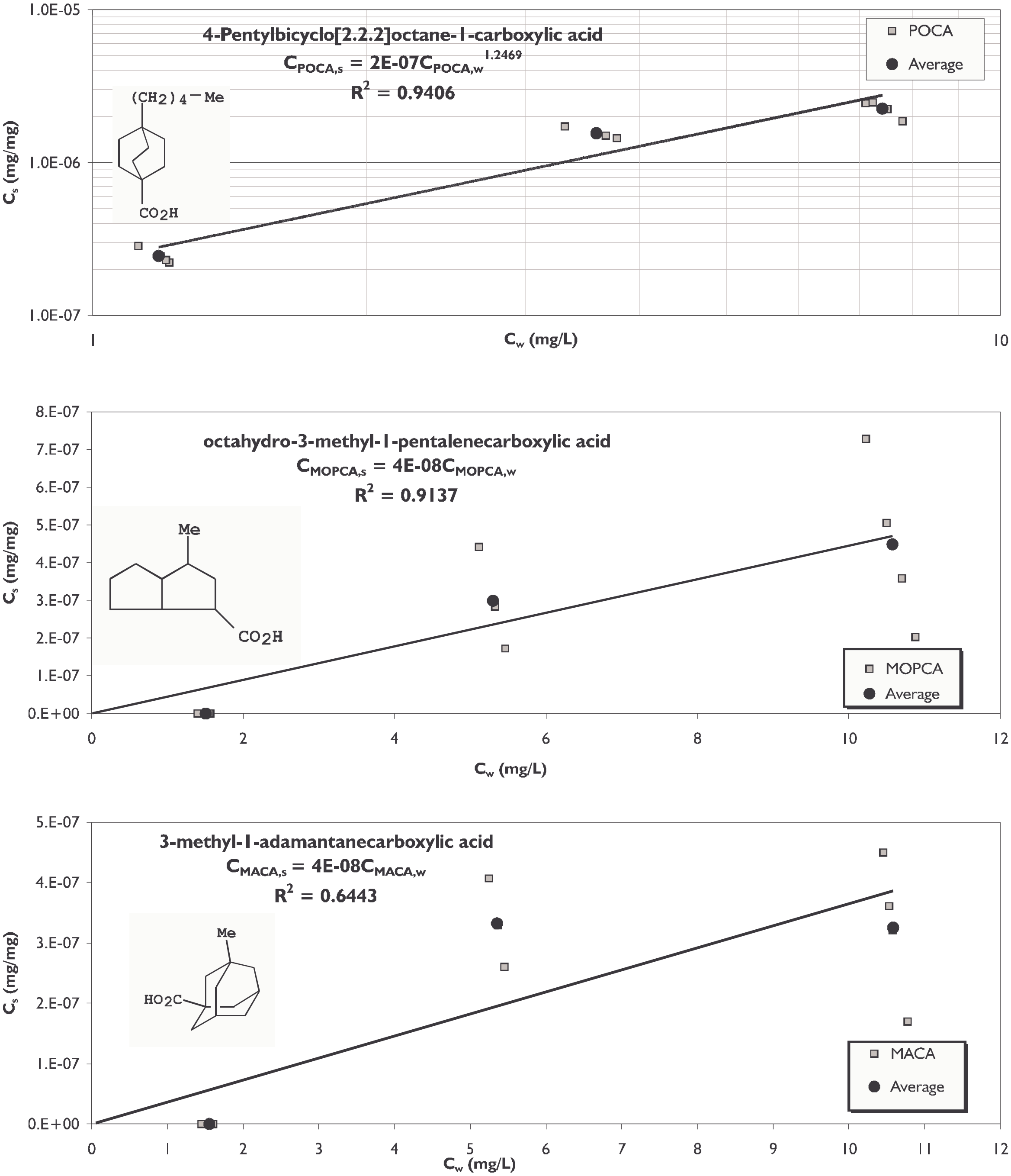


FIGURE 3.6: Freundlich isotherms for MOPCA, POCA and MACA at an ionic strength of 37 mM onto soil sample from the Sand Pit. Isotherm is for the arithmetic mean.

MOPCA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (mL/g)	Average	+/-	RSD	Kd using Ki,F
Type 1A	10.9	11.1	0.1839	210000	2.0E-07	0.019				
Type 1B	10.7	11.1	0.1834	210020	3.6E-07	0.033				
Type 1C	10.5	11.1	0.1731	210040	5.0E-07	0.048				
Type 1D	10.2	11.1	0.1723	210010	7.3E-07	0.071	0.042	+/-	53%	0.040
Type 2A	4.6	5.66	0.1850	210020	9.4E-07	0.205				
Type 2B	5.1	5.66	0.1711	210010	4.4E-07	0.086				
Type 2C	5.3	5.66	0.1805	210000	2.8E-07	0.053				
Type 2D	5.5	5.66	0.1852	210010	1.7E-07	0.032	0.056	+/-	49%	0.040
Type 3 A	1.6	1.35	0.1839	209990	0E+00	0.000				
Type 3 B	1.5	1.35	0.1813	210000	0E+00	0.000				
Type 3 C	1.6	1.35	0.1833	209990	0E+00	0.000				
Type 3 D	1.4	1.35	0.1730	209990	0E+00	0.000	0.000	+/-	0%	0.040

MACA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (mL/g)	Average	+/-	RSD	Kd using $K_{i,F}$
Type 1A	10.8	11.0	0.1839	210000	1.7E-07	0.016				
Type 1B	10.5	11.0	0.1834	210020	4.5E-07	0.043				
Type 1C	10.5	11.0	0.1731	210040	3.6E-07	0.034				
Type 1D	10.6	11.0	0.1723	210010	3.2E-07	0.030	0.031	+/-	37%	0.040
Type 2A	4.5	5.75	0.1850	210020	1.1E-06	0.235				
Type 2B	5.2	5.75	0.1711	210010	4.1E-07	0.078				
Type 2C	5.4	5.75	0.1805	210000	3.3E-07	0.061				
Type 2D	5.5	5.75	0.1852	210010	2.6E-07	0.048	0.062	+/-	24%	0.040
Type 3 A	1.6	1.44	0.1839	209990	0E+00	0.000				
Type 3 B	1.6	1.44	0.1813	210000	0E+00	0.000				
Type 3 C	1.6	1.44	0.1833	209990	0E+00	0.000				
Type 3 D	1.4	1.44	0.1730	209990	0E+00	0.000	0.000	+/-	0%	0.040

POCA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (mL/g)	Average	+/-	RSD	Kd using $K_{i,F}$
Type 1A	7.5	10.1	0.1839	210000	2.2E-06	0.298				
Type 1B	7.2	10.1	0.1834	210020	2.5E-06	0.342				
Type 1C	7.1	10.1	0.1731	210040	2.4E-06	0.344				
Type 1D	7.8	10.1	0.1723	210010	1.9E-06	0.239	0.304	+/-	16%	0.328
Type 2A	2.3	5.42	0.1850	210020	2.8E-06	1.234				
Type 2B	3.3	5.42	0.1711	210010	1.7E-06	0.519				
Type 2C	3.7	5.42	0.1805	210000	1.5E-06	0.409				
Type 2D	3.8	5.42	0.1852	210010	1.4E-06	0.383	0.434	+/-	17%	0.274
Type 3 A	1.2	1.47	0.1839	209990	2E-07	0.183				
Type 3 B	1.2	1.47	0.1813	210000	2E-07	0.205				
Type 3 C	1.2	1.47	0.1833	209990	2E-07	0.191				
Type 3 D	1.1	1.47	0.1730	209990	3E-07	0.253	0.207	+/-	15%	0.208

TABLE 3.14: Sorption calculations for MOPCA, MACA and POCA. Kd is calculated using equations 3.2 and 3.3. See table 3.9 for legend.

HA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (mL/g)	Average	+/-	RSD
Type 1A	12.0	10.8	0.1839	210000	0.0E+00	0.000			
Type 1B	10.5	10.8	0.1834	210020	2.6E-07	0.025			
Type 1C	10.4	10.8	0.1731	210040	3.1E-07	0.029			
Type 1D	10.8	10.8	0.1723	210010	0.0E+00	0.000	0.013	+/-	122%
Type 2A	4.6	4.80	0.1850	210020	1.6E-07	0.035			
Type 2B	4.8	4.80	0.1711	210010	0.0E+00	0.000			
Type 2C	5.2	4.80	0.1805	210000	0.0E+00	0.000			
Type 2D	5.4	4.80	0.1852	210010	0.0E+00	0.000	0.000	+/-	0%
Type 3 A	1.2	1.06	0.1839	209990	0E+00	0.000			
Type 3 B	1.3	1.06	0.1813	210000	0E+00	0.000			
Type 3 C	1.1	1.06	0.1833	209990	0E+00	0.000			
Type 3 D	0.9	1.06	0.1730	209990	1E-07	0.105	0.022	+/-	238%

CHCA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (mL/g)	Average	+/-	RSD
Type 1A	13.7	12.3	0.1839	210000	0.0E+00	0.000			
Type 1B	12.5	12.3	0.1834	210020	0.0E+00	0.000			
Type 1C	12.0	12.3	0.1731	210040	2.2E-07	0.018			
Type 1D	12.0	12.3	0.1723	210010	2.0E-07	0.017	0.008	+/-	121%
Type 2A	5.3	5.60	0.1850	210020	3.0E-07	0.056			
Type 2B	5.3	5.60	0.1711	210010	2.4E-07	0.045			
Type 2C	6.1	5.60	0.1805	210000	0.0E+00	0.000			
Type 2D	5.9	5.60	0.1852	210010	0.0E+00	0.000	0.014	+/-	188%
Type 3 A	1.3	1.36	0.1839	209990	2E-08	0.011			
Type 3 B	1.4	1.36	0.1813	210000	0E+00	0.000			
Type 3 C	1.3	1.36	0.1833	209990	6E-08	0.048			
Type 3 D	1.1	1.36	0.1730	209990	2E-07	0.160	0.051	+/-	144%

MCCA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (mL/g)	Average	+/-	RSD
Type 1A	12.5	11.3	0.1839	210000	0.0E+00	0.000			
Type 1B	11.0	11.3	0.1834	210020	2.8E-07	0.026			
Type 1C	10.9	11.3	0.1731	210040	3.5E-07	0.032			
Type 1D	11.4	11.3	0.1723	210010	0.0E+00	0.000	0.014	+/-	122%
Type 2A	4.9	5.17	0.1850	210020	2.7E-07	0.055			
Type 2B	5.1	5.17	0.1711	210010	7.3E-08	0.014			
Type 2C	5.5	5.17	0.1805	210000	0.0E+00	0.000			
Type 2D	5.6	5.17	0.1852	210010	0.0E+00	0.000	0.004	+/-	184%
Type 3 A	1.3	1.21	0.1839	209990	0E+00	0.000			
Type 3 B	1.3	1.21	0.1813	210000	0E+00	0.000			
Type 3 C	1.2	1.21	0.1833	209990	0E+00	0.000			
Type 3 D	1.1	1.21	0.1730	209990	1E-07	0.126	0.027	+/-	235%

Table 3.15: Sorption coefficient calculations for HA, CHCA and MCCA. Kd is calculated using equation 3.2. See table 3.10 for legend.

4MCAA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (mL/g)	Average	+/-	RSD
Type 1A	6.2	5.9	0.1839	210000	0.0E+00	0.000			
Type 1B	5.4	5.9	0.1834	210020	4.0E-07	0.075			
Type 1C	5.3	5.9	0.1731	210040	4.9E-07	0.093			
Type 1D	6.0	5.9	0.1723	210010	0.0E+00	0.000	0.039	+/-	125%
Type 2A	2.7	3.03	0.1850	210020	3.2E-07	0.119			
Type 2B	2.5	3.03	0.1711	210010	4.4E-07	0.176			
Type 2C	3.0	3.03	0.1805	210000	9.7E-09	0.003			
Type 2D	3.2	3.03	0.1852	210010	0.0E+00	0.000	0.051	+/-	196%
Type 3 A	0.7	0.76	0.1839	209990	2E-08	0.026			
Type 3 B	0.8	0.76	0.1813	210000	0E+00	0.000			
Type 3 C	0.7	0.76	0.1833	209990	5E-08	0.069			
Type 3 D	0.7	0.76	0.1730	209990	8E-08	0.129	0.053	+/-	106%

4MCAA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (mL/g)	Average	+/-	RSD
Type 1A	5.9	5.3	0.1839	210000	0.0E+00	0.000			
Type 1B	5.2	5.3	0.1834	210020	1.0E-07	0.019			
Type 1C	5.0	5.3	0.1731	210040	2.8E-07	0.055			
Type 1D	5.4	5.3	0.1723	210010	0.0E+00	0.000	0.017	+/-	149%
Type 2A	2.2	2.57	0.1850	210020	2.8E-07	0.127			
Type 2B	2.3	2.57	0.1711	210010	2.1E-07	0.093			
Type 2C	2.6	2.57	0.1805	210000	0.0E+00	0.000			
Type 2D	2.7	2.57	0.1852	210010	0.0E+00	0.000	0.028	+/-	192%
Type 3 A	0.6	0.62	0.1839	209990	2E-09	0.003			
Type 3 B	0.6	0.62	0.1813	210000	0E+00	0.000			
Type 3 C	0.6	0.62	0.1833	209990	5E-09	0.008			
Type 3 D	0.5	0.62	0.1730	209990	7E-08	0.132	0.032	+/-	200%

CA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (mL/g)	Average	+/-	RSD
Type 1A	0.2	0.0	0.1839	210000	-1.1E-07	-0.740			
Type 1B	0.1	0.0	0.1834	210020	-5.4E-08	-0.630			
Type 1C	0.0	0.0	0.1731	210040	-7.7E-09	-0.233			
Type 1D	0.0	0.0	0.1723	210010	1.7E-09	0.077	-0.591	+/-	-64%
Type 2A	0.4	0.06	0.1850	210020	-3.1E-07	-0.750			
Type 2B	0.1	0.06	0.1711	210010	-2.4E-08	-0.267			
Type 2C	0.1	0.06	0.1805	210000	-5.5E-09	-0.081			
Type 2D	0.0	0.06	0.1852	210010	1.5E-08	0.345	-0.072	+/-	-433%
Type 3 A	0.1	0.01	0.1839	209990	-6E-08	-0.753			
Type 3 B	0.0	0.01	0.1813	210000	-1E-09	-0.112			
Type 3 C	0.0	0.01	0.1833	209990	4E-10	0.040			
Type 3 D	0.0	0.01	0.1730	209990	8E-10	0.083	-0.531	+/-	-73%

Table 3.16: Sorption coefficient calculations for the cis- and trans- isomers of 4MCAA, as well as CA. Kd is calculated using equation 3.2. See table 3.9 for legend.

	Kd (mL/g) with initial solute concentration of			Retardation when the initial solute concentration is		
Chemical	**10 mg/L**	**30 mg/L**	**130 mg/L**	**10 mg/L**	**30 mg/L**	**130 mg/L**
stock NA	0.092	0.12	0.16	1.5	1.6	1.8

assuming a porosity of 0.3, bulk density of 1.5

TABLE 3.17: Retardation values based on the results of the batch equilibration for the stock NA.

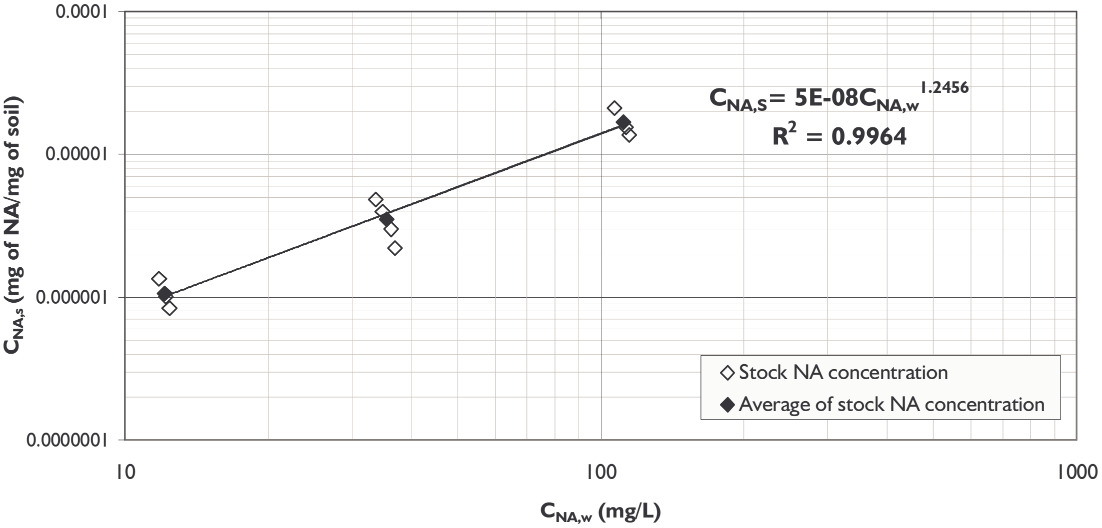


FIGURE 3.7: Freundlich isotherms for the stock naphthenic acids derived from the Mildred Lake Settling Basin at high ionic strength onto soil sample from the Sand Pit. Isotherm is for the arithmetic mean.

Stock NA

Sample ID	C_w	C_0	V_w	M	C_S	Kd (ml/g)	Average	Kd using Ki,F
10 Act-1	12.2	13.37	0.721	833950	1.0E-06	0.08		
10 Act-2	11.8	13.37	0.715	834350	1.3E-06	0.11		
10 Act-3	12.4	13.37	0.716	834140	8.3E-07	0.07	0.088	0.092
30 Act-1	33.7	39.63	0.338	417020	4.8E-06	0.14		
30 Act-2	34.8	39.63	0.343	417200	1.4E-05	0.12		
30 Act-3	36.9	39.63	0.337	417610	1.5E-05	0.14		
30 Act-4	36.3	39.63	0.375	417840	3.0E-06	0.08	0.099	0.120
100 Act-3	114.9	130.33	0.075	84170	1.4E-05	0.12		
100 Act-4	113.0	130.33	0.075	84200	1.5E-05	0.14		
100 Act-2	106.7	130.33	0.075	84220	2.1E-05	0.20	0.151	0.159

TABLE 3.18: Sorption calculations for the stock naphthenic acids. See table 3.10 for legend.

were used to calculate K_d twice: once for f_{oc} = 1.5% and once for 0.4%. The results for NA surrogates in low I environment and f_{oc} = 1.1% were also included.

Both the prediction and batch equilibration methods showed that stearic acid (SA) would sorb and retard very strongly. The calculated $K_{UA,oc}$ underestimates measured $K_{UA,d}$, especially at low concentrations. For the second linear surrogate, the empirical and theoretical $K_{UA,d}$ agree with each other when $C_{w,initial}$ =10 mg/L. However, at lower initial solute concentrations, theoretical $K_{UA,d}$ underestimates retardation by half.

MOPCA has $K_{MOPCA,d}$=10^{-2} for both the experimental and theoretical calculations, with the exception of pH 8 and f_{oc} of 0.4%.

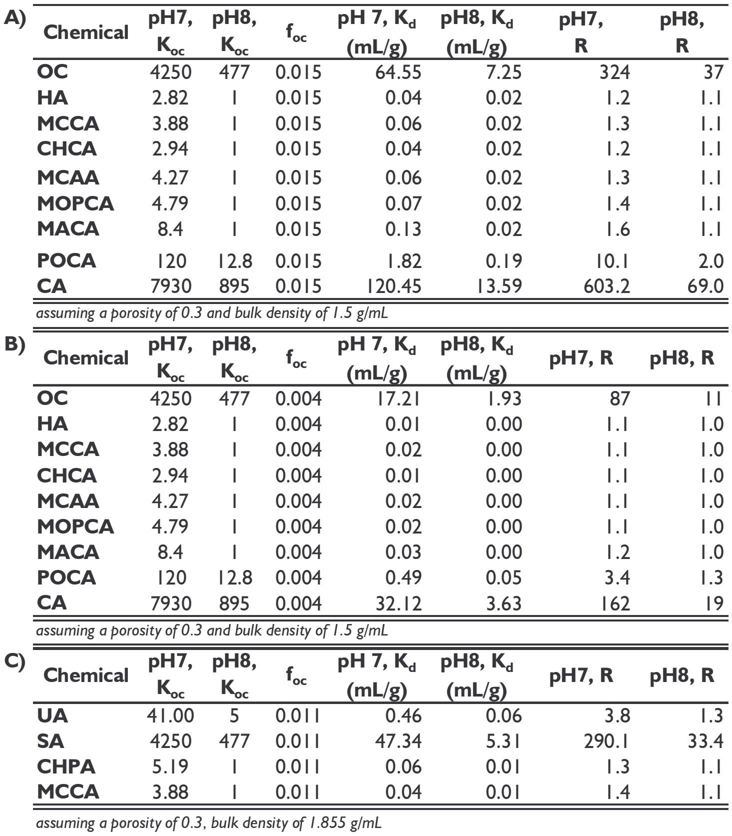
The two experimental $K_{MACA,d}$ at two different initial solute concentrations give results around 10^{-2} mL/g. The calculated $K_{MACA,d}$ decreases by an order of magnitude between pH 7 and 8, and f_{oc} 1.5 and 0.4%: 10^{-1} to 10^{-2} mL/g for f_{oc} 1.5% and 10^{-2} to 10^{-3} mL/g for f_{oc} 0.4%. Theory and experimental results fall within the same order of magnitude.

As with MACA, the calculated $K_{POCA,d}$ decreases by an order of magnitude from pH 7 and 8, and f_{oc} 1.5 and 0.4%: 10 to 10^{-1} for f_{oc} 1.5% and 10^{-1} to 10^{-2} for f_{oc} 0.4%. Since the f_{oc} and pH are not precise, the fact that the empirical $K_{POCA,d}$=10^{-1} mL/g means that there is a good agreement between empirical and theoretical $K_{POCA,d}$.

The estimated and batch K_d's are generally similar within an order of magnitude and there is good agreement between theory and empirical results. As long as the $K_{ion,oc}$ and $K_{neutral,oc}$ are both taken into account, the calculated K_d and retardation would provide a good first estimate. However, since the calculated K_{oc} does not compensate for non-linear isotherms, it must remain a first estimate only.

3.5.4 Detailed Naphthenic Acids Analysis

In an attempt to determine if the "signature" of stock naphthenic acids would be changed by sorption, the aqueous solution in the batch equilibration bottles was analyzed by the gas chromatograph-mass spectrometer method which allows a semi-quantitative characterization of the naphthenic acids (St John et al., 1998). The "signature" is derived by placing the analytical results of the abundance of specific ions corresponding to naphthenic acids (Holowenko et al., 2002) into a matrix of Z number versus carbon number and then plotting the data as a three-dimensional plot.



A)

Chemical	pH7, K_{oc}	pH8, K_{oc}	f_{oc}	pH 7, K_d (mL/g)	pH8, K_d (mL/g)	pH7, R	pH8, R
OC	4250	477	0.015	64.55	7.25	324	37
HA	2.82	1	0.015	0.04	0.02	1.2	1.1
MCCA	3.88	1	0.015	0.06	0.02	1.3	1.1
CHCA	2.94	1	0.015	0.04	0.02	1.2	1.1
MCAA	4.27	1	0.015	0.06	0.02	1.3	1.1
MOPCA	4.79	1	0.015	0.07	0.02	1.4	1.1
MACA	8.4	1	0.015	0.13	0.02	1.6	1.1
POCA	120	12.8	0.015	1.82	0.19	10.1	2.0
CA	7930	895	0.015	120.45	13.59	603.2	69.0

assuming a porosity of 0.3 and bulk density of 1.5 g/mL

B)

Chemical	pH7, K_{oc}	pH8, K_{oc}	f_{oc}	pH 7, K_d (mL/g)	pH8, K_d (mL/g)	pH7, R	pH8, R
OC	4250	477	0.004	17.21	1.93	87	11
HA	2.82	1	0.004	0.01	0.00	1.1	1.0
MCCA	3.88	1	0.004	0.02	0.00	1.1	1.0
CHCA	2.94	1	0.004	0.01	0.00	1.1	1.0
MCAA	4.27	1	0.004	0.02	0.00	1.1	1.0
MOPCA	4.79	1	0.004	0.02	0.00	1.1	1.0
MACA	8.4	1	0.004	0.03	0.00	1.2	1.0
POCA	120	12.8	0.004	0.49	0.05	3.4	1.3
CA	7930	895	0.004	32.12	3.63	162	19

assuming a porosity of 0.3 and bulk density of 1.5 g/mL

C)

Chemical	pH7, K_{oc}	pH8, K_{oc}	f_{oc}	pH 7, K_d (mL/g)	pH8, K_d (mL/g)	pH7, R	pH8, R
UA	41.00	5	0.011	0.46	0.06	3.8	1.3
SA	4250	477	0.011	47.34	5.31	290.1	33.4
CHPA	5.19	1	0.011	0.06	0.01	1.3	1.1
MCCA	3.88	1	0.011	0.04	0.01	1.4	1.1

assuming a porosity of 0.3, bulk density of 1.855 g/mL

TABLE 3.19: Kd and retardation based on calculated Koc for different fraction of organic carbon at ionic strength of 37 mM for A and B and low ionic strength for C

The distribution of carbon numbers and Z families of naphthenic acids in the complex mixtures extracted and derivatized from the batch reactors are shown in Figure 3.8 and 3.9. The control (water only) graphs have undergone no sorption while the active graphs show the NA homologue distribution after sorption; the final concentrations are indicated on the graphs. The bars represent the percentage (by number of ions) of NAs in the mixture that can account for a given carbon number of a given Z family (a specific m/z value). The sum of all bars equals 100% (Holowenko et al., 2002). A visual examination of the data leads to a conclusion that sorption caused no obvious change in the "signature".

A t-test using arcsine-transformed data can be used to compare groups in samples (Clemente et al., 2003). The student's t-test indicates probabilities (P) that the mean found from a finite number of measurements will differ from the "true" mean by a given amount and is useful for comparing data sets of finite number that have random errors characterized by a Gaussian distribution. The author of the two-tailed t-test for NAs chose three groups based on carbon number after examining multiple three dimensional plots: Group 1 contains carbon number 5-14, Group 2 numbers 15-21 and Group 3 numbers 22-33. If $P<0.05$, then we can conclude that there is a significant difference in a group between two samples being compared.

Since none of the t-tests had $P<0.15$ when $P<0.05$ is the cutoff point (Table 3.20), the abundance of ions in any one group did not change enough to affect the results of the t-test. Even when sorption decreased the solute concentration by 15%, there was no significant change in the NA "signature".

The batch experiment should be performed again with process-affected water since the preparation of stock NA produces a NA mix that is very low in the high molecular weight molecules, which may be expected to have a greater sorption (CA in Table 3.19).

3.6 Discussion

Attempts to anticipate the sorption of organic acids in order to speculate on their transport in groundwater can be difficult since the dominant sorption mechanism depends on pH, presence of exchangeable cations (solution ionic strength), specific

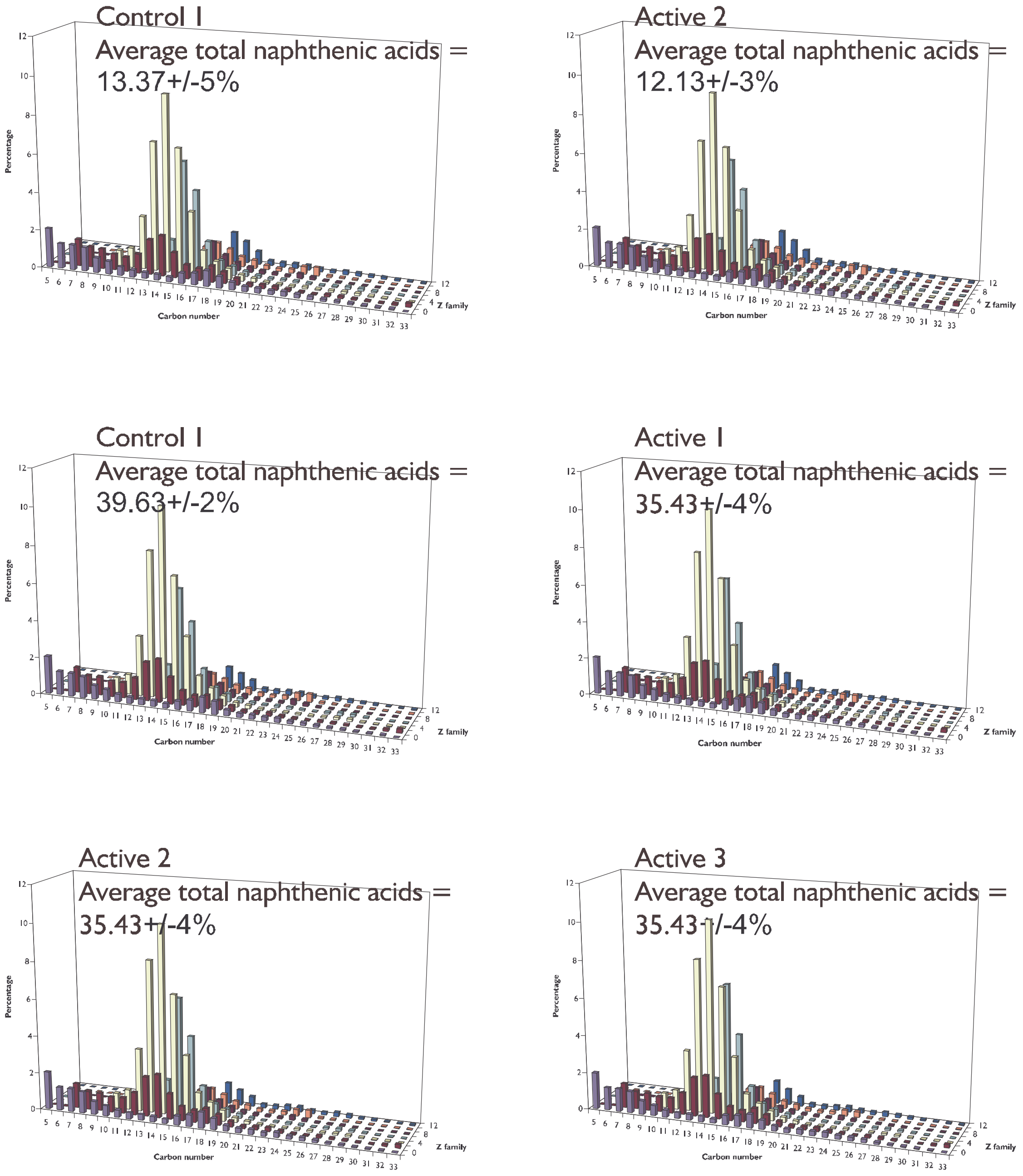


FIGURE 3.8: The distribution of carbon numbers and Z families of naphthenic acids in the complex mixtures extracted and derivatized from the control and active batch reactors with initial naphthenic acids concentration of 13 and 40 mg/L.

	Active 2, 10 mg/L			Active 1, 30 mg/L			Active 2, 30 mg/L			Active 3, 30 mg/L			Active 2, 130 mg/L			Active 3 130 mg/L			Active 4, 130 mg/L		
Groups	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Control 10 mg/L	0.87	0.97	0.34	0.99	0.99	0.83	0.98	0.97	0.74	0.98	0.99	0.97	0.95	0.96	0.80	0.99	0.99	0.77	0.97	0.95	0.49
Control 30 mg/L	0.87	0.96	0.51	0.98	1.00	0.94	0.97	0.98	0.97	0.99	0.98	0.80	0.96	0.95	0.58	0.98	0.99	0.56	0.97	0.94	0.33
Control 130 mg/L	0.92	0.98	0.15	0.94	0.94	0.48	0.93	0.92	0.41	0.97	0.96	0.59	1.00	0.99	0.81	0.94	0.96	0.84	0.98	1.00	0.85

TABLE 3.20: Results of the t-test analysis of the naphthenic acids extracted and derivatized from batch equilibration bottles. Group 1 is composed of carbon number 5 to 13, Group 2 has C14-C21 and Group 3>C21-C33. Values less than 0.05 means the two samples are considered to be significantly different (P<0.05).

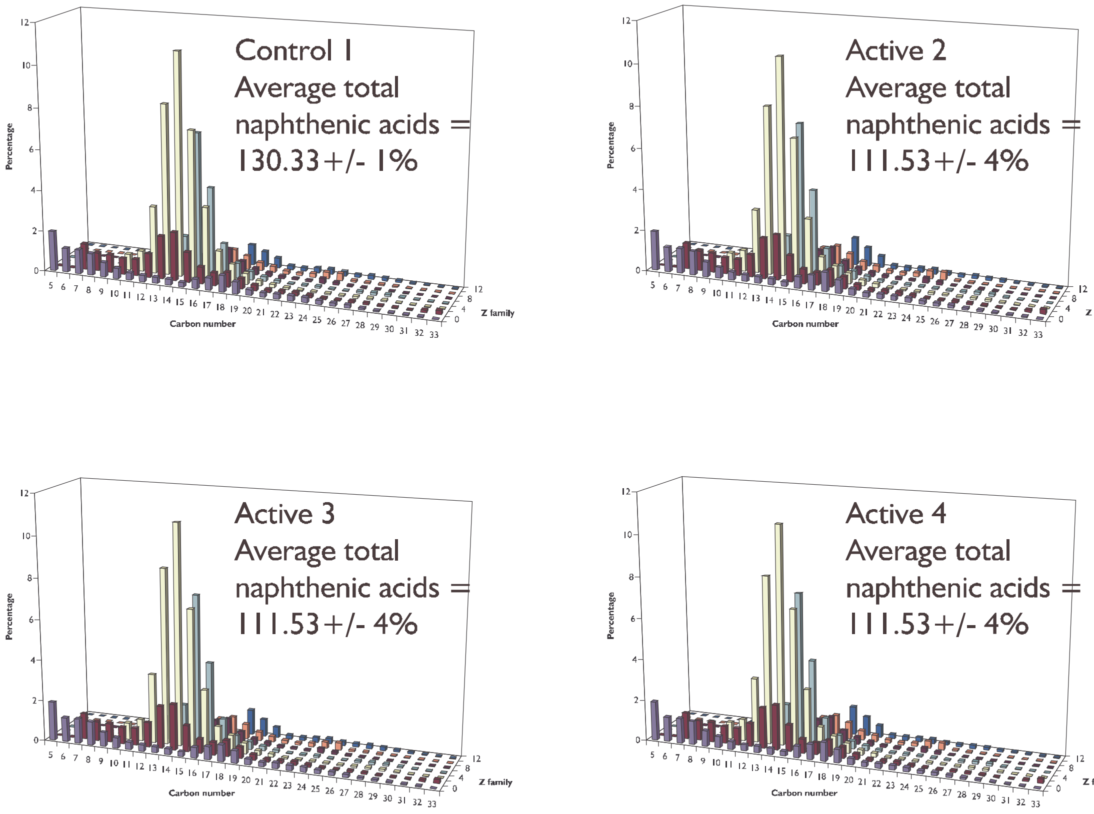


FIGURE 3.9: The distribution of carbon numbers and Z families of naphthenic acids in the complex mixtures extracted and derivatized from the control and active batch reactors with initial naphthenic acids concentration of 130 mg/L.

surface area, grain size distribution, f_{oc} and the type of mineral fraction. Generalizations are further complicated by the fact that we only have a general molecular formula for naphthenic acids (NAs) and it is not possible to know with certainty that the NA surrogates are present in naturally occurring NA mixes. The isotherms and, more generally, the sorption coefficients (K_d) support the claim that the carboxylic acids used are adequate substitutes for naturally occurring NAs.

Three of the six surrogate isotherms and the stock NA isotherm had $n>1$, a pattern which has been seen before in surfactant sorption (Schwarzenbach et al., 2002). The three linear isotherms are probably not as representative. It is unlikely that undecanoic acid is a common component of naturally occurring NAs for reasons discussed in Chapter 2. The other two chemicals have apparently linear isotherms only because the sorption onto solid at low aqueous concentrations is below the method detection limit.

The isotherm for the stock NA is actually the sum of the various sorption processes experienced by different NAs. The fact that the surrogate isotherms and the stock NA isotherm have a Freundlich exponent greater than one supports the use of CHPA, MCHCA and POCA as surrogates. Add to that the fact that $K_{NA,d}$ and all the surrogate K_d, except for UA and CA, fall between 10^{-1} and 10^{-3} mL/g further supports the relevance of surrogate behaviour to anticipate field behaviour of NAs.

While the values for K_d are small and NAs will prefer to remain in the aqueous phase, sorption is nevertheless sufficient to lead to a measurable concentration decrease if the initial solute concentration is high enough. At $C_{NA,w,initial}$=10 mg/L, the decrease in solute concentration was 9%, which is probably too small to see with any confidence in field sites with their many heterogeneities. However, at $C_{NA,w,initial}$ = 130 mg/L, K_d is 0.16 mg/L and the average concentration decrease was 15%. Retardation values around two were calculated. Concentrations high enough for measurable sorption would probably occur only close to the source. Given the volume of sorbent present in an aquifer, a decrease in solute concentration may be seen if the initial solute concentration is high enough and the path length long enough.

The two main processes that may decrease solute concentration of NAs in the laboratory are biodegradation and sorption. A major goal of the NA batch equilibration was to see if a consistent pattern change could be identified that could act as "sorption signature". Even though there was a 15% decrease in solute concentration in the stock NA mix reactors from 130 to 112 mg/L, there was no change in the signature. This may be because the 15% decrease in concentration was distributed over too many homologues to be reflected as significantly different in the t-test.

The decrease in mass is attributed to sorption since a microbial inhibitor was added to remove biodegradation as a factor. Except for the small variations in the Z=-4 and Z=-6 families, there is little or no change in the 3D graphs. The lack of sorption "signature" in the 3D graphs and the relatively small decrease in concentration means that even if sorption were occurring in the field, it would be difficult to conclude that it was a factor in the retardation of NAs. As well, since field measurements tend to be "noisy" due to heterogeneity, a decrease in mass due to sorption may only be seen with any confidence at high NA concentrations. On the positive side, the apparent lack of change of NA "signature" due to sorption means that, in the field, a change in the 3D signature may be attributed to biodegradation.

Since the stock NA was poor in the high molecular weight homologues (Figure 2.6 and 3.8), it is worthwhile to examine the small changes in relative concentration that do occur in the mix, as well as looking at surrogate behaviour. There was little or no change in the Z=0, -2, -8 -10 and -12 families between all reactors, no matter the sorbate concentration. The Z=-4 (2-ring) and Z=-6 (3-ring) families show some change. The two-ring molecules tend to have a lower relative solute concentration after sorption with an accompanying relative increase in the 3-ring molecules. Because the analytical method measures relative concentration, this does not mean that the absolute concentration of Z=-6 molecules is increasing but rather that the absolute concentration of other carbon number/Z number combinations are decreasing more than the Z=-6 family with carbon numbers 13 to 17. Given the general lack of change, it is probable that the molecules from Z=-4 family with carbon number 12 to 17, with some minor contribution from the Z=-12 family with carbon number 18 to 20, are being sorbed preferentially. The pattern is similar for the surrogates, where the Z=-6 MACA is more hydrophilic than the Z=-4 POCA. These findings agree with Havre *et al.* (2003).

It is believed that the most toxic portion of NAs is the low molecular weight molecules (Mackinnon & Boerger, 1986; Holowenko et al., 2002; Herman et al., 1994; Lai et al., 1996; Clemente et al., 2004). The results of the surrogate batch reactors show no substantial preference for either the low or high molecular weight molecules. It may be that under I=37 mM and pH 7 to 8 aqueous conditions, sorption decreases the relative solute concentrations of all homologues with a slight preference for the carbon numbers 12 to 17, Z=-4 and -6. Since the stock NA (Figure 3.10) was poor

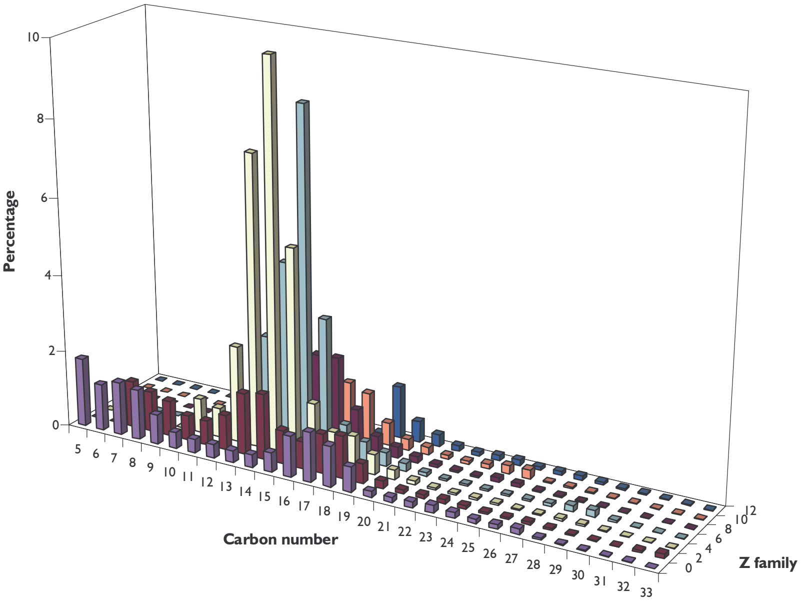


FIGURE 3.10: The distribution of carbon numbers and Z families of naphthenic acids in the complex mixture extracted and derivatized from naphthenic acids stock (UW456) used for the batch equilibration.

in the high molecular weight molecules compared to unprocessed NA, more batch equilibration experiments would be needed to confirm these findings.

The expectation was to see a "salting out" effect in the second surrogate batch equilibration, as increased inorganic ion concentration increased the thermodynamic gradient between the water and organic matter. However, aqueous solubility of the surrogates increased with increasing ionic strength. MCCA had no measurable sorption in the I=37 mM reactors while the sorption was measurable in the 15 mM ionic strength reactors (Table 3.21). Sorption of the weak base diisopropanalamine, a polar N-containing compound, decreased by $^1/_3$ as the solution concentration of K_2SO_4 increased from 10 to 100 mM and by $^1/_2$ as ionic strength went from 1 to 10 mM (Luther et al., 1998), similar to the behaviour of MCCA. When f_{oc}<0.1%, cation exchange capacity was a useful parameter for predicting sorption for this compound. Adsorption may be important and the higher ionic strength may lead to increased competition for sorption sites. This provides evidence that adsorption is the dominant process, not partitioning. The best sorbent will probably be clays as opposed to sands (Schramm et al., 2000). The clay content of the solids in the two batches

MCCA

SAMPLE ID	C_w	C_0	V_w	M	C_S	Averate Kd (L/mg)	Averate Kd (mL/g)
Type 1	11.43	11.28	0.1723	210010	0.0	0.0	0.0
Type 2	5.40	5.17	0.1852	210010	0.0	0.0	0.0
Type 3	1.24	1.21	0.1730	209990	0.0	0.0	0.0
10 mg/L	6.83	8.71	0.0369	50640	1.4E-06	2.0E-07	0.20
5 mg/L	3.31	3.81	0.0366	50570	3.7E-07	1.1E-07	0.11
2.5 mg/L	1.84	1.96	0.0379	51340	8.3E-08	9.9E-08	0.099

Table 3.21: Sorption coefficients for 1MCCA at a high ionic strength (Type 1, 2 3) and low ionic strength (10 mg/L, 5 mg/L 2.5 mg/L).

are unknown. The 15 mM solid was collected from a glaciofluvial sand aquifer while the solid for the 37 mM was collected from an active sand pit. Since the sand pit was being commercially mined, it is probable that it's clay content is low.

3.7 Conclusion

Sorption coefficient values and retardation are generally small for both the NA surrogates and the stock NA in sands. K_d values were measured which lead to retardation ranging from 1 (no difference in travel time between chemical and groundwater) up to 3 (solute travels 1/3 slower than the groundwater). As with many surfactants, sorption increased with increasing solute concentration so the decreases in mass due to sorption may only be seen in the field when the source has high NA concentrations. It is possible that sorption may be higher in aquifers with a higher clay content. It may be useful to investigate the use of cation exchange capacity as a parameter for predicting NA sorption.

Since increasing ionic strength seemed to increase the solubility of the naphthenic acids surrogates, sorption may increase as the process-water mixes with background ground water and so becomes less saline.

As opposed to biodegradation, sorption is a chemical process which leaves no "signature" as it slows the transport of NAs in sand, although this may change if sorption could be enhanced. This means that changes in the NA "signature" in glaciofluvial sands and gravels may be mainly attributed to biodegradation. However, Z=-4 and -6 low molecular weight homologues seem to sorb more strongly than other NAs and this should be kept in mind when interpreting 3D graphs.

Chapter 4

Muskeg River Mine

4.1 Introduction

The majority of chemical components found in process-affected water, including naphthenic acids (NAs), also occur naturally in groundwater from the McMurray Formation (quartzose sand impregnated with heavy oil), tills containing reworked McMurray oil sand and the McMurray Basal Aquifer. The Albian Sands Test Pit plume at the Muskeg River Mine provides the opportunity to evaluate an existing plume of natural “process-affected water” (naturally NA rich ground water) from the McMurray Basal Aquifer in a shallow glacial aquifer. Vertical and horizontal groundwater profiling along the plume supplied field data to determine if the naphthenic acids front coincided with the conservative chloride front or was attenuated or retarded due to physical or biological processes.

4.2 Site Locations

The town of Fort McMurray is located 400 km north of Edmonton, Alberta (Figure 4.1). Albian Sands Energy Inc. (Albian Sands) is located 75 kilometres north of Fort McMurray, on the east side of the Athabasca River, near the Muskeg River (Figure 4.2). Albian Sands is the newest operation to begin mining in the Fort McMurray area. The study site is near the Muskeg River and downgradient from the Muskeg River Pilot Plant Test Pit (Figure 4.3). One profiling transect, B-B’, was taken beneath a fen, fed mostly from groundwater and runoff from adjacent mineral uplands. The

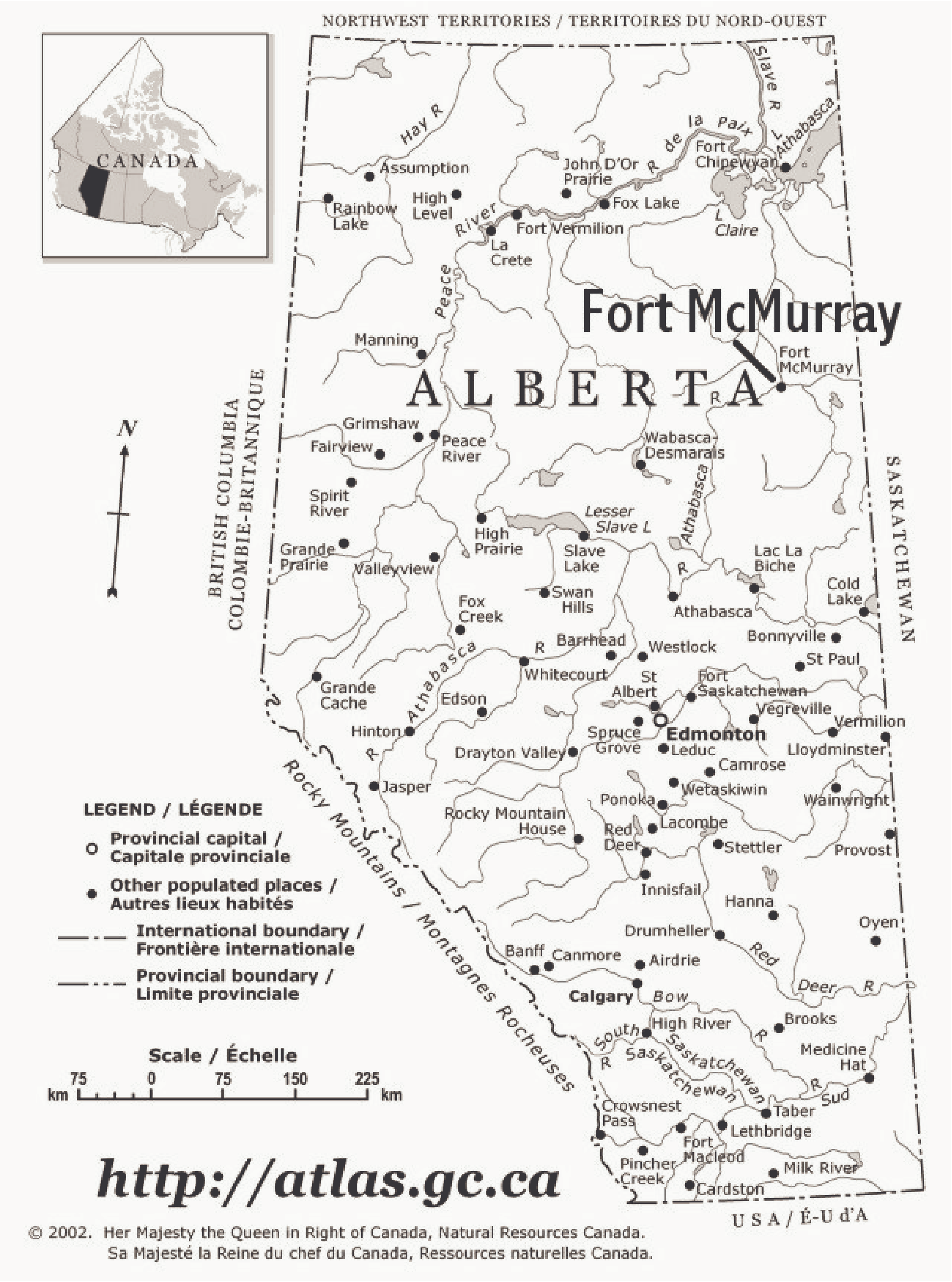


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FIGURE 4.1: Line map of the province of Alberta, showing the location of Fort McMurray, approximately 400 km north of Edmonton.

physiography also includes boreal forest and riverside. The topography varies from around 295 to 270 masl (Figure 4.6). The impacted unconfined aquifer is generally about 4 to 5 m thick and is connected to the Basal Aquifer via the Test Pit (Figure). Bayrock (1971 as stated in Komex International Ltd, 2002) mapped the area as very permeable Quaternary outwash sand and gravel, underlain by very low-permeability oil sand.

4.3 Regional Geology

This geological summary (Figure 4.4) is presented in descending stratigraphic order and the geological time unit is the period, while the hydrogeological summary is presented in ascending stratigraphic order.

The surficial deposits of organic matter, till, sand, silt and gravel were laid down during the Quaternary and Recent periods. Below that, an erosional unconformity removed any Tertiary period deposits. The Grand Rapids Formation (lithic sand and sandstone), the Clearwater Formation (shale) and the McMurray Formation (quartzose sand impregnated with heavy oil) were deposited during the Cretaceous. These formations are regional in extent but not continuous; the Grand Rapids Formation does not occur in the Muskeg River area. The Cretaceous is considered to be the bedrock in the area of the Muskeg River Mine. An erosional unconformity removed any deposits from the Jurassic, Triassic, Permian and Carboniferous periods. The limestone of the Upper Devonian is considered to be the bedrock in the area of Suncor Energy Inc. and Syncrude Canada Ltd.

The Upper Devonian Waterways Formation is either limestone reef or limestone mud. Near the unconformity, the limestone may be highly weathered and may form a locally important aquifer in connection with the McMurray aquifer. There is frequently a water bearing zone of variable thickness under artesian pressure below the bitumen bearing section called the McMurray Basal Aquifer, the source of naphthenic acids in the Test Pit water. The chemistry, especially the chloride content, of the McMurray Basal Aquifer water varies considerably. The water is usually relatively high in bicarbonate. There is some chemical evidence to indicate that the waters of the lower part have higher chloride concentrations than those in the upper part, perhaps due to vertical connection with the highly saline Devonian waters. McMurray waters to the west of the Athabasca river generally have a higher salinity than those east of

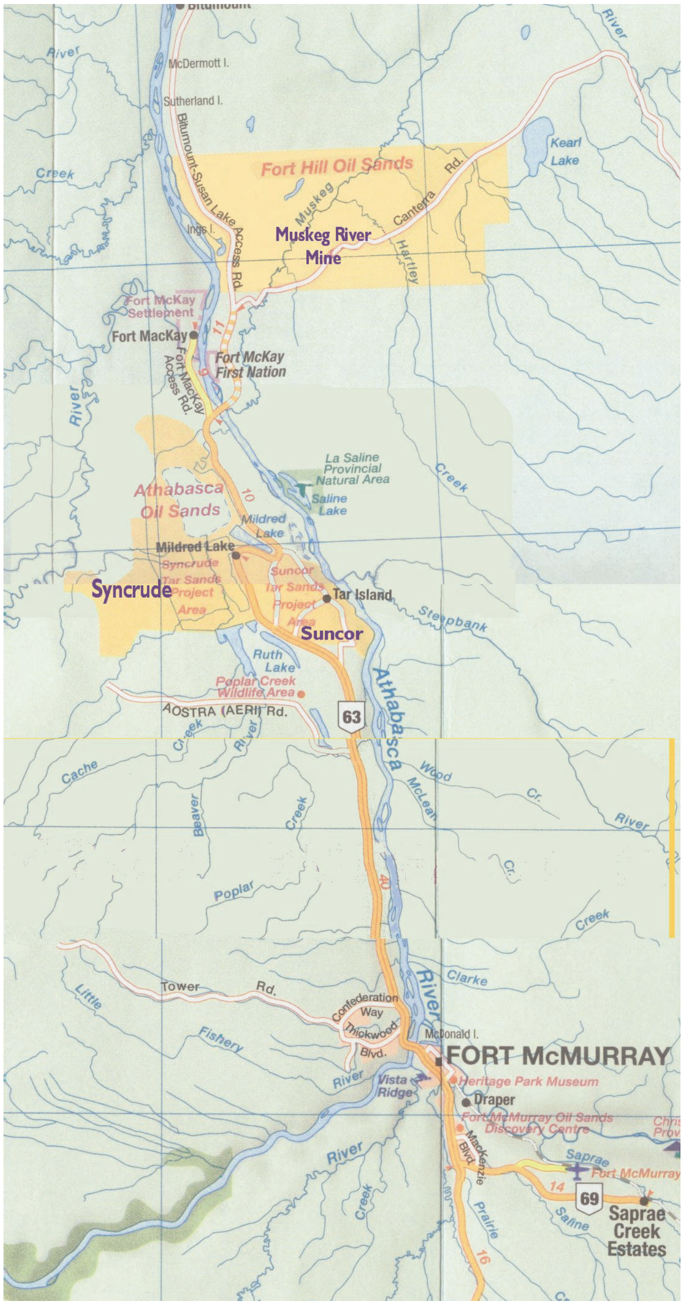


FIGURE 4.2: Location of the three mines north of Fort McMurray, Alberta MapArt, 2003.

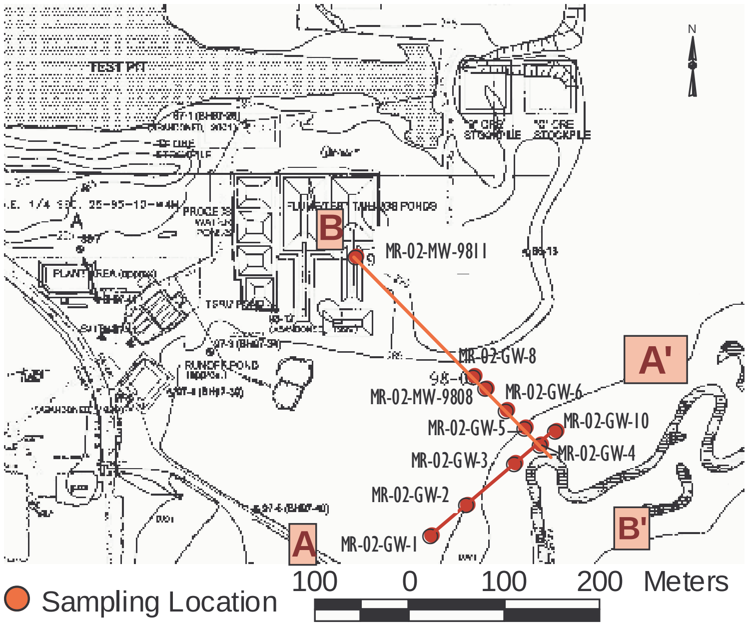


FIGURE 4.3: Plan view map of the study site near the Muskeg River, Albian Sands Energy Inc., Muskeg River Mine.

the river.

Important aquifers occur in the Quaternary deposits. Meltwater channels were cut into the underlying bedrock surface and some of these are filled with materials that have high porosity and permeability. Post-McMurray waters are generally relatively fresh but with highly variable sulfate concentrations. Sulfate may be recharged locally or may be associated with weathering of the oil sands spoil from the holding ponds (M. Trudell, personal communication, May 10, 2004).

In short, the stratigraphy of the near surface is Holocene organic matter over Quaternary glacial deposits such as till and sequences of glacially deposited sand and gravel. This succession lies on top of dense grey clay till, Clearwater shale, or McMurray Formation oil sand (Farvolden et al., 1976; Evison, 2000a; Hunter, 2001).

4.4 Previous Studies

Reports produced by Komex International Ltd. (Komex) and Albians Sands provided historical, chemical and hydrological information, estimates of hydraulic properties

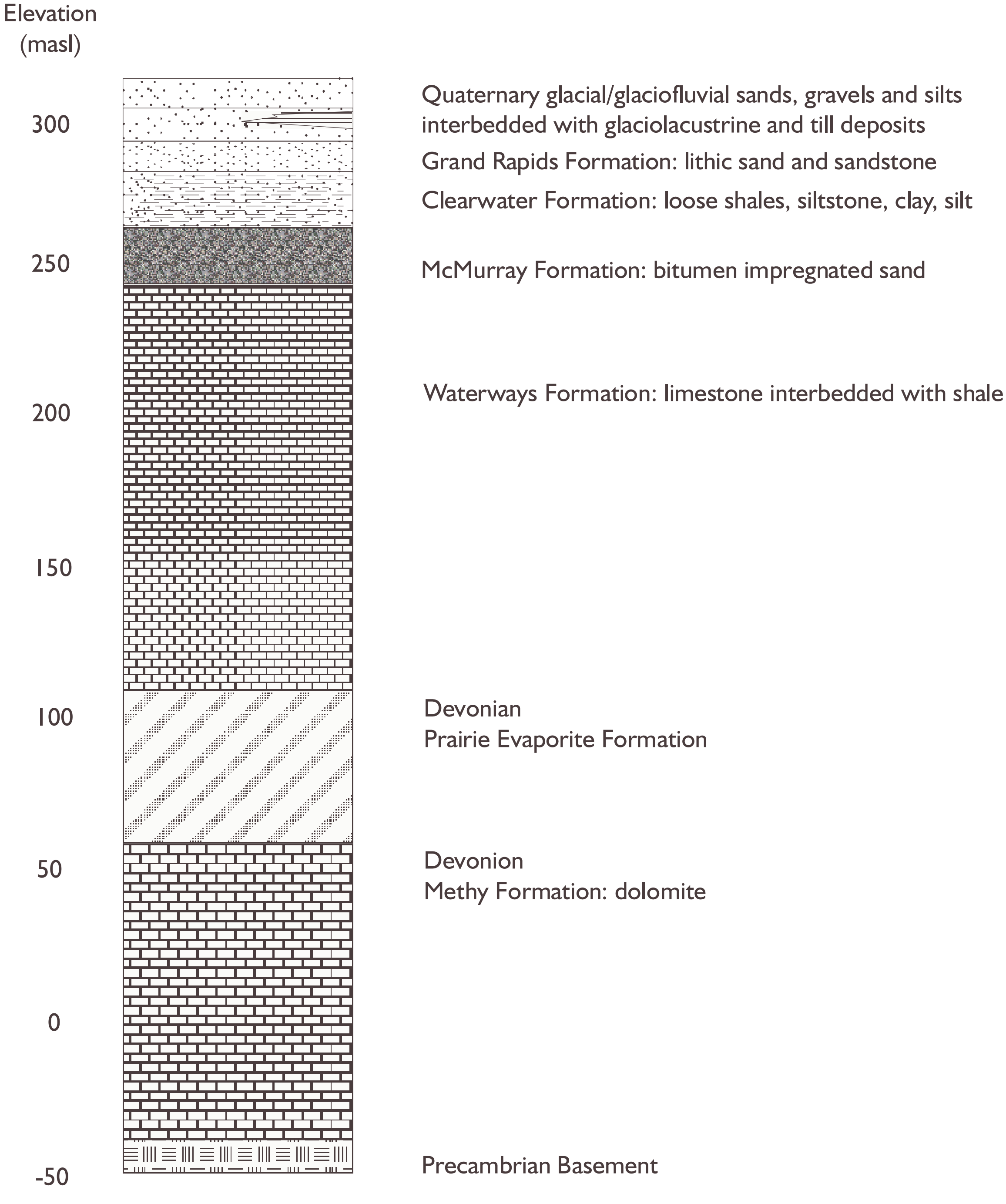


Figure 4.4: Geological sequence in the Athabasca Oil Sand Region.

and site geology, and conceptual groundwater flow models.

The former Alsands Test Pit was excavated in 1975 and was cored deeply enough to become hydraulically connected to the McMurray Basal Aquifer (Figure 4.5). After the pumping wells were shut off, the water level in the Test Pit rose to near ground surface by late 1976 (Komex International Ltd, 2000). Water in the Test Pit has historically been a mixture of natural groundwater from surficial glacial deposits, McMurray Formation and McMurray Basal Aquifer plus surface runoff and precipitation. This mixture, containing naphthenic acids from the McMurray Formation, is high enough to recharge the surficial aquifers. The Test Pit is no longer a valid sample of the initial source groundwater since it was used for Pilot Plant process water disposal in 1998-99.

The area around the Test Pit is a local topographic high and the Muskeg River is a local topographic low (Figure 4.6)

In 1997, water in the Test Pit was characterized by chloride concentrations of 350 to 460 mg/L, and naphthenic acids concentrations of 13 to 17 mg/L. Groundwater quality monitoring data collected by Komex (2002) to the south and east of the Test Pit indicate that a plume of impacted groundwater in the surficial sand aquifer is emanating from the Test Pit, and extends at least 400 m to the southeast, toward the Muskeg River. The impacted surficial sand aquifer is generally about 4 to 5 m thick. The monitoring well furthest downgradient (98-8) had chloride concentrations of 386 mg/L and naphthenic acids concentrations of 11 mg/L in November 2001 (Komex International Ltd, 2002). The chloride levels suggest that the leading edge of the plume has passed this location.

The ground water gradient is from the area around the Test Pit towards the Muskeg River (Figure 4.7). The estimated groundwater velocity in the plume area is 15 to 21 m year^{-1}, corresponding to a travel time to the Muskeg River (370 m) of 18 to 25 years (Komex International Ltd, 2000). The time available for seepage to groundwater and subsequent migration is more than 25 years (starting in 1977), thus the chloride plume with Basal Aquifer naphthenic acids from the Test Pit could presently be reaching the Muskeg River. The Pilot Plant process-affected water added to the Test Pit in 1998-1999 should have travelled a maximum of 100 m. The well nearest the Test Pit sampled for our project (98-11) is 200 m from the source and, therefore, the process-affected water will probably not have reached any of the sampling points.

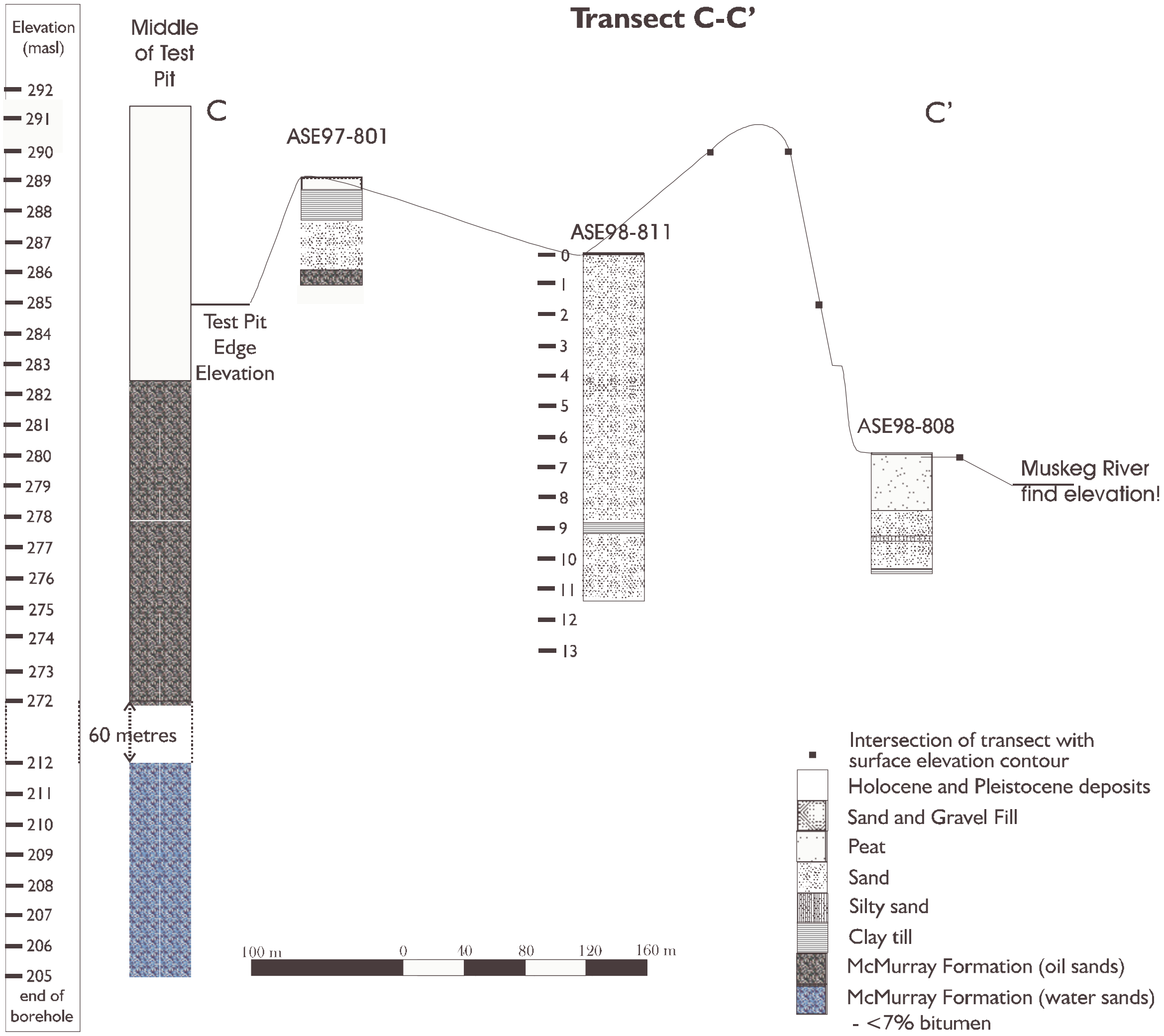


Figure 4.5: Geological cross-section of the Muskeg River Mine site showing the hydraulic connection between the McMurray Basal Aquifer and the surficial Holocene and Pleistocene deposits.

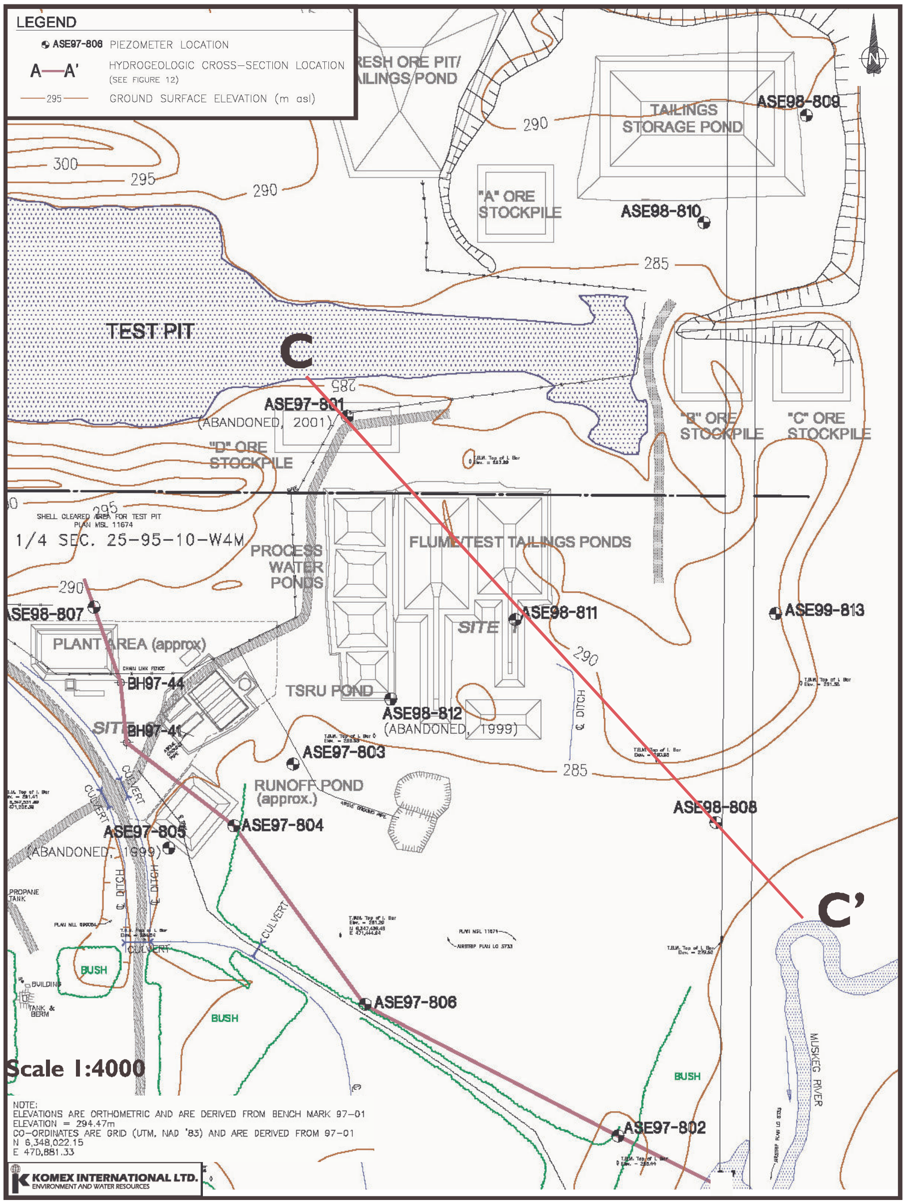


FIGURE 4.6: Topographic map of the Muskeg River Mine, Test Pit site (pers. comm., W. Stein, August 16, 2004).

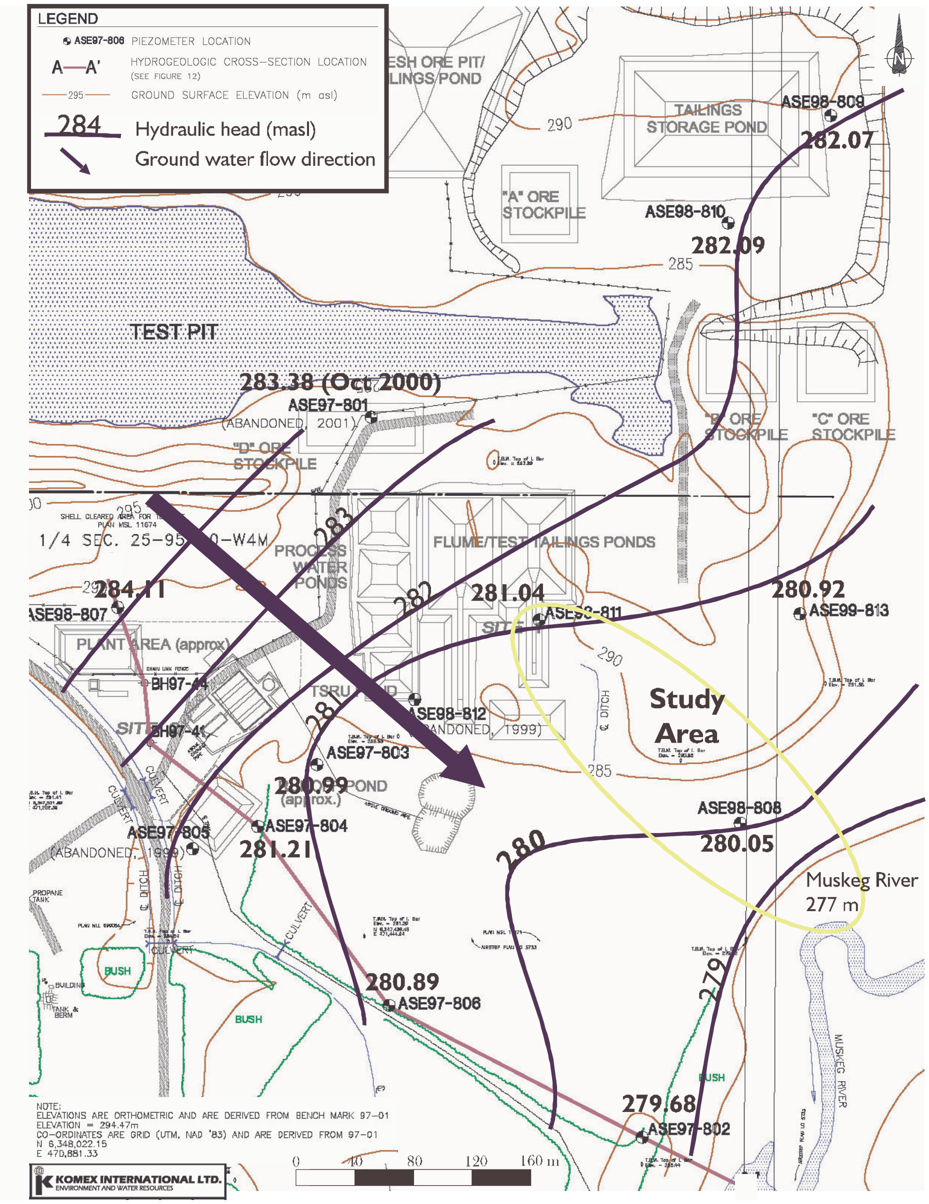


FIGURE 4.7: Water-table map of the surficial Quaternary sand aquifer (October to November 2002) (pers. comm., N. Easterbrook, August 16, 2004).

FIGURE 4.8: Steve Berg using a jackhammer to advance the Waterloo Profiler.

4.5 Methods

4.5.1 Sampling

Except for two pre-existing monitoring wells and the river, samples were taken with the Waterloo Profiler. The equipment required was minimal: a sampling manifold, peristaltic pump, flow-through cell, a jackhammer to advance the profiler and a floor jack to pull it out, as well as the profiler itself (Figure 4.8). The profiler was pre-assembled and field tested as per Appendix H, then decontaminated before the first sample and between each sampling point.

The sampling station was up-wind of any source of exhaust and wind blown contamination. A small bottomless tent similar to the kind used by telephone and hydro workers was set up with a heater to stop the water samples from freezing in the stainless steel sampling tubing.

The sampling equipment was decontaminated of both organic and inorganic contaminants (Appendix H). Deionized water (DIW) from the on-site Albian Sands laboratory was used for every sampling step. The equipment was washed with a non-phosphate detergent (Sparkleen®) and scrubbed with an inert brush. For internal mechanisms and tubing, three rinse volumes of the detergent solution was circulated through the equipment, after the entire profiling system has been assembled and bottles inserted in sampling manifold. Then, the entire system was rinsed with 4 rinse volumes of deionized water followed by 1-2 rinse volumes of dilute 1% hydrochloric acid (HCl). A low HCl concentration was used to prevent the removal of iron from the stainless steel tubing of the profiler. Finally, the tubing was flushed with 5 rinse volumes of DIW to remove the acid wash solution. The equipment was stored in an inert container or wrapped in clean plastic or aluminium foil for storage and transport. Excess groundwater and rinse water was poured out at some distance from the profile location. The 1% HCl solution was further diluted and either poured down a drain or in the field away from the profile location.

Since the profiler works best at depths of less than 6 m, areas of thick surficial sand deposits were avoided. The mechanical peristaltic operation of the pump is effective to depths of 8.5 m at sea level since it is limited by the suction lift limit. A line of profiler sampling locations through wells 98-11 and 98-8 was chosen, southeast of an artificial hill and parallel to the hypothesized flow path (Line B-B'). A second line (A-A') was taken perpendicular to the main line, near the Muskeg River (Figure 4.3). Vertical profiling was attempted at 8 different locations. Water samples were also collected from two previously installed piezometers (98-8 and 98-11), as well as from the Muskeg River. For safety reasons, sampling of the Muskeg River required a harness and rope held by someone on shore, as well as the surface water sampling equipment and an ice auger. The Test Pit was not sampled because of the addition of the process-affected water from the Pilot Plant.

We successfully collected groundwater samples at 7 of the 8 sites. Because of the shallow aquifer and the depth to the water table, as few as 1 or as many as 3 samples were collected at each location. At MR-02-GW-4, we tried to collect groundwater at 4 different locations at multiple depths (1, 1.5 and 2 m) on two different days, but were unsuccessful. For the location MR-02-GW-2, we could sample only one depth. We could not advance more than a meter below this depth before the geological material became too dense. Unfortunately, hydraulic conductivity for that meter of depth was too low to collect a water sample. Bituminous oil sand was found in the ports. The naphthenic acids, chloride and sodium at this point may be due to the Test Pit plume or may have been leached from the immediately underlying oil sand. Unfortunately, no signature is available for the oil sand.

Field parameters (dissolved oxygen, pH, temperature and electrical conductivity) were measured by probes in a flow-through cell. Low permeability thin-walled $^1/_8$ tubing was used leaving the sampling manifold to the flow-through cell to minimize diffusion of dissolved oxygen into the groundwater. Electrical conductivity greater than 100 μS/cm during pumping confirmed that the deionized water had been flushed out of the tubing. The high methane concentrations at MR-02-GW-5 support the idea that high dissolved oxygen concentrations are due to an air leak during measurements. Groundwater samples were collected using a peristaltic pump, since the hydraulic head was within 3 m of the surface. Sample bottles were under vacuum and inline with the pump to minimize contamination and volatilization.

Sampling is usually done in order of volatility but, in this case, the sampling was done in order of importance. The number of groundwater samples collected from each sampling point depended on sampling rate according to a prioritized list (Table 4.1). For example, if the pumping rate was very slow, only naphthenic acid and anion samples were collected. At one depth per location, additional groundwater (up to 1 L) was collected for detailed characterization of NAs.

Water samples were stored in a cooler with ice packs. The cooler was then closed firmly to keep the dust out and stored overnight in a warm building to make sure the water did not freeze.

Several quality assurance measures were taken. Duplicate samples were taken once for every ten samples submitted. One sample of the deionized water used in the rinse water was collected for analysis. An equipment blank was passed through the profiler and another through the probe's flow-through cell before the first sample was taken at each location. And finally, one total NA and one aromatic hydrocarbon field spike provided by the appropriate lab was run through the sampling equipment at the end of the trip; a second field spike was transferred to another bottle.

Chemical Parameter	Priority
Total naphthenic acids	1
Anions: $Cl^- + SO_4^{2-} + NO_3^- + NO_2^-$	1
Cations: Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{2+}, Mn^{2+}	2
Detailed characterization of naphthenic acids	2
Aromatic hydrocarbons (C_6 - C_{12})	2
Field dO_2, Electrical conductivity, Temperature, pH	3
Alkalinity (HCO_3^-, CO_3^{2-}, OH^-)+ lab pH + lab conductivity	4
Orthophosphorus	4
Methane	4

Table 4.1: List of chemical parameters collected during the November 2002 field trip to the Muskeg River Mine. The samples were collected in order of priority, depending on flow rate.

4.6 Results & Discussion

4.6.1 Identification of Groundwater from the Basal Aquifer

4.6.1.1 Conservative Tracer

The McMurray Basal Aquifer groundwater, the source of naphthenic acids in the Test Pit, is much higher in dissolved chloride and sodium than surficial aquifer groundwater. Chloride is a valuable indicator at Albian Sands since values increase from 35 mg/L outside the plume to a minimum of 259 mg/L inside the plume (Komex International Ltd, 2000). Therefore, any sample with dissolved chloride concentrations greater than 250 mg/L was considered to be influenced by the Test Pit plume. There may be some additinal chloride and sodium input from the underlying oil sand. The final classification is presented in Table 4.2.

4.6.1.2 Piper Diagrams

Four monitoring wells were installed at a distance of 5 to 10 km to the northwest and southwest of the Test Pit to provide baseline Basal Aquifer ground water quality data. The depth interval of the sand packs varied from 5 to 12 meters; no information was given on the screen length. The lithology was sand for all wells. The samples plot as alkaline, while the uncontaminated background groundwater is considered fresh.

Groundwater samples believed to be within the plume plot between the saline

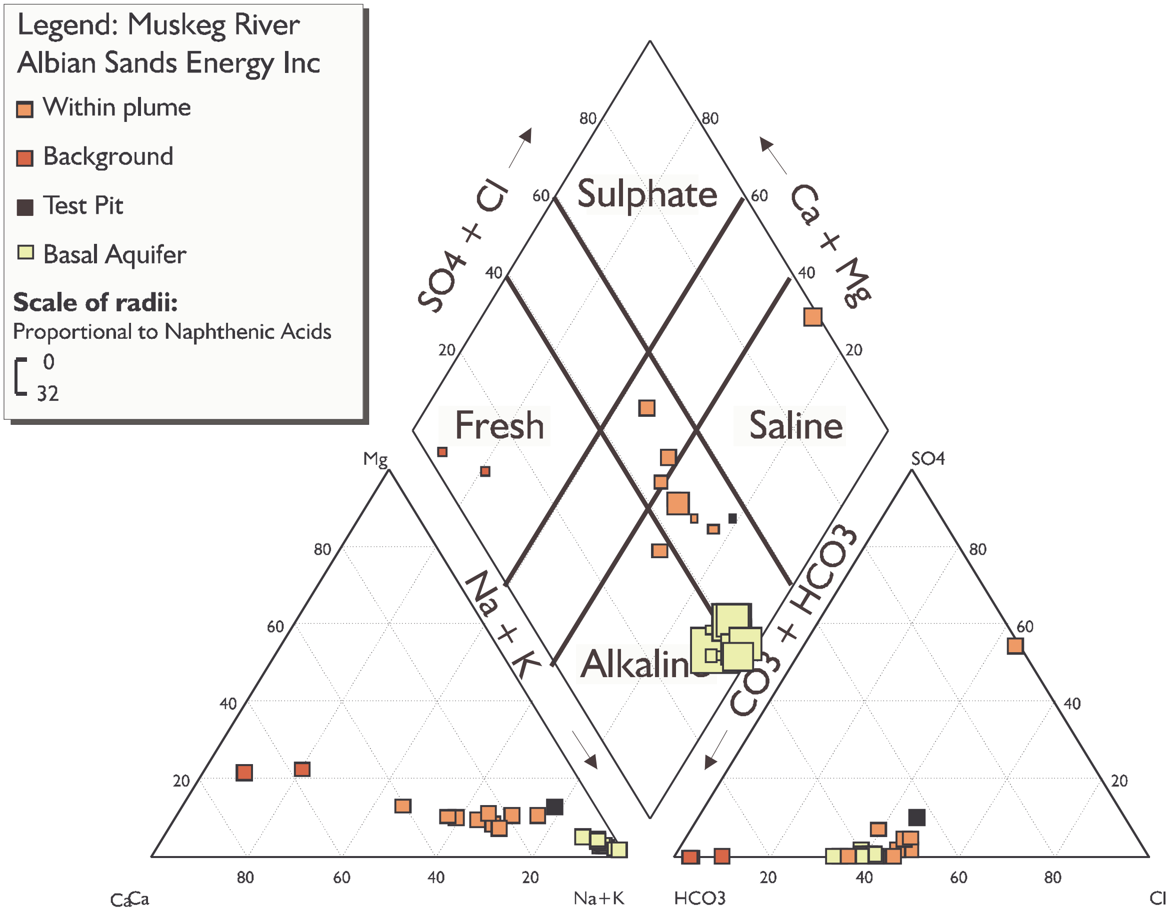
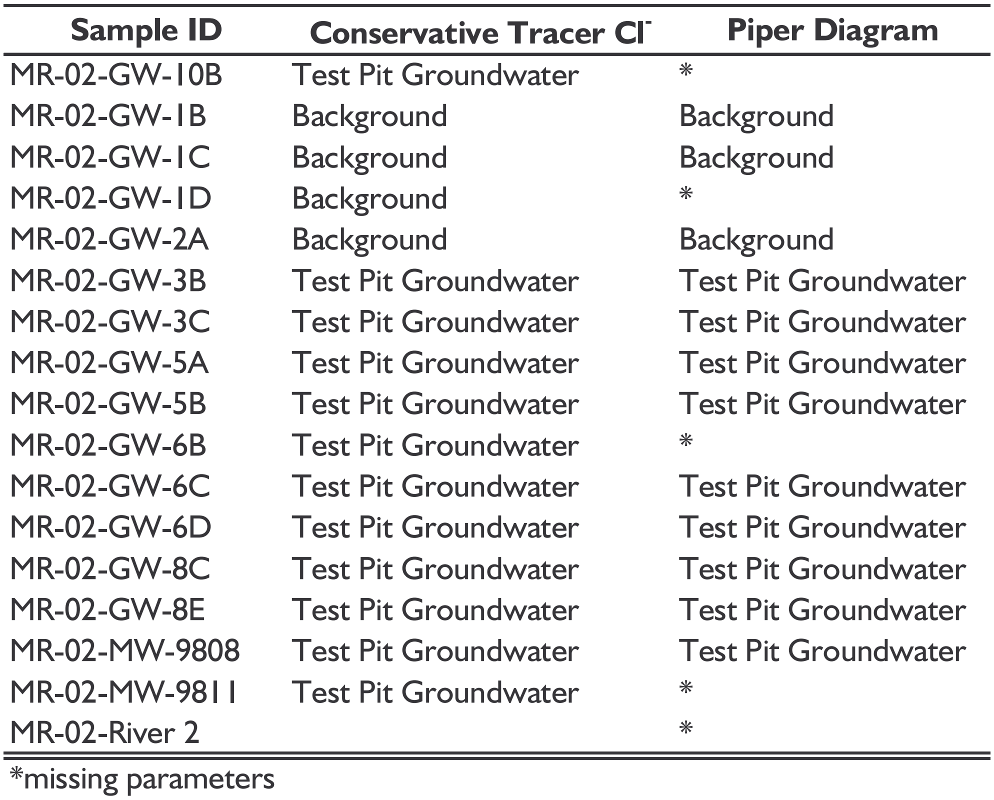


Figure 4.9: Hydrogeological facies at the Muskeg River Mine.

and fresh hydrogeochemical facies, probably indicating mixing (Figure 4.9). Historical chemical data is available for the Test Pit and 1997 data are plotted. The two samples outside the plume plot as a Ca+Mg+HCO_3 water type while the majority of samples within the plume, including the Test Pit or source sample, plot either as Na-HCO_3-Cl or Na–Ca-HCO_3-Cl. The samples suspected of low NAs due to biodegradation plot with the other samples within the plume and the Test Pit sample (discussed on page 93).

The one exception is the deepest sample at profile MR-02-GW-6; it plots as Na-Ca-SO_4-Cl since it was the only sample with substantial sulfate. The charge balance error was 5.8%; it is probable that this is not an analytical error.



Sample ID	Conservative Tracer Cl^-	Piper Diagram
MR-02-GW-10B	Test Pit Groundwater	*
MR-02-GW-1B	Background	Background
MR-02-GW-1C	Background	Background
MR-02-GW-1D	Background	*
MR-02-GW-2A	Background	Background
MR-02-GW-3B	Test Pit Groundwater	Test Pit Groundwater
MR-02-GW-3C	Test Pit Groundwater	Test Pit Groundwater
MR-02-GW-5A	Test Pit Groundwater	Test Pit Groundwater
MR-02-GW-5B	Test Pit Groundwater	Test Pit Groundwater
MR-02-GW-6B	Test Pit Groundwater	*
MR-02-GW-6C	Test Pit Groundwater	Test Pit Groundwater
MR-02-GW-6D	Test Pit Groundwater	Test Pit Groundwater
MR-02-GW-8C	Test Pit Groundwater	Test Pit Groundwater
MR-02-GW-8E	Test Pit Groundwater	Test Pit Groundwater
MR-02-MW-9808	Test Pit Groundwater	Test Pit Groundwater
MR-02-MW-9811	Test Pit Groundwater	*
MR-02-River 2		*

*missing parameters

Table 4.2: Summary of water classification.

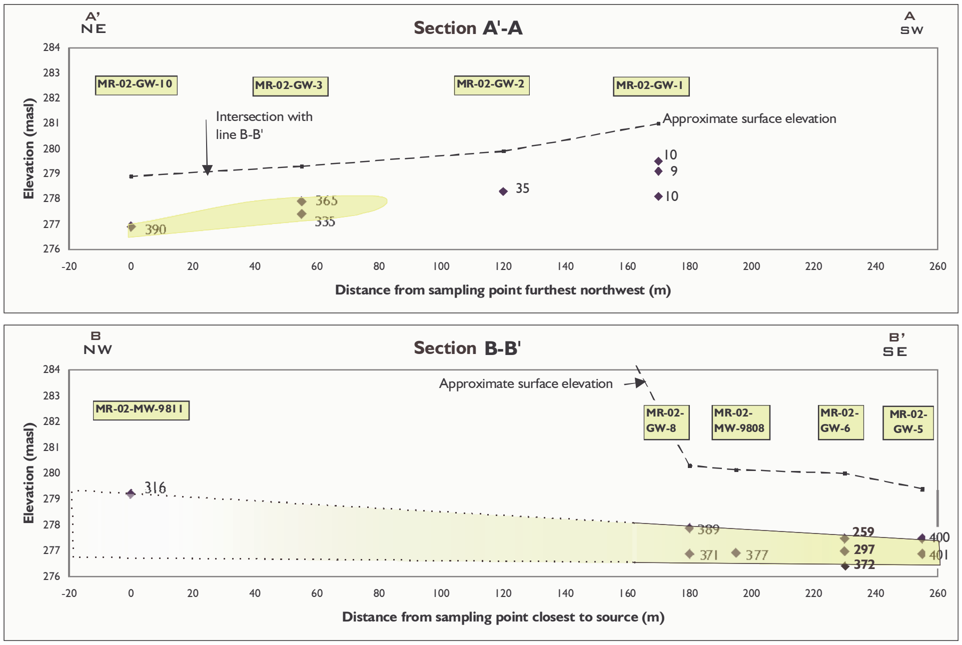


FIGURE 4.10: Dissolved chloride concentrations (mg/L) along two sections near the Muskeg River. Because background chloride concentrations are <50 mg/L, concentrations >250 mg/L are used to infer groundwater impacted by water from the Test Pit.

4.6.1.3 Section A-A'

This profiling line starts outside the plume and meets with B-B' section within the area influenced by the mixture of Basal Aquifer groundwater, precipitation and runoff from the Test Pit (Figure 4.3). The contrast in chloride concentrations between the inside and outside of the plume is dramatic (Figure 4.10).

4.6.1.4 Section B-B'

Section B-B' is believed to be roughly parallel to a flow line originating from the Test Pit. Chloride concentrations are high for all samples within section B-B' and it is probable that the Test Pit plume has reached the Muskeg River. Naphthenic acid concentrations vary both horizontally and vertically (Figure 4.11). Along line B-B', concentrations are high in piezometer 98-11 (15 mg/L) and decrease until they are <10 mg/L at distances approximately 10 m from the Muskeg River.

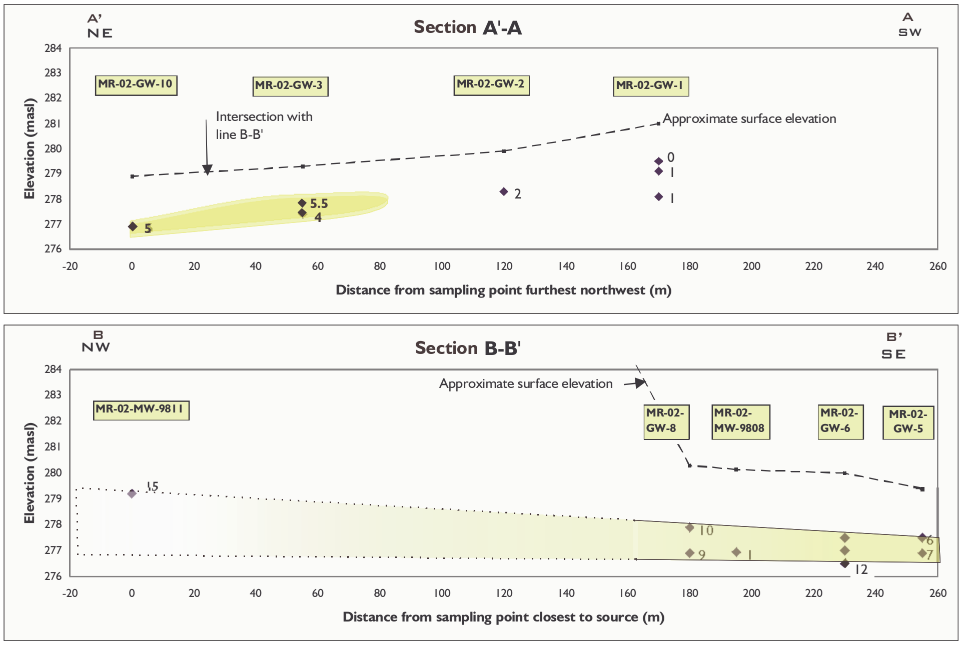


FIGURE 4.11: Naphthenic acids (mg/L) along two sections near the Muskeg River. Shaded areas indicate groundwater inferred to be impacted by water from the Test Pit.

4.6.2 Estimated Naphthenic Acid Concentrations

In order to predict the expected NA concentration based on simple dispersion and dilution during groundwater flow, a trendline was fit to naphthenic acids and chloride data as well as naphthenic acids and sodium data. Sodium and chloride are likely conservative and should provide an estimate of dispersive dilution. The fit was good for sodium with an R^2-value of 0.9103 (Figure 4.12) while chloride had an R^2-value of 0.7986 (not shown). The predicted total naphthenic acids concentration was calculated using the correlation

$$\text{Naphthenic Acids (mg/L)} = 0.0246 \times Na^{+}(mg/L) + 0.6941 \qquad \text{R}^2\text{=0.9103}$$

It was possible to estimate the expected total naphthenic acid with some confidence (Table 4.3 and Figure 4.12) and, using these predictions as a starting point, determine which samples may have concentrations lower than expected.

This correlation assumes a one dimensional flow field, no retardation or attenuation and a single source. Only samples collected with the Waterloo Profiler were included in the correlation and one sampling location near the river (MR-02-GW-3) was excluded since the detailed naphthenic acid analysis indicated that biodegradation may have occurred (see page 93). The river was excluded since provenance was unknown and the two wells were excluded since they were not point measurements i.e. screen lengths of 0.71 m and 1.11 m.

An uncertainty estimate for the equation was calculated as the residual standard deviation (RSD) between the measured and predicted NA concentration. Furthermore, five serial samples were sent to two different laboratories for analysis. The RSD of each set of two measured concentrations ranged from 6% to 34 %, with an average of 16%. Therefore any predicted NA concentration with RSD less than 16% was considered to be as precise as the measurement error. Any change in measured concentration that agrees with the predicted concentration within the range of this uncertainty may be attributed exclusively to dispersive dilution.

The majority of the samples have a RSD of less than 16%. It is assumed that normal analytical variation and differences in source NA or Na^+ concentration is responsible for any differences in concentration between the measured and predicted NA values. The largest RSD occurs for MR-02-GW-1B, but only because NA concentration is less than 1 mg/L (MDL). The two wells also have a large error, probably for the same reason they were excluded from the correlation in the first place. MR-02-GW-8E has RSD of 19% and a measured NA greater than the predicted value. There is no explanation for this. That leaves three samples at the end of section B-B' with predicted concentrations higher than measured and RSD>16%: MR-02-GW-5B, MR-02-GW-3B and MR-02-GW-3C. These three samples may have undergone some process, in addition to dispersive dilution, which decreased their NA concentration.

Figure 4.13 shows the plot of the calculated naphthenic acids versus the measured naphthenic acids concentration. Most of the samples fall on a 1 to 1 line, within error. The error bars for MR-02-GW-5B, MR-02-GW-3B and MR-02-GW-3C fall outside the one to one line and some form of natural attenuation other than dilution is suspected. Two samples, MR-02-GW-8E and the well MR-02-MW-9811 fall below the one to one line; the reason is unknown.

There is little change in chloride or sodium concentration along B-B' (Figures 4.10 and 4.14). Perhaps the lack of apparent dilution along the flow path is due to the fact that the front of the plume has passed and the transect was taken inside the core of a plume. If the source concentration remains constant, the core will show no dispersive dilution after the dispersed front has passed. The area is underlain by oil

	NA	Cl^-	Na^+	Calculated		Included in Correlation
Sample Name	(mg/L)	(mg/L)	(mg/L)	NA (mg/L)	RSD	
MR-02-GW-6D	11	372	422	11.1	0%	x
MR-02-GW-1D	1	9.9	13.5	1.0	2%	X
MR-02-GW-1C	1	9	14.3	1.0	3%	X
MR-02-GW-6B	8.2	259	288	7.8	4%	X
MR-02-GW-10B	5	389	193	5.4	6%	X
MR-02-GW-2A	2	34.7	43.8	1.8	9%	X
MR-02-GW-8C	10	389	329	8.8	9%	x
MR-02-GW-6C	9	297	392	10.3	10%	X
MR-02-GW-5A	9.8	400	318	8.5	10%	X
MR-02-GW-8E	9	371	249	6.8	19%	x
MR-02-GW-5B	7	401	349	9.3	20%	X
MR-02-GW-3B	5.5	365	327	8.7	32%	
MR-02-MW-9811	15	316	345	9.2	34%	
MR-02-River 2	2	5	14	1.0	45%	
MR-02-GW-3C	4	336	333	8.9	54%	
MR-02-MW-9808	1	377	303	8.1	111%	
MR-02-GW-1B	0	10	13.6	1.0	141%	X

TABLE 4.3: The predicted naphthenic acids concentrations are the product of the correlation of measured total naphthenic acids (NA) versus sodium (Na+). Table is sorted by residual standard deviation (RSD).

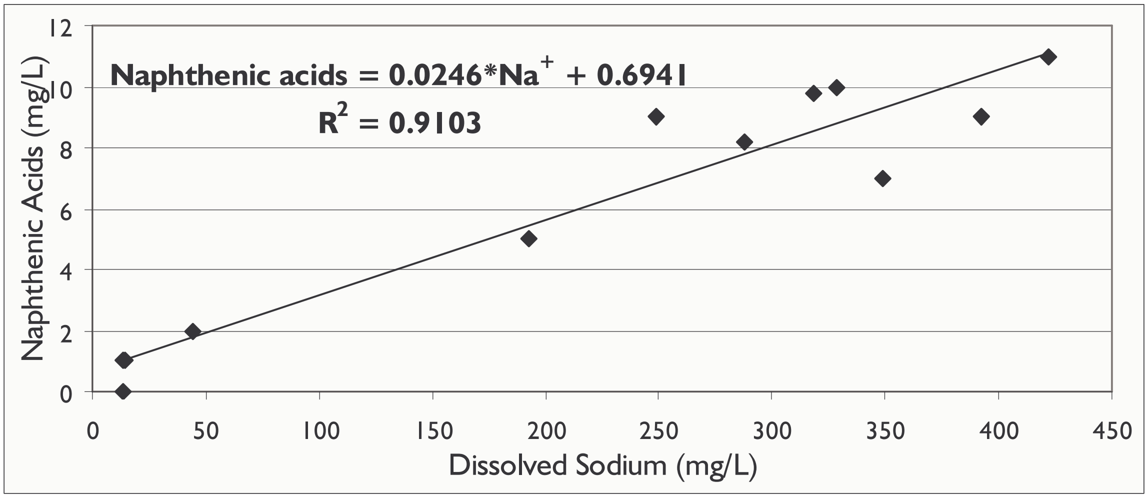


FIGURE 4.12: Correlation line for sodium versus naphthenic acids at the Muskeg River Mine.

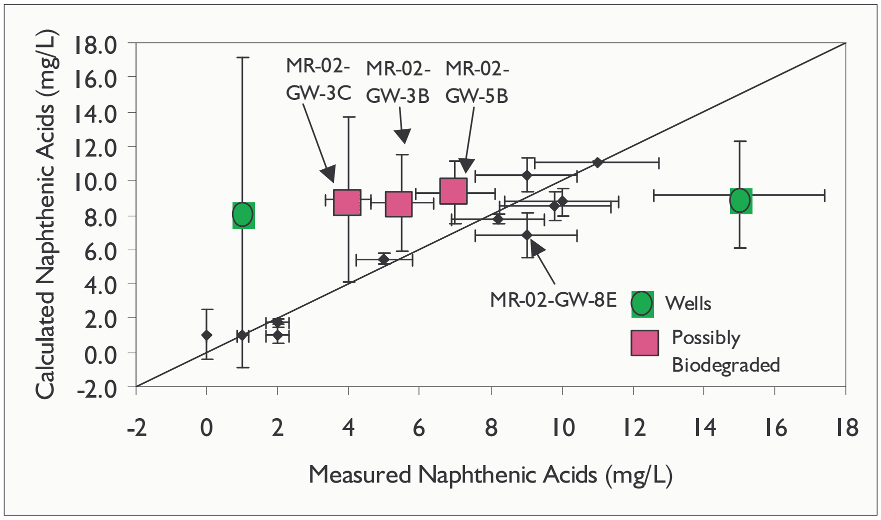


FIGURE 4.13: The measured naphthenic acids concentrations near the Muskeg River plotted against the predicted concentrations. Vertical error bars are 16% residual standard deviation while the horizontal error bars are one residual standard deviation.

sand which has low hydraulic conductivity and would inhibit upflow. The fact that naphthenic acid concentrations decrease with increasing distance while the chloride and sodium concentrations do not supports the conclusion that some process other than dispersive dilution is causing naphthenic acid attenuation.

4.6.3 Naphthenic Acids "Signature"

Samples were analyzed by the gas chromatograph-mass spectrometer method which allows a semi-quantitative characterization of the naphthenic acids present in a sample (St John et al., 1998). The relative proportions are usually shown in a graphical format after Holowenko *et al.* (2002). The bars represent the percentage of NAs in the mixture that can account for a given carbon number of a given Z family (a specific m/z value). The sum of all bars equals 100% and so the relative proportion of homologues is displayed (Holowenko *et al.*, 2002). The 3D graphs illustrate the distinct signatures that can be seen when naphthenic acids from different groundwater samples are analyzed (Figure 4.15).

Over the course of the microcosms, aerobic biodegradation decreased the relative proportion of Group 1 (carbon number less than 15, any Z number) homologues,

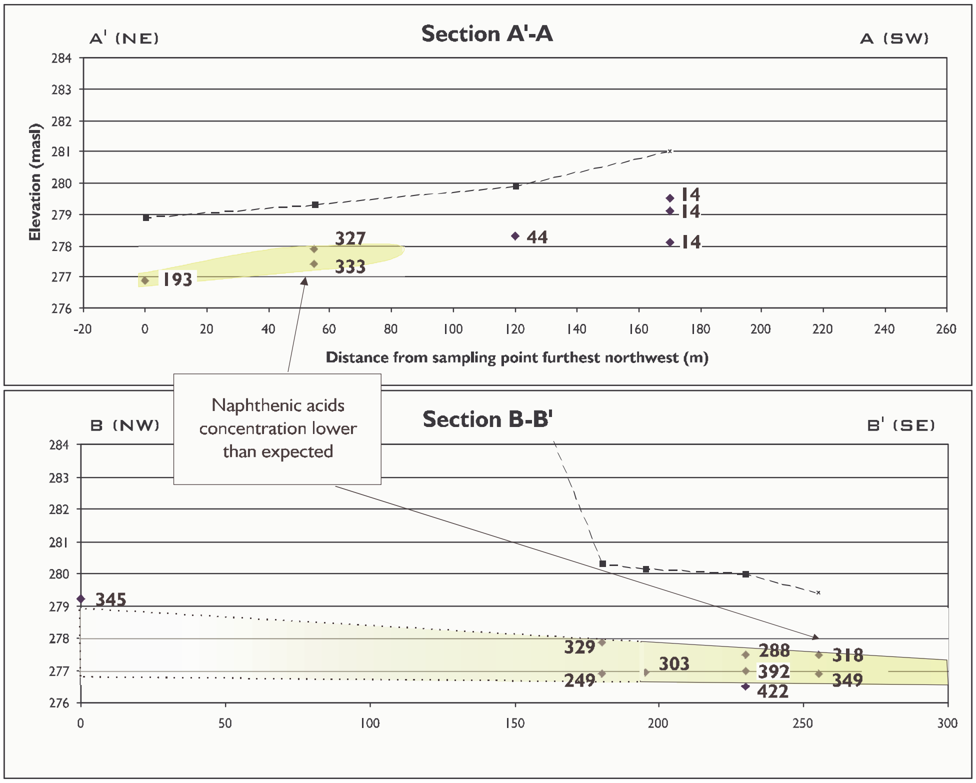
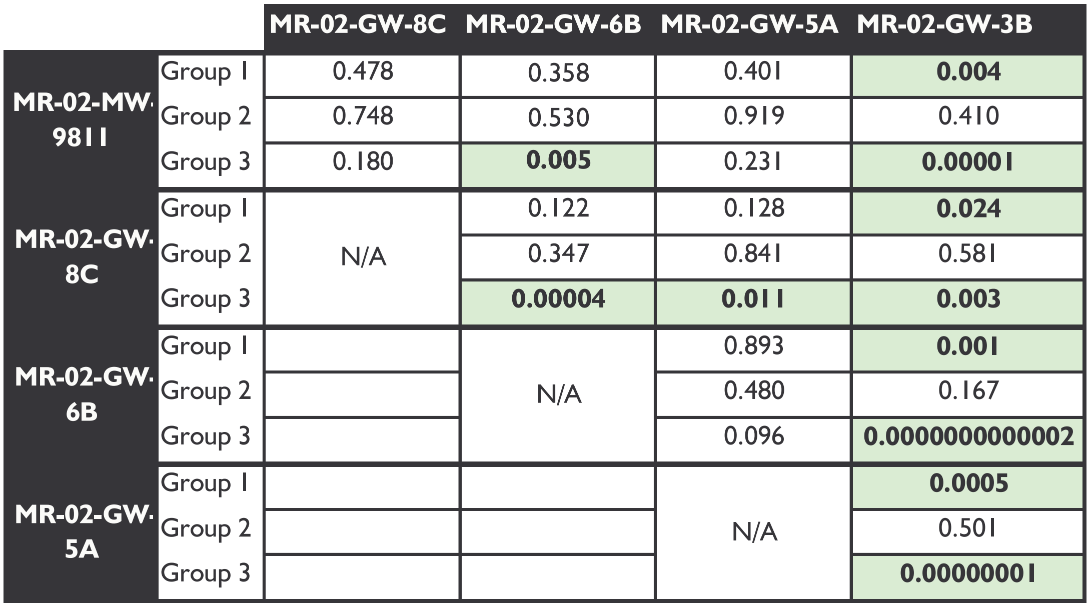


FIGURE 4.14: Dissolved sodium concentrations (mg/L) along two sections near the Muskeg River. Shaded areas indicate areas suspected of being impacted by the plume from the Test Pit.



		MR-02-GW-8C	MR-02-GW-6B	MR-02-GW-5A	MR-02-GW-3B
MR-02-MW-9811	Group 1	0.478	0.358	0.401	**0.004**
	Group 2	0.748	0.530	0.919	0.410
	Group 3	0.180	**0.005**	0.231	**0.00001**
MR-02-GW-8C	Group 1	N/A	0.122	0.128	**0.024**
	Group 2		0.347	0.841	0.581
	Group 3		**0.00004**	**0.011**	**0.003**
MR-02-GW-6B	Group 1		N/A	0.893	**0.001**
	Group 2			0.480	0.167
	Group 3			0.096	**0.0000000000002**
MR-02-GW-5A	Group 1			N/A	**0.0005**
	Group 2				0.501
	Group 3				**0.00000001**

TABLE 4.4: Results of the t-test analysis of the naphthenic acids extracted and derivatized from groundwater samples near the Muskeg River. Group 1 is composed of homologues with carbon number 5 to 13, Group 2 contains carbon numbers 14 to 21 and Group 3 contains carbon number 22 to C33. The numbers in bold and shaded boxes are considered to be significantly different ($P<0.05$).

while Group 2 (carbon number 15 to 21) remained unchanged. A visual examination of the five samples shows that change in the "signature" between the beginning and the end of transect B-B' is consistent with aerobic biodegradation . There has been a marked decrease in the relative proportion of homologues with carbon numbers less than 15 (Figure 4.16). The Z=-4 group dominates all graphs. MR-02-GW-6B has a relative concentration in Z=-6, C12 homologue comparable to the Z=-4 family.

A t-test using arcsine-transformed data can be used to compare groups in samples (see page 6 for details). The different homologues are grouped as follows: Group 1 contains carbon number 5-14; Group 2 numbers 15-21; and Group 3 numbers 22-33. If $P<0.05$, then we can conclude that there is a significant difference between the two groups in two different samples being compared. The results of a t-test analysis of the groundwater samples are presented in a matrix in Table 4.4.

Group 1 is significantly different only between the sample nearest the river, MR-02-GW-3B, and all other samples, confirming the visual observation (Figure 4.15). The percentage of molecules in Group 1 decreases while the relative proportion of

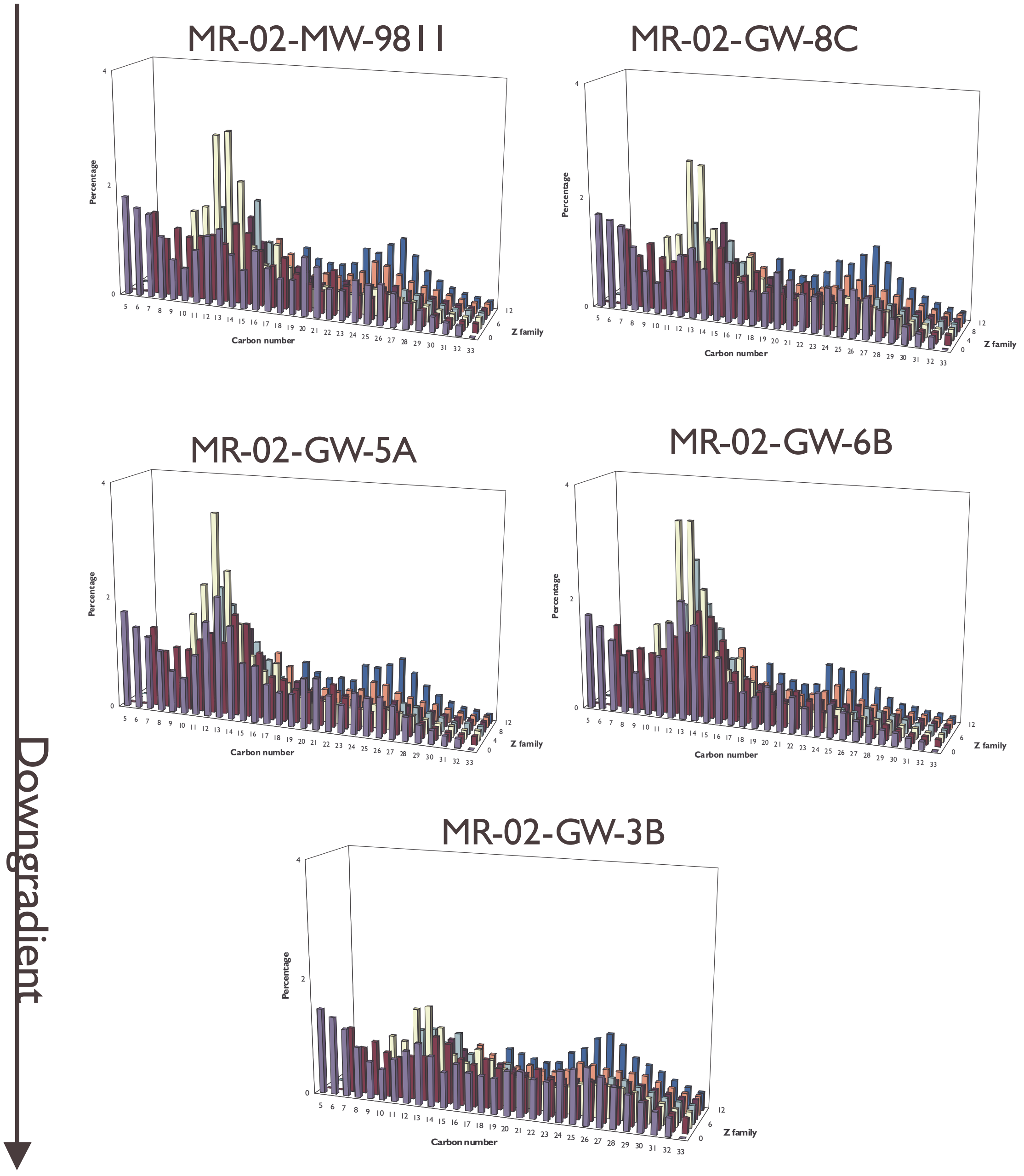


Figure 4.15: The distribution of carbon numbers and Z families of naphthenic acids in the complex NAs mixtures extracted and derivatized from the groundwater samples collected next to the Muskeg River.

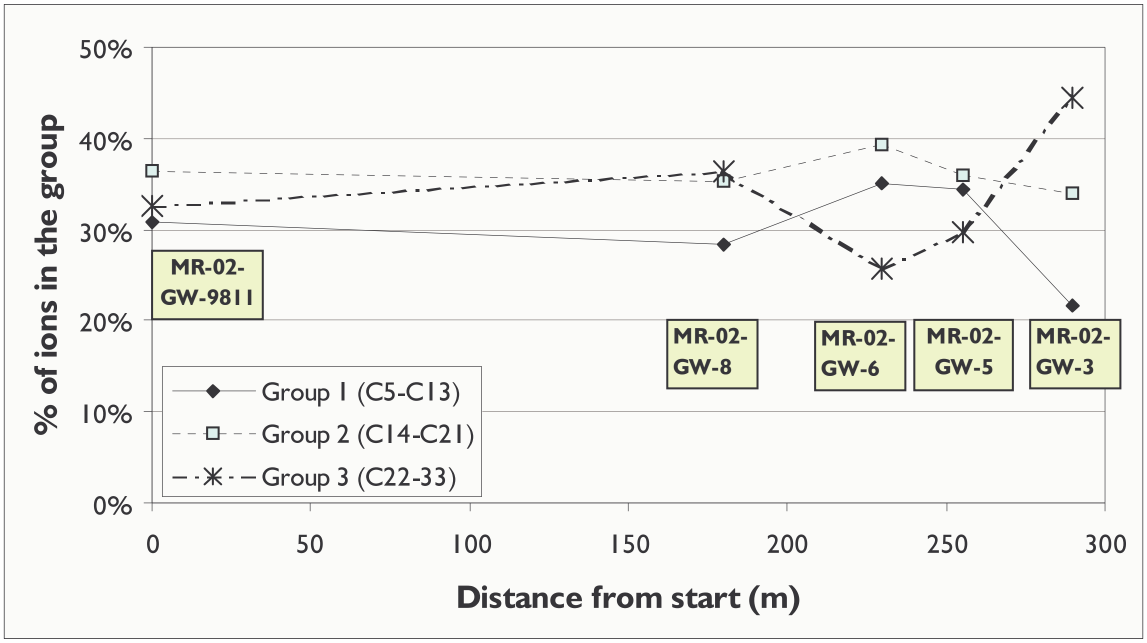


FIGURE 4.16: Changes in the relative abundances of NAs recovered from groundwater samples near the Muskeg River. The proportions of ions were summed in groups according to carbon numbers.

homologues with C≥22 in Group 3 increases from MR-02-GW-6 to MR-02-GW-3 (Figure 4.16). The increase in the relative concentrations in the C≥22 group is probably not due to production of NAs but to a decrease in the relative proportion of the low molecular weight homologues in Group 1. Group 2 percentages do not change significantly. This pattern — decrease in Group 1, no change in Group 2, increase in Group 3 — was observed in the lab for aerobic biodegradation (Figure 2.8). The predicted NA concentration is higher than the measured concentration for MR-02-GW-5 and MR-02-GW-3. The changing NA signature provides further evidence for aerobic biodegradation as an attenuation mechanism.

At the concentrations measured, sorption is probably minimal. As well, sorption does not change the "signature" so that the changes in relative proportion can be attributed solely to aerobic biodegradation.

It has already been noted that MR-02-GW-8E and piezometer 98-11 have, for reasons unknown, a higher measured NA concentration than predicted using a correlation with the conservative tracer sodium. MR-02-GW-8C and 98-11 also have a lower relative proportion of Group 1 than the two sampling points downgradient from them. However, the conceptual model described above is still valid since MR-02-GW-3 still has a lower percentage of Group 1. There is no documented biodegradation or sorption mechanism which can account for an increase in Group 1. It is possible that the true process-affected water from the operation of the Pilot Plant has travelled further than expected. As well, in theory, sorption processes could be greater for high molecular weight NAs since it may be expected that the hydrophobic moeity of these ampiphilic molecules would be larger. Since the stock NA mix used in the batch equilibration was poor in Group 3 homologues, there is no empirical evidence.

4.6.4 Oxidation Reduction Conditions

Biodegradation will occur only under specific oxidation reduction (redox) conditions. Laboratory studies have established the aerobic biodegradation can decrease NA concentrations by at least 60% over a period of 18 weeks. While the anaerobic microcosms showed no measurable decrease in NAs over a period of 6 months, methanogenesis driven by certain NA surrogates is possible under the proper laboratory conditions (Holowenko et al., 2001).

Various criteria have been used in the literature to assign a predominant terminal electron accepting process affecting the geochemistry of a groundwater sample. Plumes studied by Bjerg *et al.* (1995), Lyngkilde and Christensen (1992) and Holowenko *et al.* (2000) were used to construct a table (Table 4.5) of criteria. In order to facilitate discussion, Table 4.6 shows only the concentrations of the redox indicators available for the Muskeg River Mine, Pilot Plant Test Pit plume which are listed in Table 4.5 as indicative of a particular redox condition.

The hydrochemical redox markers (Table 4.6) indicate contradictory redox conditions since some samples had measurable oxygen and iron at the same time, which is not probable. One sample, MR-02-GW-6C had dissolved oxygen, manganese (II), iron (II), sulfate less than 20 mg/L and methane (Figure 4.17 and 4.18). Since methane is rapidly oxidized by aerobes, DO concentrations are probably caused by a leak in the water collection system; aquifer concentrations are probably lower than measured. Considerable small scale redox heterogeneity is present in the aquifer. Because of this, the indicators of the most reduced condition will be accepted. Except for the deepest sample in the vertical profile MR-02-GW-8E, which is considered aerobic, samples which have data can be classified as highly reduced, either sulfate reducing or methanogenic. This is true both inside and outside the plume.

Samples with measurable methane were found inside and outside the plume (Figure 4.17). Methane is a common constituent of anoxic groundwater and has two origins: biogenic or thermocatalytic (Apello & Postma, 1999). Thermocatalytic methane is often related to oil formation, and the aquifer at the beginning of A-A' was underlain by bituminous sands. However, little or no propene, propane, ethane or ethene was detected, and the lack of such thermogenetic hydrocarbons suggests a biogenic origin for the methane and methanogenic activity at or upgradient of the sampling point. Along B-B', methane concentrations are higher near the top of the aquifer and may reflect a source related to decay of vegetation in the fen.

Looking at cross-sections of B-B', it appears as if methane concentrations are increasing as NA concentrations are decreasing. The fours samples suspected of biodegradation were probably in methanogenic or sulfate reducing environments (Figure 4.19). Methane was not always present in measurable quantities (0 to 2.4 mg/L). While there is no evidence that NAs degrade under methanogenic conditions, the current redox status for the samples in which some NA biodegradation is suspected is probably methanogenic, at the very least sulfate-reducing.

There is evidence of aerobic biodegradation and there is a trend of increasing

Parameter	Aerobic	Nitrate reducing	Iron reducing	Sulfate reducing	Methanogenic
DO	>1	<1	<1	<1	<1
NO_3	-----------	<0.2	<0.2	<0.2	<0.2
NO_2	<0.1	>0.1	<0.1	<0.1	<0.1
Mn	<0.2	<0.2	>0.2	>0.2	>0.2
Fe	<1.5	<1.5	>1.5	>1.5	>1.5
SO_4	-----------	-----------	-----------	decrease	>0, <20
CH_4	<1	<1	<1	<1	>1

Table 4.5: Criteria used for assigning redox conditions to groundwater samples, based on papers by Bjerg et al. (1995), Lyngkilde and Christensen (1992) and Holowenko et al. (2000). All values are in mg/L.

methane with decreasing NA concentration. It is not possible to determine if NA concentrations decreased due to aerobic degradation which pushed the system into reducing conditions or if NA concentrations decreased due to methanogenic activity.

4.7 Conclusion

The purpose of performing vertical and horizontal groundwater profiling along the plume was to supply field data to determine if the naphthenic acids (NA) front coincided with the conservative chloride and sodium front, or was attenuated due to physical or biological processes. Of the four attenuation processes which may have affected NA concentrations — dispersive dilution, sorption, methanogenesis and aerobic biodegradation, the only two processes which may have had a measurable effect on NA concentration were dispersive dilution and aerobic biodegradation.

Dispersive dilution is a physical process which would act upon both NAs and conservative tracers. It is probable that the majority of the natural attenuation occurring at the Muskeg River Mine site is due to dispersive dilution. Three downgradient samples near the river show a decrease in NA concentrations greater than estimated by dispersive dilution: MR-02-GW-5B, MR-02-GW-3B and MR-02-GW-3C.

The results of batch equilibration tests showed that sorption in the laboratory produced no gross change in the relative proportion of NA homologues and therefore had no "signature" to identify it in the field. Since the points with low NA have a change in the signature, sorption is probably not the responsible process. The

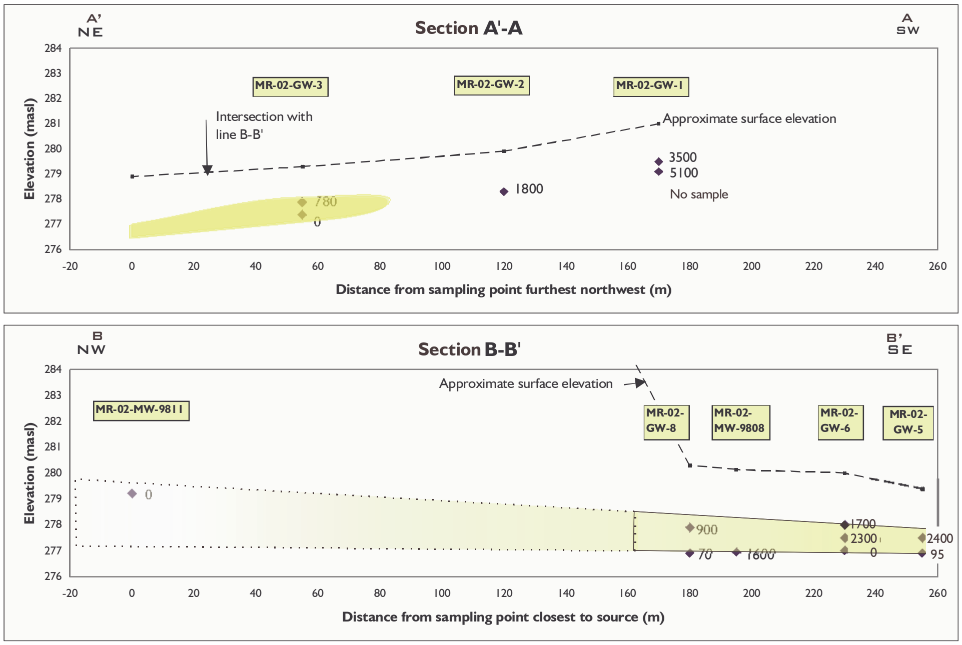


FIGURE 4.17: Dissolved methane concentrations (ug/L) along two sections near the Muskeg River. Shaded areas indicate groundwater inferred to be impacted by water from the Test Pit based on chloride concentrations

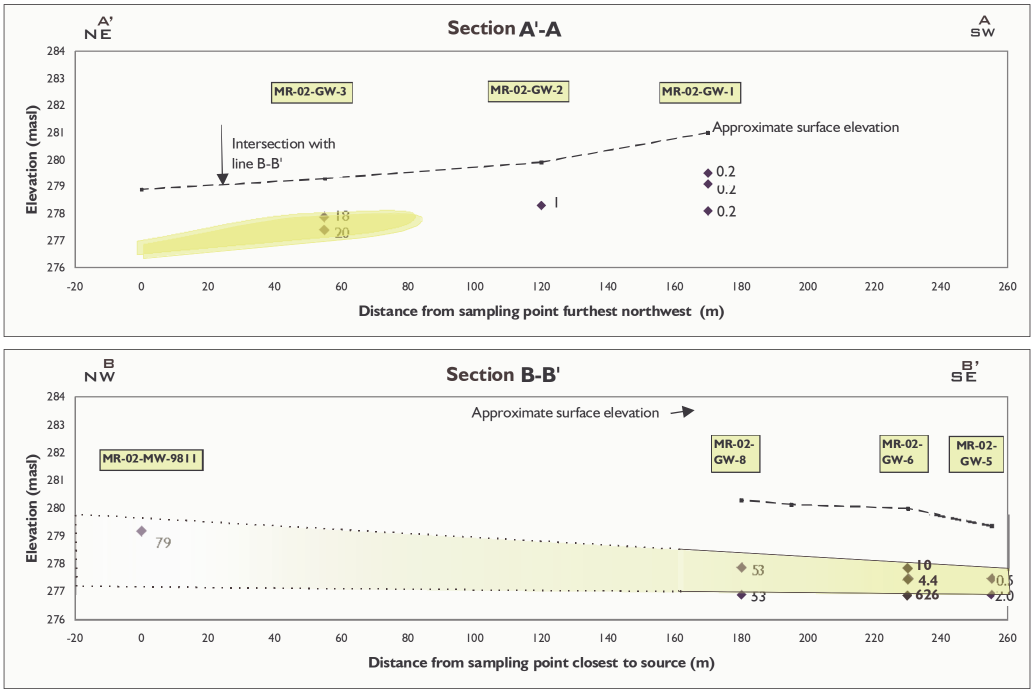


FIGURE 4.18: Dissolved sulphate concentrations (mg/L) along two sections near the Muskeg River. Shaded areas indicate groundwater inferred to be impacted by water from the Tes

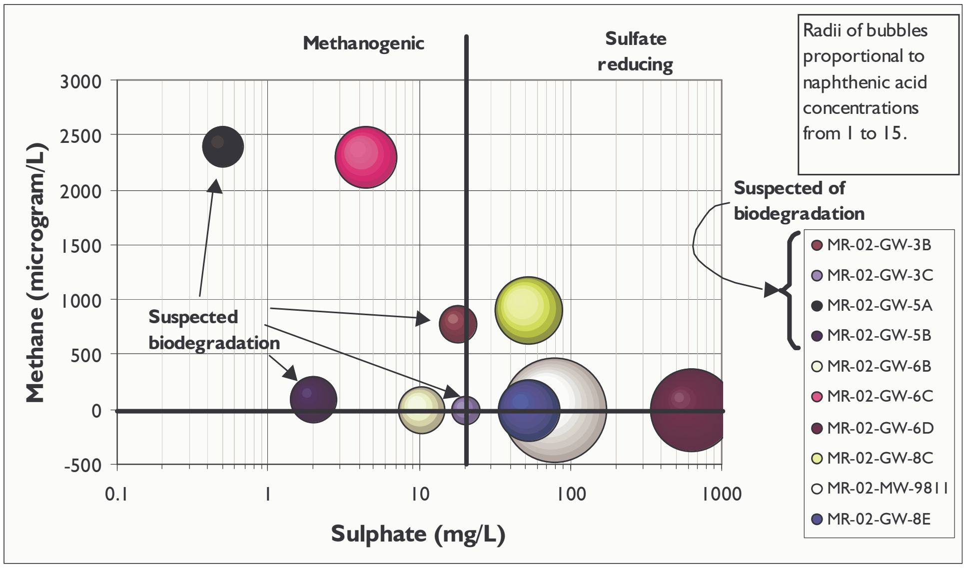


FIGURE 4.19: Relationship between sulphate, methane and naphthenic acids in groundwater impacted by saline, high NA water, Muskeg River Mine.

Sample Name	DO	NO3,	Mn	Fe	SO4	CH4
MR-02-GW-1B	2		0.2		≤20	**3**
MR-02-GW-1C	1				≤20	**5**
MR-02-GW-1D	1		0.2		**≤20**	ns
MR-02-GW-2A	3		0.2		≤20	**2**
MR-02-GW-3B	1			*0.7*	**≤20**	
MR-02-GW-3C				*1.0*	**≤20**	
MR-02-GW-5A	10		0.2		≤20	**2**
MR-02-GW-5B	9				**≤20**	
MR-02-GW-6B	7		0.2	2.4	≤20	**2**
MR-02-GW-6C	1		0.2	*0.6*	≤20	**2**
MR-02-GW-6D			0.2	1.7	626	
MR-02-GW-8C					53	1
MR-02-GW-8E	**3**		ns	ns	53	
MR-02-GW-10B	ns		0.3		ns	ns
MR-02-MW-9808	ns		ns	ns	ns	**2**
MR-02-MW-9811	ns		1.4		79	

ns = no sample

Table 4.6: Values for the groundwater samples which fit the criteria for assigning a redox status based on hydrochemical data. Numbers in bold are the most reduced indicator available for that samples. The data in grey do not fit the criteria but may be considered high. All values given in mg/L.

good correlation between the conservative tracer sodium and the NA concentration in samples which show no change in signature also suggests that no sorption occurred. Finally, sorption of NAs follows the behaviour of many surfactants: sorption increases as solute concentration increases. At the low NA concentrations found within the Muskeg River Mine plume, sorption is not expected to play a major role in the retardation of NAs.

There is a potential for NA biodegradation under methanogenic conditions. However, even though methane was present, no reduction in NA concentrations could be linked to methanogenesis in the laboratory microcosms. Even though the lowest NA concentrations at the Muskeg River Mine occurred in the methanogenic redox zone, not all samples believed to have undergone biodegradation had measurable methane concentrations. If methanogenesis using NAs as a substrate does occur, it is likely not dominant nor significant.

T-test results of the distribution of 156 NA homologues (Clemente et al., 2003) determined that MR-02-GW-03B, the sample at the end of line B-B' was significantly different from the other samples along B-B' in both Group 1 and Group 3. The relative proportion of low molecular weight homologues in Group 1 decreased, the same "signature" seen in the lab with aerobic biodegradation.

Laboratory evidence shows that aerobic biodegradation may occur using aquifer material and groundwater. Evidence of degradation has been sought in the lab and has been confirmed only for aerobic conditions. The change in naphthenic acids composition found in MR-02-GW-3B, the decrease in Group 1 relative proportions, along with a general decrease in naphthenic acids concentration unaccompanied by a decrease in chloride concentration, all provide evidence that the naphthenic acids are naturally attenuated by biodegradation, most likely under aerobic conditions.

Chapter 5

Southwest Aquifer, Pond 2/3

5.1 Introduction

The process-affected water from the Suncor Energy Inc. (Suncor) holding Pond 2/3 has migrated into a semi-confined anaerobic aquifer, probably from dewatering of Dyke 2W. In addition to pre-existing piezometers, a network of piezometers at two different depths was installed along a hypothesized flow path. Vertical and horizontal profiling was performed to study the heterogeneity of the process-affected water plume by measuring not only for the organic contaminant of interest, but also other chemicals or stable isotopes which may be considered to act as conservative tracers or indicators of groundwater conditions. The purpose is to determine if the naphthenic acids front coincided with the conservative chloride or stable isotope front, or was attenuated due to physical or biological processes.

5.2 Location and Physiography

Suncor is located in northern Alberta (Figure 4.1), about 40 km north of the town of Fort McMurray (Figure 4.2 and 5.1). Fee Lot 2 is located on the west side of the Athabasca River. The study site (Figure 5.2) is covered with dense boreal forest and muskeg, except for a band parallel to Ruth Lake Channel where a slight topographic high has led to drier conditions and a forest of deciduous trees. There is a natural wetland beside Pond 2/3 that receives groundwater and dyke seepage discharge.

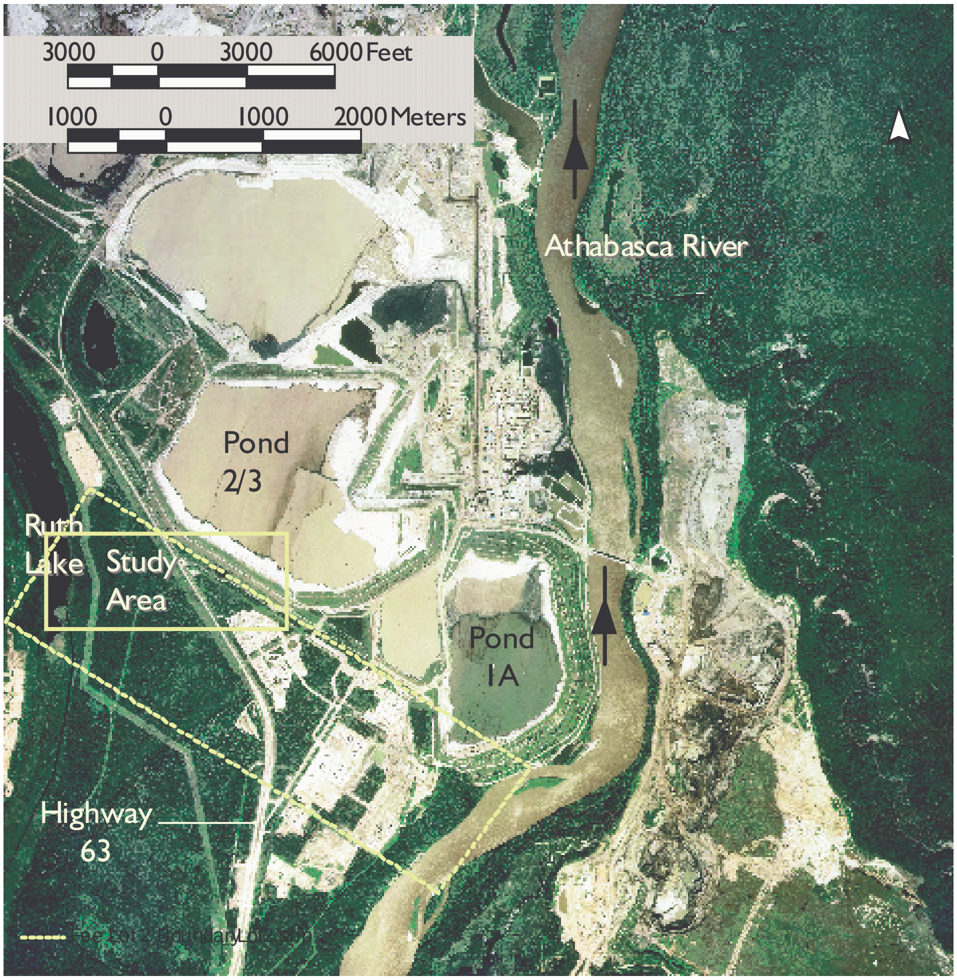


FIGURE 5.1: Airphoto of Suncor Energy Inc. showing the study site, source (Pond 2/3) and probable surface receptor (Ruth Lake). The boundaries of Fee Lot 2 are outlined by the dashed line. Created on April 13, 2004 based on 2001 airphoto.

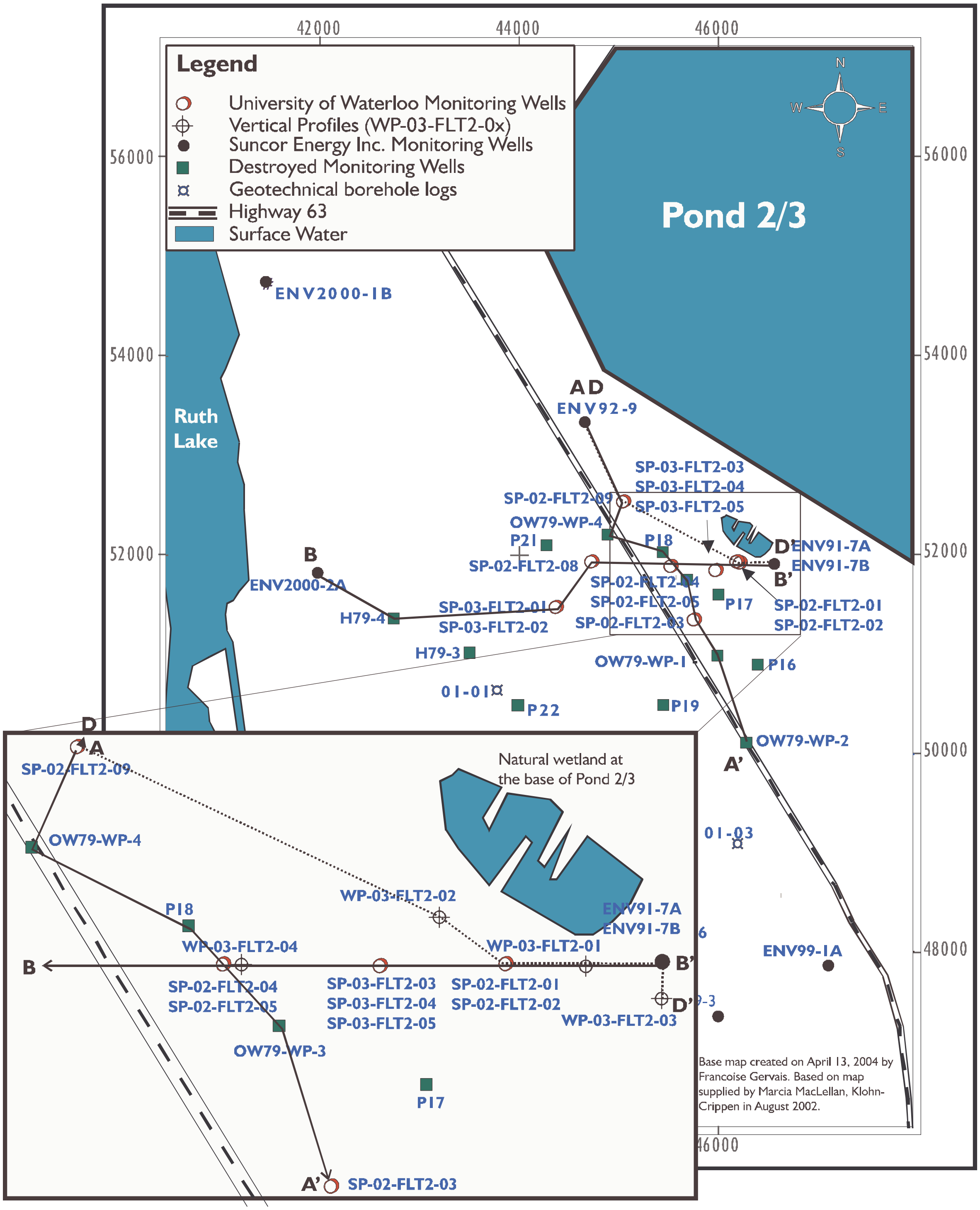


FIGURE 5.2: Plan view of the Suncor site showing the location of the wells, vertical profiles and cross-sections.

5.3 Previous Studies

5.3.1 Physical Hydrogeology

The stratigraphy of the area is Holocene organic matter over intermittent till and sequences of glacially deposited sand and gravel. This succession lies on top of dense grey clay till, Clearwater shale, or McMurray Formation oil sand. A more detailed description of the regional geology can be found in Chapter 4.

The Southwest (SW) Aquifer was identified as a major aquifer of interglacial buried channels of Quaternary age (Evison, 2000a; Evison, 2000b). The SW aquifer has been further subdivided into two complex sand/gravel/silt aquifers called the upper (UA) and lower aquifer (LA) with a discontinuous till between. The two aquifers are not referred to as "confined" or "unconfined" but as the upper or lower aquifer because of the intermittent nature of the confining unit.

The southern boundary of the LA is believed to be approximately coincident with the southern boundary of Fee Lot 2 (Figure 5.3). The LA is found at depths of up to 25m (80 feet) below ground surface. The LA is crescent shaped and the geological material changes laterally from a very coarse-grained aquifer in the east to a silty and clayey fine sand unit in the west, adjacent to the Ruth Lake Channel (Evison, 2000b). The UA becomes thin and discontinuous on the west side of Highway 63 and is not seen near Ruth Lake.

Pond 2/3 is located in a mined out area. The South Pit Wall is the portion of the pit wall located along Highway 63 (Figure 5.3). Both a lower and an upper sand deposit were visible on the pit slope. A 0.75-2.5 m overburden blanket was placed over the exposed sand and gravel to reduce pond seepage into the sand and gravel on the South Pit Wall (AGRA, 1998). Based upon this, the area around ENV91-7 may have a hydraulic connection to Dyke 2W construction water or with tailings water.

Cross-section B-B' and A-A' (Figure 5.4 and 5.5), along with the isopach map, illustrate the shape and placement of the buried channels of interest. The Southwest Aquifer is deep near Pond 2/3. Ground water flow is physically constrained towards Ruth Lake in this area by thick deposits of till.

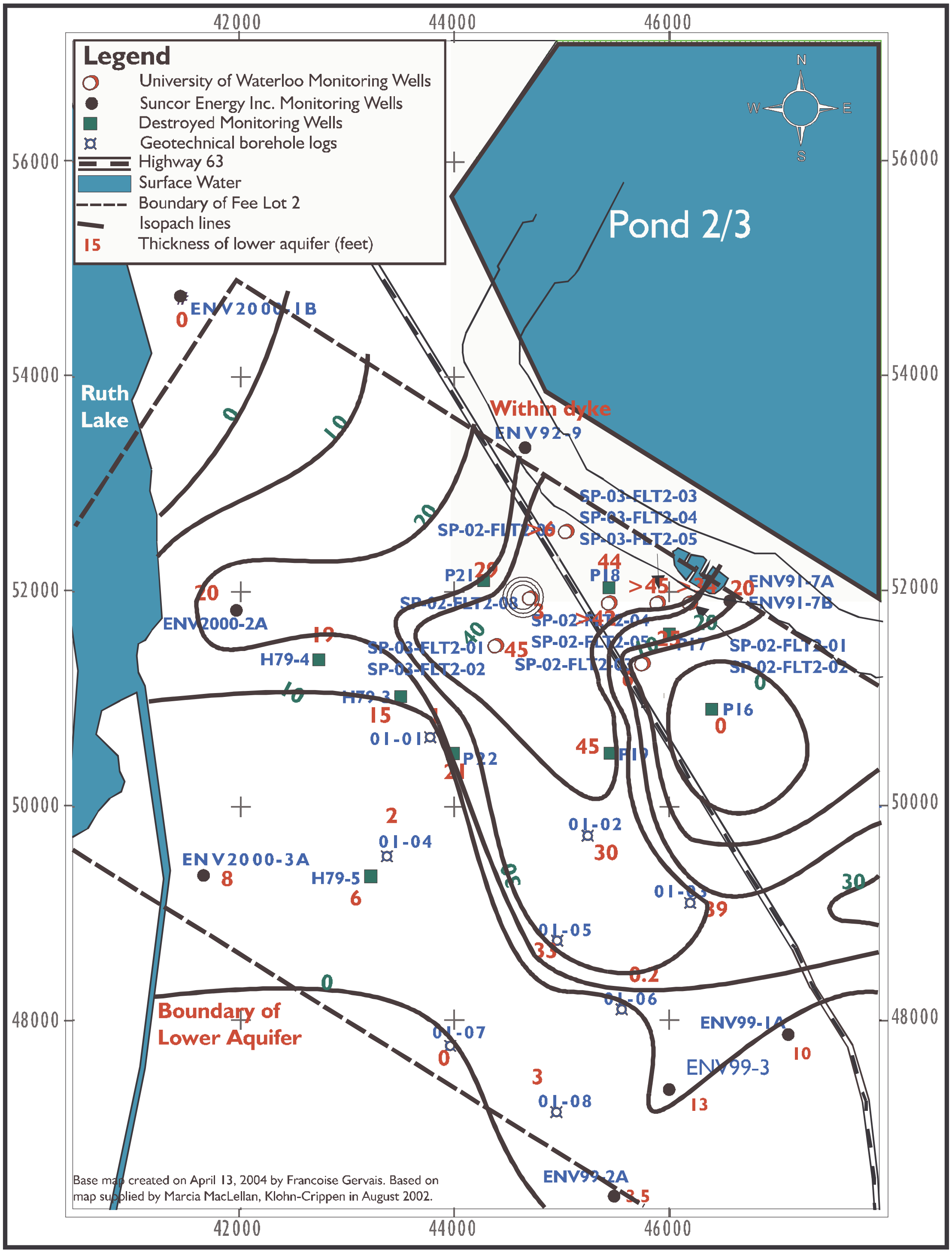


FIGURE 5.3: Isopach map of the Lower Aquifer, Southwest Aquifer, under Fee Lot 2. Both historical and new borehole logs were used in constructing the contours, as well as the electrical resistivity survey results. Units of feet are used to conform with the mine coordinate system in this area.

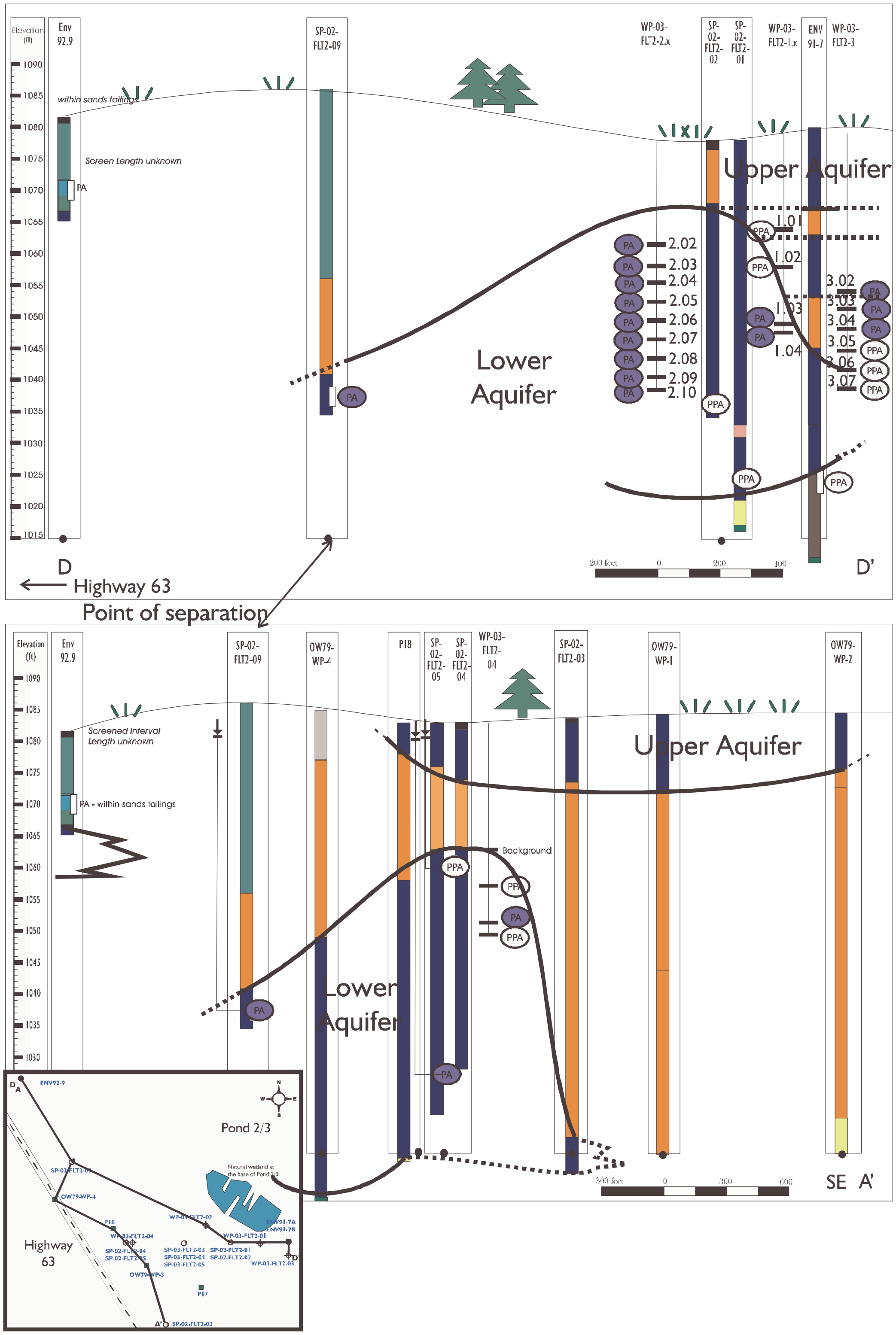


Figure 5.4: The local geology at the base of Dyke 2W, the start of the hypothesized flow path towards Ruth Lake.

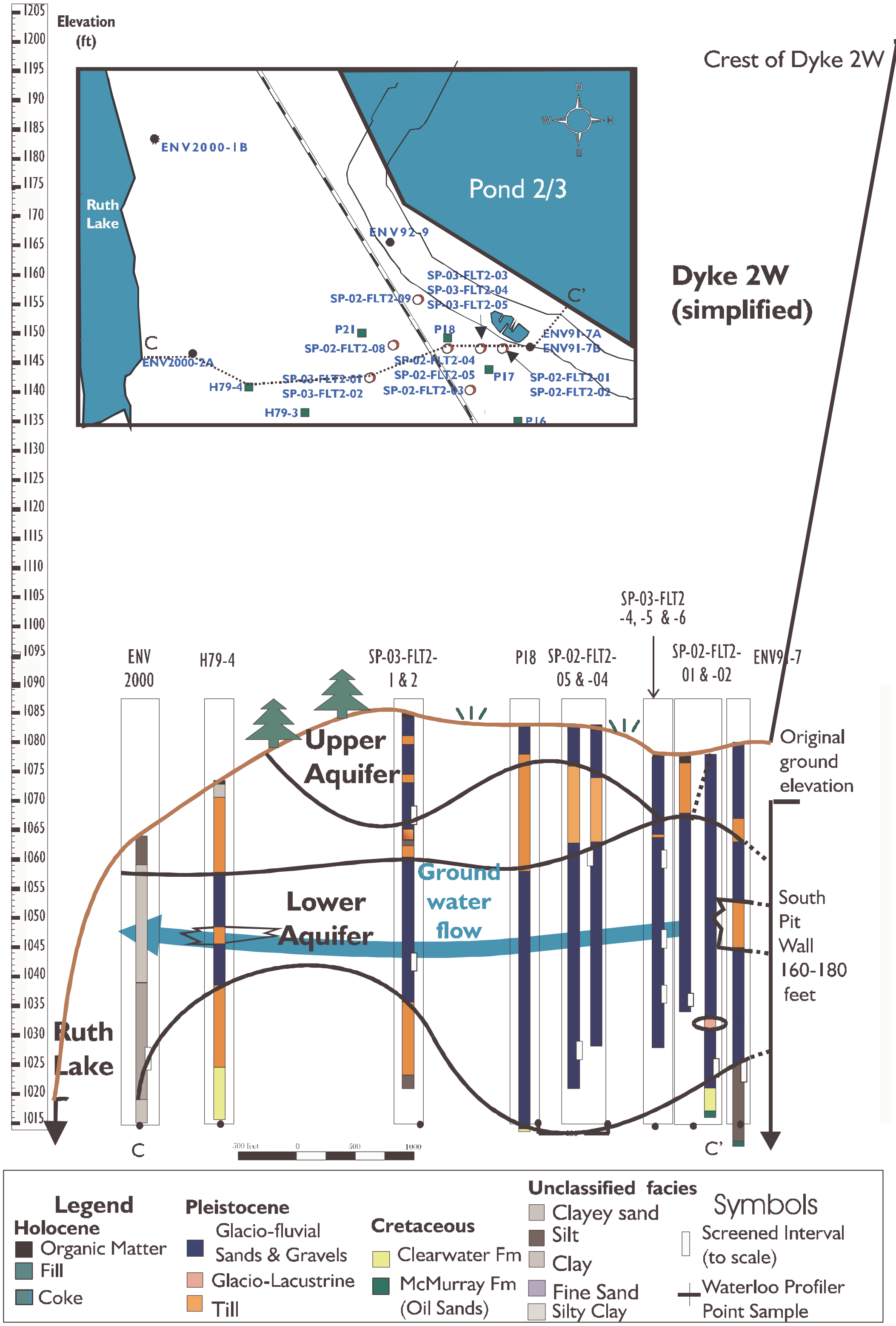


Figure 5.5: Geology along transect parallel to the predicted flow path near Pond 2/3.

5.3.2 Groundwater Flow Regime

Historically, a groundwater mound exists in the surficial deposits and limestone around pond 2/3 (Evison, 2000a; Evison, 2000b). The groundwater flows radially outward until it falls under the influence of regional flow (Figure 5.6). The hydraulic head distribution shows a complex flow system with groundwater coming from two hydraulic highs: Pond 2/3 and the area around ENV99-2. At the end of the summer 2003, dry conditions had led to a new hydraulic high in the muskeg between the highway and Ruth Lake. Wells ENV99–1, –2 and –3, at the south end of Fee Lot 2, are all classified as being possibly process-affected in the LA. Considering the flow regime in this area, it is likely that the naphthenic acids (NA) and sodium concentrations which led to the possibly process-affected designation are naturally occurring.

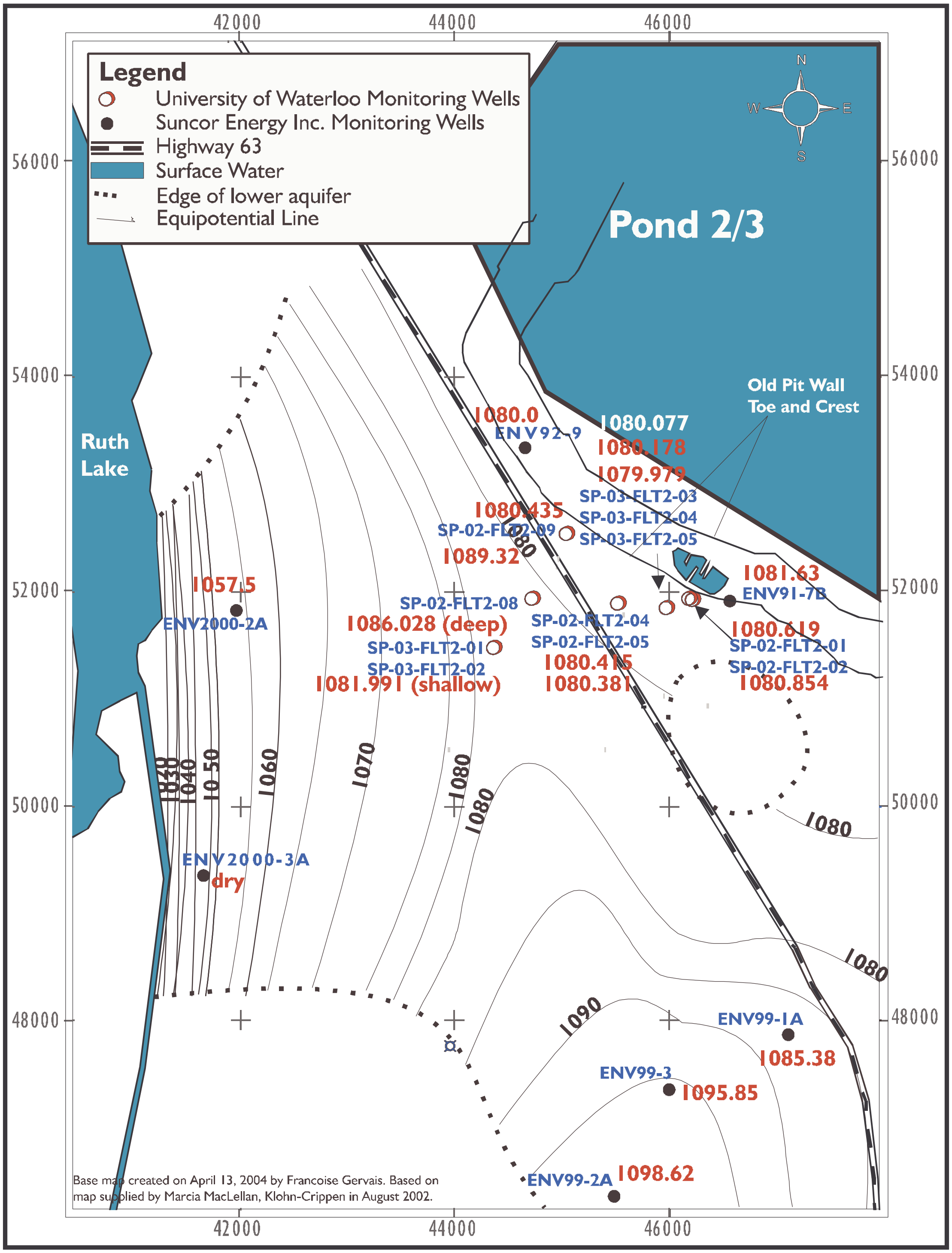
We sought an aquifer segment further to the northwest for two reasons: to avoid the potential mixture of this natural water and the PA water from Pond 2/3 and to avoid placing monitoring wells on either side of a groundwater divide.

5.4 Methods

5.4.1 Surface Geophysics

Komex International Ltd. (Komex) performed an electrical resistivity tomography (ERT) survey during the last week of June 2002 (Figure 5.15). Multi-electrode resistivity surveying instruments and computer inversion software were used. A typical setup for the 2D survey was a straight line of 400 metres with 61 electrodes connected to a multicore cable with constant spacing of 5 metres between adjacent electrodes. The equipment consisted of an ABEM-SAS 1000 Terrameter for resistivity measurements along with an ES 464 electrode selector (switching box) (Andrews, 2002). The switching computer was programmed with the sequence of measurements, the type of array (Wenner) and other survey parameters such as current. A “roll-along” method was used. When the measurements for a 400 metre line was completed, the cable at the beginning of the line was picked up and moved to the head of the line to form a new 400 metre line that overlapped with the first line.

In order to get a 2D image of the subsurface, information was collected both laterally and vertically. As the current electrode spacing along the 400 metre cable



Base map created on April 13, 2004 by Francoise Gervais. Based on map supplied by Marcia MacLellan, Klohn-Crippen in August 2002.

FIGURE 5.6: Potentiometric surface of the lower aquifer west of Pond 2/3, based upon measurements taken in July and August 2003. Units are in feet, as given by Suncor.

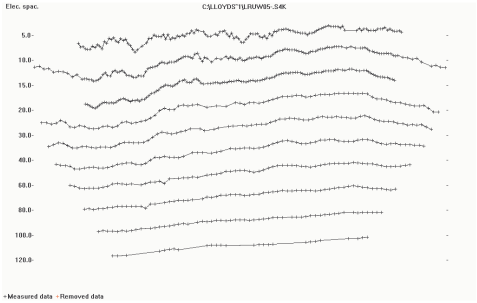


Figure 5.7: Apparent resistivity data values displayed as a profile for each data level for the line run parallel to the toe of Dyke 2W (UW05). Note: a contoured version of these diagrams is a "pseudo-section". The final results for the inversion software is an image or resistivity model.

was changed through the series of 15, 30, 45, 60, 90, 120, 180, 240, 300 and 360 metres, the effective depth of measurement increased with increasing spacing. The data are inverted using a 2-D finite-difference inversion routine. The final product is a two-dimensional resistivity image in omh-meters (Ωm). The maximum estimated depth of current penetration was 60 metres, the approximate location of the limestone bedrock in this area. The electrode spacing was a compromise between resolution and depth of sampling. The depth from surface to the bottom of the LA in the various borehole logs varied from 9 to 23 metre.

Line positions were surveyed with a Trimble Geo-Explorer 3 differential global positioning system. The data was provided in Universal Transverse Mercator coordinates referenced to the 1983 North American Datum (NAD83) Zone 12N and converted to Suncor mine coordinates for mapping (Andrews, 2002).

UW05 A geophysical survey line 900 m long was run along a generally east-west access road along the edge of the old Pit Wall crest, until the survey line almost intersected the highway. There were 856 datum points and 181 electrodes. The ground was dry and the contact between electrodes and soil was poor. However, the data looks to be free of anomalies (Figure 5.7). Originally, the line had been planned to run closer to Dyke 2W along a dirt road that was straight and longer. However, a look at Figure 5.6 shows the location of the old Pit Wall; the proposed line would have measured an unknown amount of tailings sand, not aquifer. The new location was shorter and passed by the "natural" wetland and piezometer ENV91-7B.

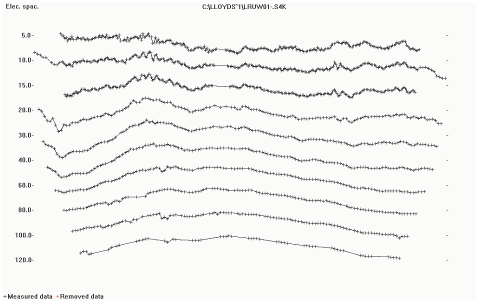


FIGURE 5.8: Apparent resistivity data values displayed as a profile for each data level for the line run parallel to Highway 63 and perpendicular to hypothesized flow path (UW01).

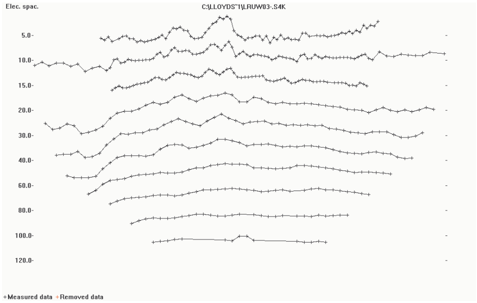


FIGURE 5.9: Apparent resistivity data values displayed as a profile for each data level for the line run perpendicular to Highway 63 and parallel to hypothesized flow path (UW03).

UW01 The electrical resistivity tomography along the highway edge was the longest line run, with a total of 1583 datum points and a line length of 1 500 m. The profile travels from southeast to northwest towards Pond 2/3. The ground was dry, grassy and compact so there were no contact problems between the electrodes and the ground. The elevation was fairly level, with an abrupt change in elevation twice to go across dirt roads. This was no more than 2 m and should not be a problem since the anomalies are small compared to the final image. Figure 5.8 shows that the values were consistent.

UW03 This particular line has 520 data points and 121 electrodes. The line length is 600 m. It starts at the highway, runs partly in muskeg up to line UW02. It is perpendicular to Highway 63. The plots show significant lateral variations; but since these are not single point anomalies, they were not removed (Figure 5.9).

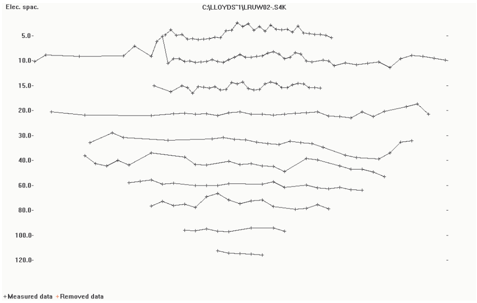


FIGURE 5.10: Apparent resistivity data values displayed as a profile for each data level for the line run perpendicular to and west of Highway 63 (UW02).

UW02 The second line was roughly parallel to the highway, halfway between the highway and Ruth Lake. The day was sunny and hot, and the ground was dry. The elevation did not change perceptibly. We ran the minimum line length of 400 m for this section, with a total of 203 datum points and 81 electrodes (Figure 5.10). The data are sparse near the surface and there appear to be anomalies, perhaps caused by proximity to the high pressure gas pipeline.

UW04 UW04 was located along a power right of way (ROW) and was the least successful ERT transect. Because the ROW had a bend, a straight line meant taking resistivity measurements below the power lines. During acquisition, the geophysicist considered the data under the hydro lines to be of poor quality. Since there was a possibility that the readings could be salvaged, the full line was measured. However, the power line effects are seen even at depth. This can easily be seen by comparing the data points for UW04 (Figure 5.11) against Figure 5.7, 5.8 and 5.10.

5.4.2 Monitoring Well Installation

The first piezometers were installed in the fall of 2002. Two drilling methods were used: hollow-stem augering with bolted augers and mud rotary drilling using Kim mud. A tracked Nodwell drilling rig from Layne Christensen was used since it would safely travel over muskeg and near high-pressure gas pipelines.

Split-spoon samples, some with sterile lexan liners to maintain the physical, chemical, and microbiological integrity of the samples, were taken every 5 feet (1.5 m) for two of the deep wells. Split-spoon samples in liners were collected from other wells as

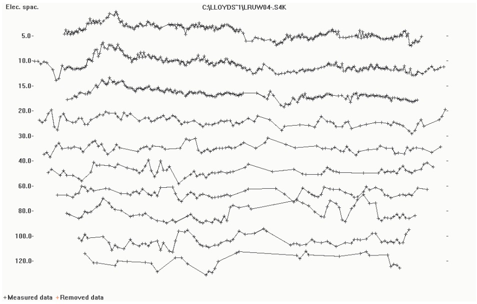


FIGURE 5.11: Apparent resistivity data values displayed as a profile for each data level for the line run parallel to the shore of Ruth Lake (UW04).

cost permitted in order to collect more material for microbial microcosms. Samples from various levels were bagged for permeameter analysis. Samples were also collected off the auger flights at one foot intervals for the top 10 feet (3 m). Otherwise, the driller's comments were used to determine changes in lithology. When the drilling method changed to mud rotary, mud cuttings were taken at least every 5 feet (1.5 m).

Beck Drilling was contracted for March 2003, before the spring thaw made the last drilling sites inaccessible. Five piezometers were installed using threaded hollow-stem augers. Samples were retrieved using shelby tubes, split-spoon sampling or collected off the auger flights. Soil cores were either bagged or stored in a core box and shipped to the University of Waterloo.

Some piezometers were screened deep in the LA. Maximum depth of boreholes was down to the Clearwater Formation, the McMurray Formation (oil sand), a maximum of 23 m (75 feet) or a recalcitrant refusal (1 hour drilling), whichever occurred first. The depth of the other piezometers was near the top of the semiconfined surficial LA. A borehole log was constructed with well installation data for each piezometer (Appendix E). Stratigraphy was based on an overburden stratigraphic classification and material properties chart from Terracon Geotechnique Ltd. Colour and grain size description was based on a geotechnical gauge manufactured by W.F. McCollough.

Standpipes were installed in separate boreholes. The protocol for the standpipes installation was:

- Store well construction material in sealed plastic bag

- Clean rubber gloves worn for each installation
- 2" diameter schedule 40 PVC casing with flush threaded joints and #10 machined slots
- Environmental silica sand (10/20) for filter pack
- 3/8"bentonite chips backfill poured directly into annulus to avoid bridging
- development by Waterra® pump

5.4.3 Hydrological Testing

5.4.3.1 Hydraulic Head

Hydraulic head was measured relative to the top of the standpipe in July 2003, using a water level tape.

5.4.3.2 Hydraulic Conductivity

Single well response tests (slug tests) were performed by Komex under the supervision of a delegate from Suncor. Komex was informed that the majority of the wells responded very quickly, and a short measuring time needed to be used. The specifications were:

1. three slug tests at each well. The only exception was SP-02-FLT2-08 because of its slow recovery time. Three tests were requested because a shift in aquifer parameters would show if wells need to be redeveloped.
2. two different initial displacements. The first and last test had 1 L added or removed, while the second test had 2 L volume change. Since the volume of water and the radius of the pipe were known, the initial displacement (H_0^*) was calculated using the equation $H_0^* = \frac{\text{volume of water}}{\pi r^2}$. H_0^* for the first and last tests was 0.493 m and 0.987 m for the middle test.
3. that the slug be introduced in a near instantaneous manner with a good estimate of initial displacement;

4. that the change in hydraulic head be measured by a pressure transducer and data logger for all wells except SP-02-FLT2-08 where an electronic water level tape may be used;
5. that either bail down or slug test may be used.

With the exception of SP-02-FLT2-08, slug test data were analyzed using a spreadsheet implementation of a modification of the analysis approach proposed for slug tests in highly permeable aquifers (Butler Jr. et al., 2003; Butler Jr. & Garnett, 2000). Even though not all slug tests had an oscillating response, the high-K test was used since it is appropriate for a partially penetrating screen in an unconfined formation screened below the water table.

No correction was made for the accelerating water column above the pressure transducer (pressure transducer was not <0.5 m below static water level). As a check against the Butler spreadsheet, the data for SP-03-FLT2-02 was analyzed using the spreadsheet and the KGS method in *AQTESOLV* (3.01). The Cooper-Bredehoeft-Papadopulos (1967) Solution for a Slug Test yielded a α value of 1e-10. This is not implausibly low; therefore the data were analyzed using the KGS method for a confined aquifer, assuming that K_z=K_r. The K_r obtained using the KGS method for confined aquifer was 0.7114 m/day, while the high-K KGS method yielded 0.6858 m/day. These values are precise for field data and the rest of the slug tests were analyzed by high-K test only.

The test data were processed prior to analysis (Butler Jr., 1998). The pressure head data were converted into deviation of head from static (H(t)), then transformed into the normalized deviation from static, H(t)/H_0^*, where H(t) is the head displacement at any time t and H_0^* is the calculated initial displacement. The calculated head (H_0^*) was used as the initial head change, and the start time was estimated from the graph. The normalized data from the three tests performed at each piezometer were examined to see if early-time noise was present or if the initial head change was accurately measured.

SP-02-FLT2-02 was the only well where all three tests had an initial normalized deviation of one (Figure 5.12). A plot of normalized head deviation from static versus time reveals a typical overdamped curve with apparent exponential decay. The three plots are almost coincident, indicating that there was no dependence on the magnitude of the initial displacement or dynamic skin effects.

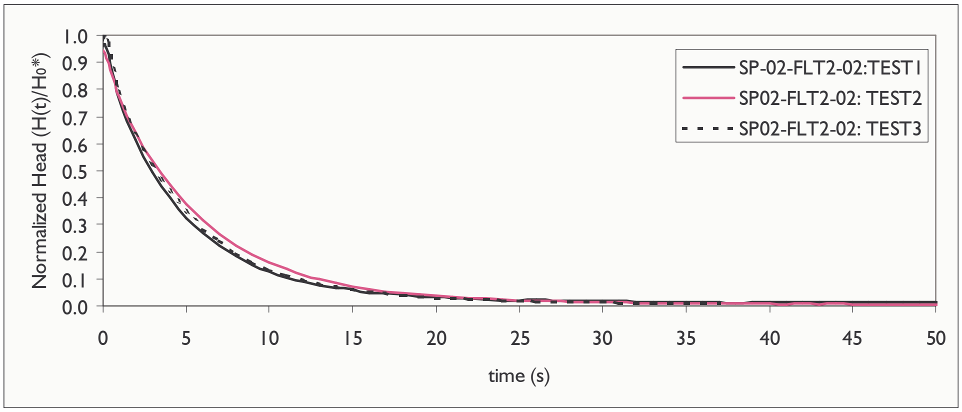


FIGURE 5.12: The response data for SP-02-FLT2-02 plotted as the normalized deviation from static versus time showing a typical overdamped response with apparent exponential decay.

There was only one other piezometer that had at least one test where $H(t)/H_0^*=1$, SP-03-FLT2-04. The other slug response data needed to be processed for early-time noise. Early-time noise is a measurement artifact caused by short, dynamic, pressure disturbances as the slug is moved and/or the slug hitting or rubbing against the pressure transducer or cord during test initiation. Perhaps because of the large time intervals (1 or 3 seconds), the measured initial head was not always recorded. It was not possible to use H_0^* and t_0^* and ignore the early time portion of the graphs since it was very difficult to superimpose the three graphs (Figure 5.13). A pre-procession method called the translation method was applied to the data. The "noisy" early-time data were ignored. A new point was chosen as the start time (t_0) and measured initial head (H_0) (Figure 5.14).

Only two wells shows an underdamped or oscillating pattern; SP-02-FLT2-01 and SP-02-FLT2-09. Both were screened in the sand and gravel near the base of Dyke 2W and had at least 30 feet of water column above the top of the screen. In both cases, none of the tests had $H(t)/H_0^*=1$; and the oscillation had damped out within 15 seconds of measurement initiation.

Because the time interval for SP-02-FLT2-01 was 3 seconds, it was very difficult to fit the period or curvature. The best fit was for Test 3. The results should be considered a rough estimate. At borehole SP-02-FLT2-01, the average hydraulic conductivity as determined by falling head permeameter is 0.27 m/day (Table 5.3),

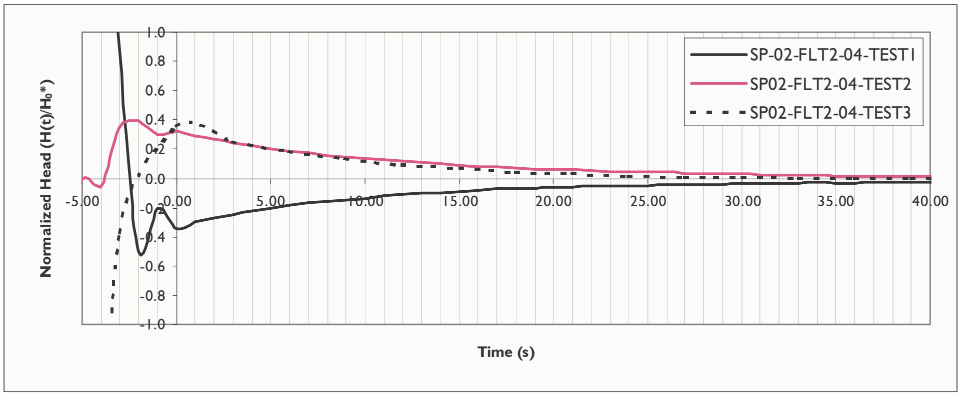


FIGURE 5.13: Example of slug test response data with early time noise where the initial head change was not captured.

although values of 1.2 and 0.04 were also measured showing a variation of one order of magnitude in either direction. This is much lower than the value determined by slug test, 57 m/day, confirming the previously stated opinion that that test should be ignored.

The test results for SP-02-FLT2-09 were difficult to interpret. The initial assumption for all tests was that the data represented an oscillating system. However, an attempt to fit the data to a curve using the High-K KGS spreadsheet was unsuccessful for test 1 and 3. The H_0 used for the first and third tests, 0.0146 and 0.049 respectively, were much smaller than H_0^* (0.493 m). Since curve fitting was not possible, the data were not interpreted. For test 2, the only estimated H_0 which did not lead to normalized values greater than one lead to an overdamped curve. Although it was possible to estimate K for the second test, it should be considered a very rough estimate. SP-02-FLT2-09 is also screened in the same aquifer as SP-02-FLT2-01 and its K values as measured by permeameter range from 0.1 to 6 m/day, contrary to the slug test results of 17 m/day. See Appendix G for raw data.

Further tests in this aquifer should use a much shorter time interval for measurement (0.25 seconds) in oder to be able to interpret the curve properly.

5.4.3.3 Laboratory Testing

Falling head permeameter tests measured the hydraulic conductivity of aquifer samples to better estimate the hydraulic properties of the South-West Aquifer and deter-

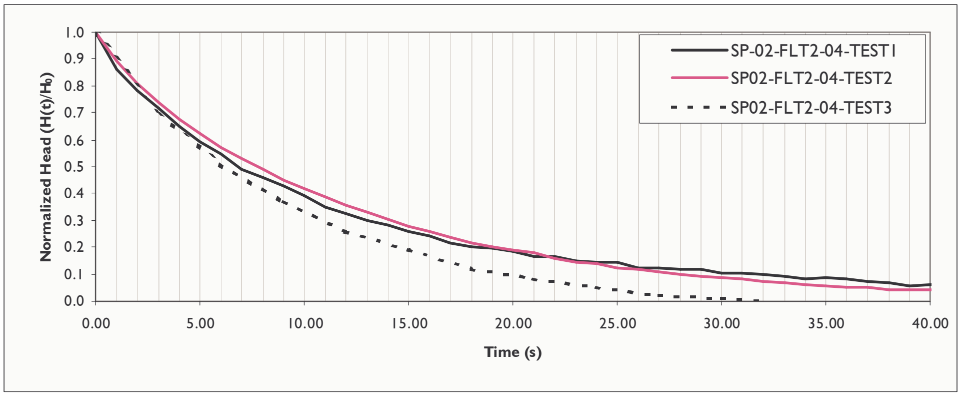


Figure 5.14: Slug test response data after translation.

mine heterogeneity in the area. As well, the soil samples were crushed and analyzed for fraction of organic carbon.

5.4.4 Groundwater Sampling

5.4.4.1 Vertical Profile Sampling

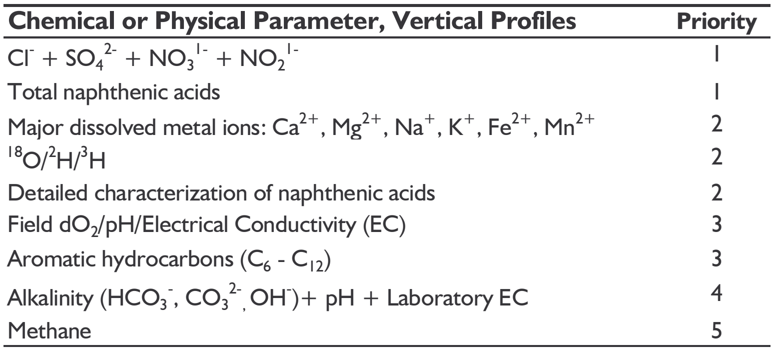
The third trip in July 2003 used the Waterloo Profiler for detailed vertical profiling. The Waterloo sampler drive point device was used where detailed vertical data was needed or if a sampling site could not be safely accessed by truck. The Waterloo Profiler is a direct-push groundwater sampling tool developed by researchers at the University of Waterloo in Ontario, Canada (Pitkin et al., 1994; Pitkin et al., 1999). The Profiler is designed to collect depth-discrete groundwater samples in a single hole from numerous depths with one probe entry. Earth Probe Technologies was hired since they had a 1-ton auger rig that could be set up with a hammer to drive the direct push rods and, more importantly, a winch to pull them up. A solid-stem auger was used to drill to the top of the water table. Then the Profiler tip was attached to heavy-duty threaded 1-m long standard drill rods and advanced using the hammer. Groundwater samples are brought to the surface via small diameter stainless steel tubing attached to a fitting inside of the Profiler tip and passing up through the inside of the drill rods. The profiler was preassembled and field tested as per Appendix I, then decontaminated before the first sample and between each sampling point. Except for the field spikes, the decontamination procedures and quality assurance measures for Albian Sands were used (see section 4.5.1). Field parameters were measured by probes in a flow-through cell and sample bottles were in line with the pump. A peristaltic pump was used. Appendix I provides detailed sampling, handling and shipping guidelines.

In cohesionless sands, the hole caused by inserting the profiler will collapse upon removal, restoring the original permeability of the formation. Low permeability silt, till and oil sand units can be quickly recognized as providing no water; these depths are abandoned and the profiler is advanced, collecting groundwater only from sand units. These intervals might not be sealed after the Waterloo Profiler is withdrawn.

The Suncor site was profiled at four locations (Figure 5.2). Three of the locations were parallel to the base of Dyke 2W, at the edge of the old mining pit (Figure 5.3). Two of the four locations had a high vertical resolution, meaning that samples were taken every 3 feet or 1 metre. Every other depth sample (every 6 feet or 1.8 meters) included the complete suite of samples except for detailed naphthenic acid analysis, which was only be sampled once per vertical profile (Table 5.1). Chloride and total naphthenic acids were measured every three feet (1 m). If the flow rate was sufficiently high, then other samples were taken in order of priority. The other two locations were profiled with a vertical resolution of 2 m.

5.4.4.2 Piezometer Sampling

All equipment was decontaminated prior to use. Piezometers were developed prior to sampling using a Waterra® pump. Static water levels were measured using a water level tape. Piezometers were purged three wells volumes and then groundwater samples were collected using a Waterra® pump or a siphon (artesian wells). If possible, electrical conductivity, pH, temperature and dissolved oxygen were measured by probes in a flow through cell. Groundwater samples were collected for BTEX, C_6-C_{10} hydrocarbons, trimethylbenzene, naphthalene, methane, oxygen and hydrogen stable isotopes, tritium, total and dissolved organic carbon, fluoride, dissolved metals, total ammonia, total and detailed naphthenic acid and routine analysis (carbonate, major ions, etc). Detailed descriptions and field guidelines can be found in Appendix J.



Chemical or Physical Parameter, Vertical Profiles	Priority
$Cl^- + SO_4^{2-} + NO_3^{1-} + NO_2^{1-}$	1
Total naphthenic acids	1
Major dissolved metal ions: Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{2+}, Mn^{2+}	2
$^{18}O/^2H/^3H$	2
Detailed characterization of naphthenic acids	2
Field dO_2/pH/Electrical Conductivity (EC)	3
Aromatic hydrocarbons (C_6 - C_{12})	3
Alkalinity (HCO_3^-, CO_3^{2-}, OH^-)+ pH + Laboratory EC	4
Methane	5

TABLE 5.1: Samples, and their priorities, collected by Waterloo Profiler at Suncor Energy Inc.

5.5 Results

5.5.1 Geology

5.5.1.1 Electrical Resistivity Tomography (ERT) Survey

The two resistivity images nearest Dyke 2W (UW01 and UW05) are dominated by high resistivity values (pink), interpreted as glacio-fluvial sand and gravel channel bounded by tills (blue) on either side (Figure 5.15 and 5.16) (Andrews, 2002).

The variations in the resistivity values in the middle layer must be interpreted in terms of changes in fines content or pore fluid chemistry. The uppermost resistive values are probably due to the unsaturated zone. However, the results Archie's Law calculations were not confirmed by the boreholes. It is assumed that the aquifer is not pure sand but contains sufficient clay to violate the basic assumption of these calculations, that the aquifer is pure sand. Therefore, variations in resistivity values is due to changes in fines content, not pore fluid chemistry.

ERT Results ERT images are presented as cross-sections of resistivity values plotted along the geophysical profiles. ERT images are displayed as color grids in which cool to warm colors (blues to reds), correspond to low to high resistivity. All sections are displayed with a consistent colour-bar range of resistivity values (Andrews, 2002). All images can be seen in Figure 5.16 and 5.15.

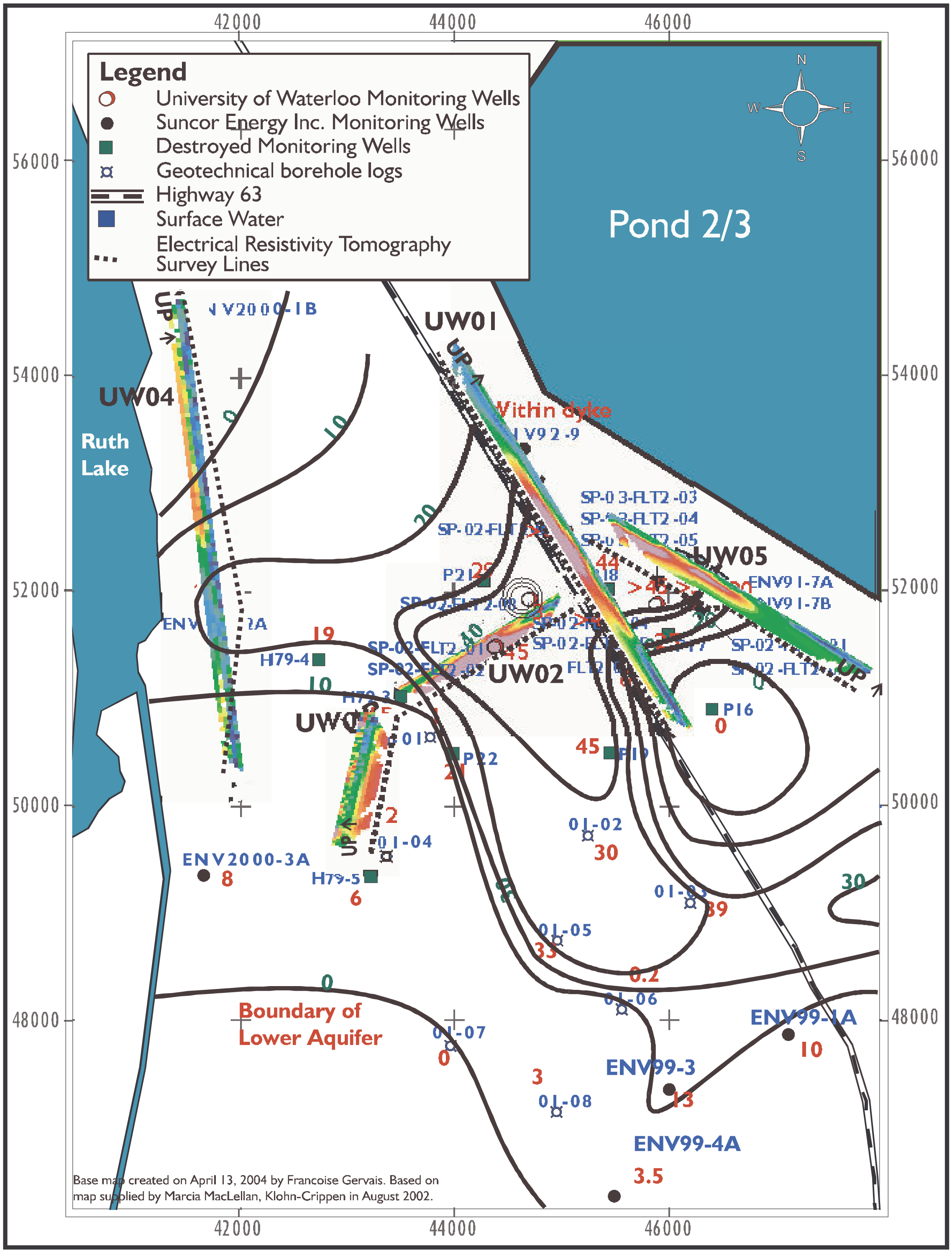


FIGURE 5.15: Isopach map of the Lower Aquifer (Southwest Aquifer), showing the relationship between the thickness contours (feet) and the geophysical survey lines.

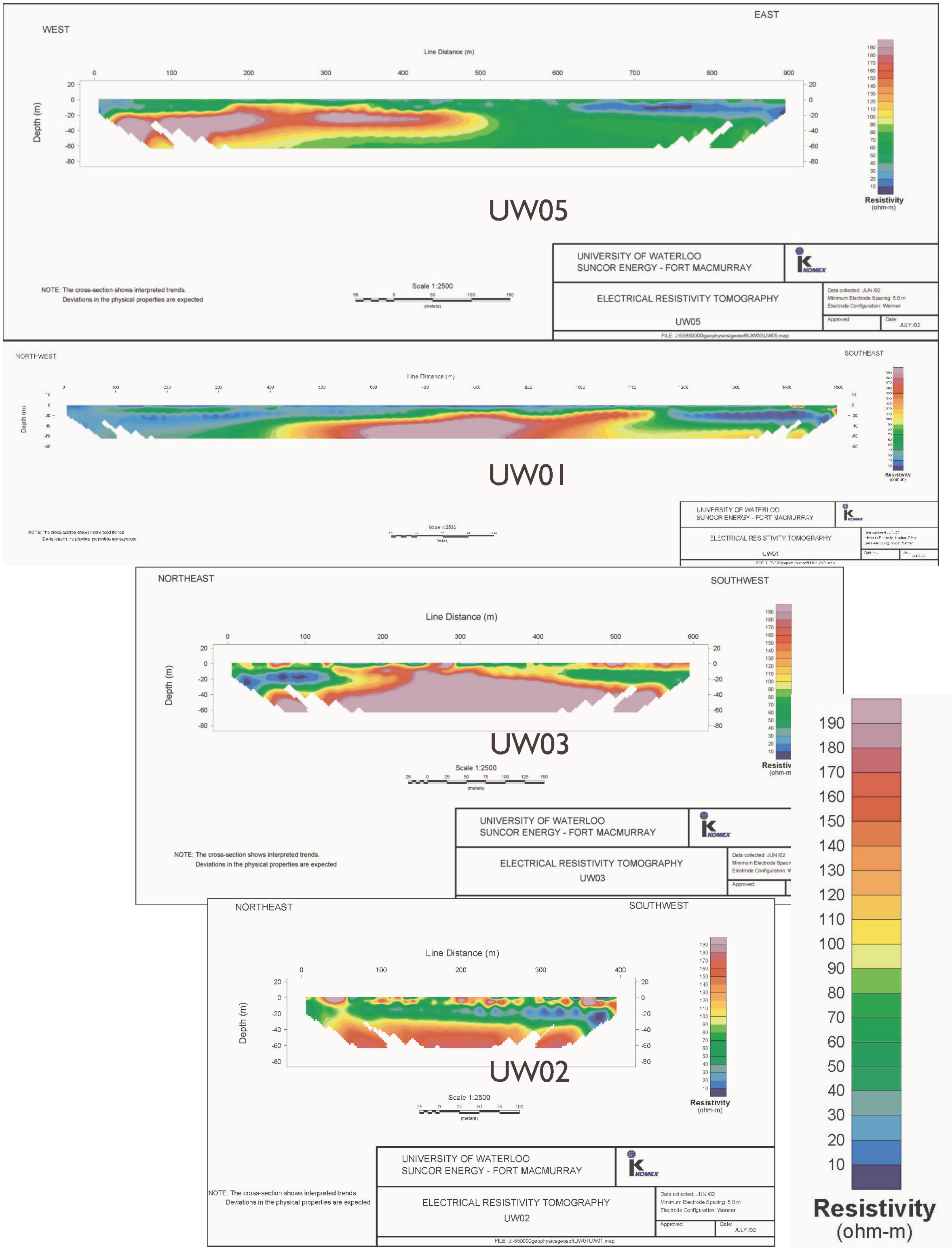


Figure 5.16: Electrical resistivity tomography images.

UW05 There is a low resistivity zone to the east which goes from near surface to 20 m deep (65 feet). The LA is thin to nonexistent in this area and the values are consistent with clay till (Evison, 2000a; Evison, 2000b). The wells in the lower aquifer along UW05 all have low ρ_0 due to high TDS water, probably seeping process-affected water from Pond 2/3 or Dyke 2W. However, the low theoretical apparent resistivity is not seen in the image and drilling confirmed that the resistive body was sand and gravel. The deep resistive body at the west end probably represents the limestone bedrock, which does move up around 40 feet at the west end relative to the east end.

UW01 UW01 lends itself well to interpretation. There is a high resistivity zone bounded on either side by areas of low resistivity. SP-02-FLT2-03 was drilled in the high conductivity zone in the east to discover if the low resistivity in the ERT image was due to a high clay content or a highly saline plume in sand and gravel. The 55 foot thick layer of stiff clay till logged, underlain by only 5 feet of sand and gravel until oil sand is reached indicates that the cause is a high fines content, not pore water salinity.

A deep and highly resistive body was found near P18 which may be the deep sand and gravel seen in cross-section. Additional wells verified the lithology. Even though in theory apparent resistivity should be high enough to affect the ERT, wells indicate that this is not so and it is probable that conductive zones are clay till and resistive zones are sand and gravel.

UW03 The resistivity high in the middle of the ERT image probably sand or sandy till as seen in nearby wells. The resistivity low at the base may be Clearwater Shale or limestone bedrock. The conductive zone in the northeast corresponds with open water in muskeg.

UW02 The borehole data used to build the isopach map indicated that there would be no upper aquifer in this area and that the lower aquifer would be thin and possibly discontinuous, but thickening as we moved north. This line was run near a gas pipeline, which is probably visible as anomalies in this line. The point furthest south ended up with an apparent resistivity value near surface in the 2400s. The location of the pipeline was not known, so the line was placed as close to the woods as possible based on the hypothesis that the pipeline would be near the middle of the right of way (ROW).

Summary The objective was to delineate possible sand/gravel units in Quaternary deposits using ERT methods. Monitoring wells indicated that ERT values were controlled by lithology. It was possible to identify sand and gravel channels cut into tills since they were more electrically resistive. The results of the ERT was then incorporated into the isopach map of the study area (Figure 5.15).

5.5.1.2 Field Hydrological Testing

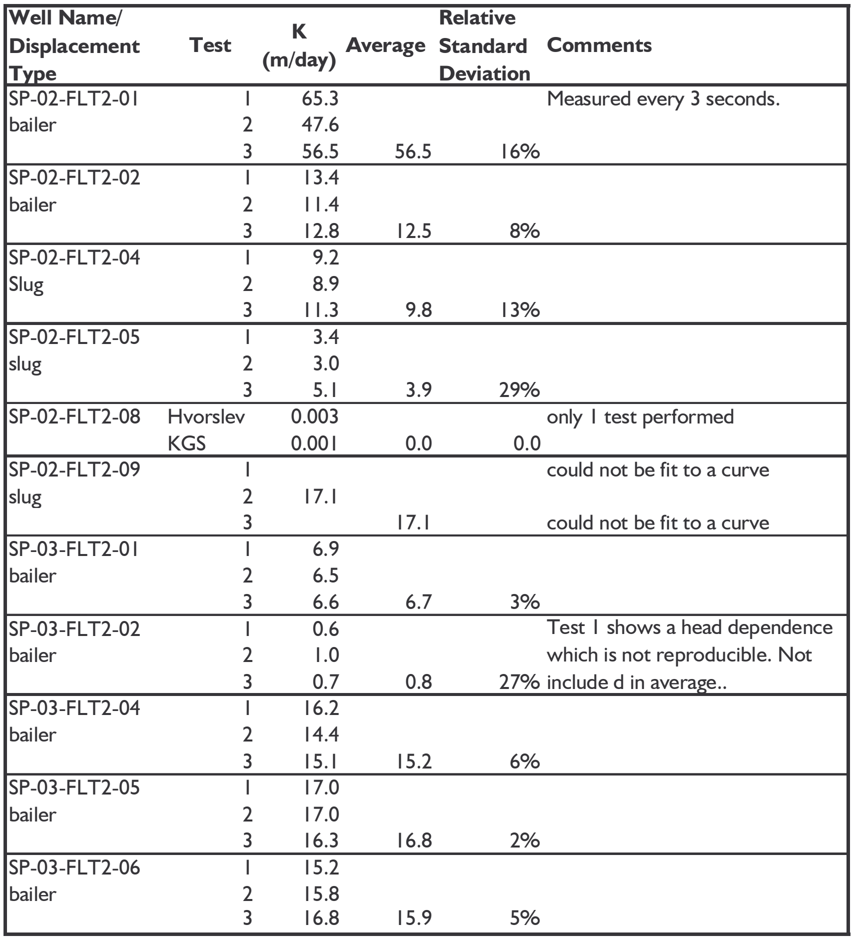
Hydraulic Head All samples on the pond side of the highway have similar water elevations, no matter the elevation of the screen tops (Figure **??** and 5.6). The following wells revealed an upward gradient: SP-02-FLT2-01 and SP-02-FLT2-02 — 0.032; SP-03-FLT2-01 and SP-03-FLT2-02 — 0.2; and SP-03-FLT2-04, SP-03-FLT2-05 and SP-03-FLT2-06 — 0.01. There is a downward gradient at SP-02-FLT2-04 and SP-02-FLT2-05 — 0.001.

In this area, a horizontal groundwater gradient (i) of 0.005 exists in the sands between the toe of Dyke 2W (wells SP-02-FLT2-09, ENV91-7, SP-02-FLT2-01 and SP-02-FLT2-02) and well ENV2000-2 near Ruth Lake channel (Figure 5.6). As well, the gradient was calculated for two wells screened at approximately the same elevation. The gradient between SP-02-FLT2-02 and SP-03-FLT2-05 is 0.00004; and 0.01 between SP-03-FLT2-05 and ENV2000-2.

Muskeg occurs between SP-02-FLT2-01 and SP-03-FLT2-01, suggesting the whole area is a groundwater discharge zone. The strong upward gradient at SP-03-FLT2-01 indicates that even though this is a hydraulic high, this area can still be considered a discharge, not a recharge zone.

Hydraulic Conductivity As we move away from the base of Dyke 2W, hydraulic conductivity (K) as measured by permeameter (Table 5.3) is 0.3 m/day near the base and varies with increasing distance from 0.06, 0.4, 0.9 to 0.2 at SP-03-FLT2-01. It is not unusual for the K as measured by slug test (Table 5.2) to be higher by an order of magnitude than the permeameter K, as values range from 16 m/day at SP-03-FLT2-04, 05 and 06; 16 and 4 m/day at SP-02-FLT2-04 and -05 respectively; and 7 and 0.8 m/day at SP-03-FLT3-01 and -02.

Groundwater Velocity The local groundwater is believed to flow radially away from Dyke 2W of Pond 2/3 (Figure 5.6) in sand and gravel glacio-fluvial aquifers



Well Name/ Displacement Type	Test	K (m/day)	Average	Relative Standard Deviation	Comments
SP-02-FLT2-01	1	65.3			Measured every 3 seconds.
bailer	2	47.6			
	3	56.5	56.5	16%	
SP-02-FLT2-02	1	13.4			
bailer	2	11.4			
	3	12.8	12.5	8%	
SP-02-FLT2-04	1	9.2			
Slug	2	8.9			
	3	11.3	9.8	13%	
SP-02-FLT2-05	1	3.4			
slug	2	3.0			
	3	5.1	3.9	29%	
SP-02-FLT2-08	Hvorslev	0.003			only 1 test performed
	KGS	0.001	0.0	0.0	
SP-02-FLT2-09	1				could not be fit to a curve
slug	2	17.1			
	3		17.1		could not be fit to a curve
SP-03-FLT2-01	1	6.9			
bailer	2	6.5			
	3	6.6	6.7	3%	
SP-03-FLT2-02	1	0.6			Test 1 shows a head dependence
bailer	2	1.0			which is not reproducible. Not
	3	0.7	0.8	27%	include d in average..
SP-03-FLT2-04	1	16.2			
bailer	2	14.4			
	3	15.1	15.2	6%	
SP-03-FLT2-05	1	17.0			
bailer	2	17.0			
	3	16.3	16.8	2%	
SP-03-FLT2-06	1	15.2			
bailer	2	15.8			
	3	16.8	15.9	5%	

Table 5.2: Hydraulic conductivity values determined by single well aquifer tests.

(Figure **??**). Using a gradient (i) of 0.006, a range of hydraulic conductivity (K) from 2.8 to 10 m/day and assuming an effective porosity (η) of 0.25, groundwater velocity (v = K$i\eta^{-1}$) is estimated from about 24 to 80 m/year. PA groundwater could have advanced 360 to 1200 m from the dyke over a 15 year period since construction of Dyke 2W. A process-affected water plume of a few hundred metres length is thought most possible in this area.

5.5.1.3 Fraction of Organic Carbon

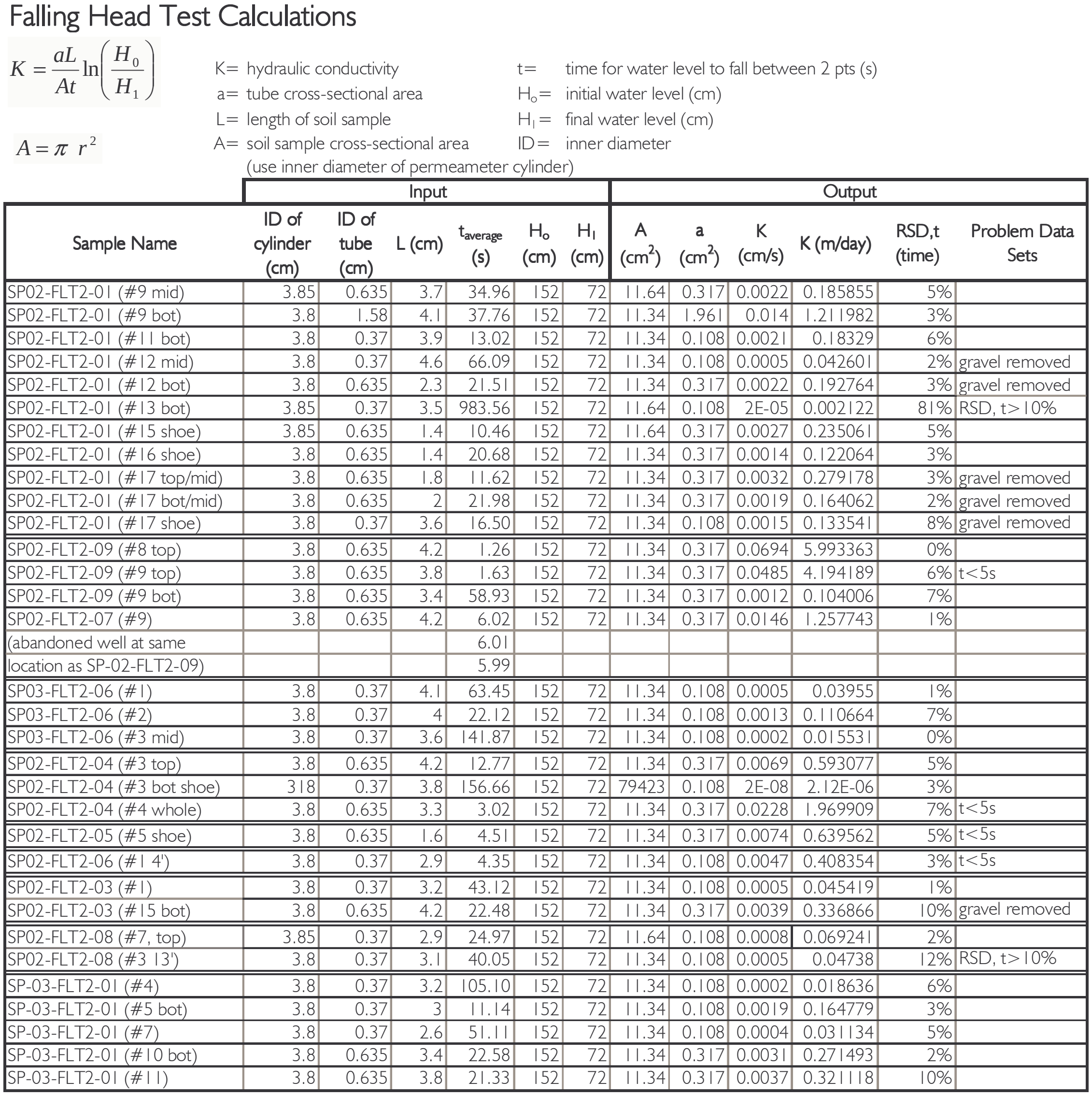
Samples of Suncor geological material from outside the SW aquifer were sent to be analyzed for fraction of organic carbon (f_{oc}) in the soil and one sample, G-01-245 with f_{oc} of 1.1%, was chosen for the initial batch sorption isotherms with low ionic strength aqueous solution (section 3.4.2). As might be expected for a glaciofluvial depositional environment which can be expected to have low biological activity, the f_{oc} was generally low. Samples from both outside the study area and the piezometers installed for this study had an average f_{oc} of 0.2±9%, although values ranged from a minimum of 0.05 to a maximum of 1.2.

5.5.2 Identification of Process-affected Water

The identification of process-affected water in groundwater can be difficult. However, Baker (2000) has identified several chemical indicators that, used in conjunction, are useful in identifying process water at Suncor. A more traditional Piper diagram has been included. This study also seeks to extend the work of Hunter (2001) in using stable isotopes and tritium to identify process-affected water.

5.5.2.1 Process Water Tree and Index

There are three chemicals used to classify groundwater samples: dissolved chloride, dissolved sodium and total naphthenic acid. Identifiers are used in combination since the chemicals may have other natural sources. For example, dissolved sodium is naturally high in tills and naphthenic acids can be found in lodgement tills (reworked McMurray Formation) and the McMurray Formation itself. Baker (2000) formulated two classification schemes that are sensitive to local geology: Tree and Index.



Falling Head Test Calculations

$$K = \frac{aL}{At}\ln\left(\frac{H_0}{H_1}\right)$$

$$A = \pi\ r^2$$

K= hydraulic conductivity
a= tube cross-sectional area
L= length of soil sample
A= soil sample cross-sectional area (use inner diameter of permeameter cylinder)
t= time for water level to fall between 2 pts (s)
H_o= initial water level (cm)
H_l= final water level (cm)
ID= inner diameter

	Input						Output					
Sample Name	ID of cylinder (cm)	ID of tube (cm)	L (cm)	$t_{average}$ (s)	H_o (cm)	H_l (cm)	A (cm^2)	a (cm^2)	K (cm/s)	K (m/day)	RSD,t (time)	Problem Data Sets
SP02-FLT2-01 (#9 mid)	3.85	0.635	3.7	34.96	152	72	11.64	0.317	0.0022	0.185855	5%	
SP02-FLT2-01 (#9 bot)	3.8	1.58	4.1	37.76	152	72	11.34	1.961	0.014	1.211982	3%	
SP02-FLT2-01 (#11 bot)	3.8	0.37	3.9	13.02	152	72	11.34	0.108	0.0021	0.18329	6%	
SP02-FLT2-01 (#12 mid)	3.8	0.37	4.6	66.09	152	72	11.34	0.108	0.0005	0.042601	2%	gravel removed
SP02-FLT2-01 (#12 bot)	3.8	0.635	2.3	21.51	152	72	11.34	0.317	0.0022	0.192764	3%	gravel removed
SP02-FLT2-01 (#13 bot)	3.85	0.37	3.5	983.56	152	72	11.64	0.108	2E-05	0.002122	81%	RSD, t>10%
SP02-FLT2-01 (#15 shoe)	3.85	0.635	1.4	10.46	152	72	11.64	0.317	0.0027	0.235061	5%	
SP02-FLT2-01 (#16 shoe)	3.8	0.635	1.4	20.68	152	72	11.34	0.317	0.0014	0.122064	3%	
SP02-FLT2-01 (#17 top/mid)	3.8	0.635	1.8	11.62	152	72	11.34	0.317	0.0032	0.279178	3%	gravel removed
SP02-FLT2-01 (#17 bot/mid)	3.8	0.635	2	21.98	152	72	11.34	0.317	0.0019	0.164062	2%	gravel removed
SP02-FLT2-01 (#17 shoe)	3.8	0.37	3.6	16.50	152	72	11.34	0.108	0.0015	0.133541	8%	gravel removed
SP02-FLT2-09 (#8 top)	3.8	0.635	4.2	1.26	152	72	11.34	0.317	0.0694	5.993363	0%	
SP02-FLT2-09 (#9 top)	3.8	0.635	3.8	1.63	152	72	11.34	0.317	0.0485	4.194189	6%	t<5s
SP02-FLT2-09 (#9 bot)	3.8	0.635	3.4	58.93	152	72	11.34	0.317	0.0012	0.104006	7%	
SP02-FLT2-07 (#9)	3.8	0.635	4.2	6.02	152	72	11.34	0.317	0.0146	1.257743	1%	
(abandoned well at same				6.01								
location as SP-02-FLT2-09)				5.99								
SP03-FLT2-06 (#1)	3.8	0.37	4.1	63.45	152	72	11.34	0.108	0.0005	0.03955	1%	
SP03-FLT2-06 (#2)	3.8	0.37	4	22.12	152	72	11.34	0.108	0.0013	0.110664	7%	
SP03-FLT2-06 (#3 mid)	3.8	0.37	3.6	141.87	152	72	11.34	0.108	0.0002	0.015531	0%	
SP02-FLT2-04 (#3 top)	3.8	0.635	4.2	12.77	152	72	11.34	0.317	0.0069	0.593077	5%	
SP02-FLT2-04 (#3 bot shoe)	318	0.37	3.8	156.66	152	72	79423	0.108	2E-08	2.12E-06	3%	
SP02-FLT2-04 (#4 whole)	3.8	0.635	3.3	3.02	152	72	11.34	0.317	0.0228	1.969909	7%	t<5s
SP02-FLT2-05 (#5 shoe)	3.8	0.635	1.6	4.51	152	72	11.34	0.317	0.0074	0.639562	5%	t<5s
SP02-FLT2-06 (#1 4')	3.8	0.37	2.9	4.35	152	72	11.34	0.108	0.0047	0.408354	3%	t<5s
SP02-FLT2-03 (#1)	3.8	0.37	3.2	43.12	152	72	11.34	0.108	0.0005	0.045419	1%	
SP02-FLT2-03 (#15 bot)	3.8	0.635	4.2	22.48	152	72	11.34	0.317	0.0039	0.336866	10%	gravel removed
SP02-FLT2-08 (#7, top)	3.85	0.37	2.9	24.97	152	72	11.64	0.108	0.0008	0.069241	2%	
SP02-FLT2-08 (#3 13')	3.8	0.37	3.1	40.05	152	72	11.34	0.108	0.0005	0.04738	12%	RSD, t>10%
SP-03-FLT2-01 (#4)	3.8	0.37	3.2	105.10	152	72	11.34	0.108	0.0002	0.018636	6%	
SP-03-FLT2-01 (#5 bot)	3.8	0.37	3	11.14	152	72	11.34	0.108	0.0019	0.164779	3%	
SP-03-FLT2-01 (#7)	3.8	0.37	2.6	51.11	152	72	11.34	0.108	0.0004	0.031134	5%	
SP-03-FLT2-01 (#10 bot)	3.8	0.635	3.4	22.58	152	72	11.34	0.317	0.0031	0.271493	2%	
SP-03-FLT2-01 (#11)	3.8	0.635	3.8	21.33	152	72	11.34	0.317	0.0037	0.321118	10%	

TABLE 5.3: Results of falling head permeameter tests on aquifer material from the Suncor site. Three tests were done on each sample and only the average is shown here.

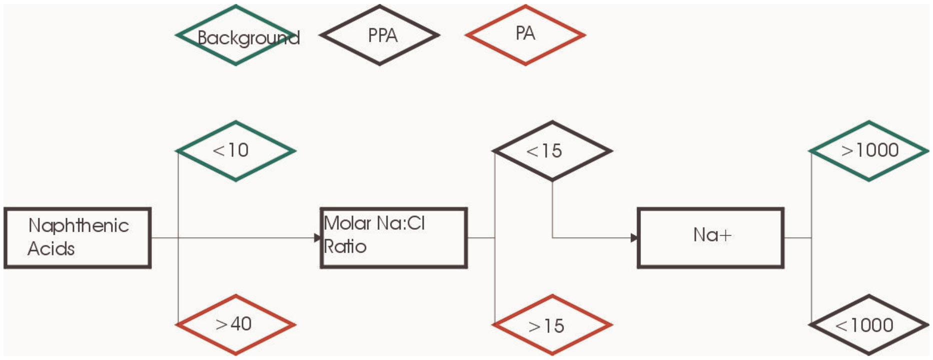


FIGURE 5.17: Dichotomous process-affected water tree developed by Baker (2000) to identify groundwater containing process-affected water from tailings storage ponds and sand tailings pore water. All concentration units are mg/L. PPA=possibly process affected and PA=process affected.

	Values				
Indicator	**0**	**1**	**2**	**3**	**Weighting**
Naphthenic Acid (mg/L)	<10	10-20	20-40	>40*	40
molar Na^+:Cl^-	<5	5-15	>15	—	30
Na^+ (mg/L)	<5 or >1000**	50-200	200-1000	—	20

*definitely process-affected

**saline unit

TABLE 5.4: Index classification scheme for the identification of process-water at Suncor Energy Inc.

The decision tree is simple and straightforward (Figure 5.17). The index method (Table 5.4) assigns numeric values to each groundwater sample, where <30% indicates a background or uncontaminated sample; 30-75% means the sample is possibly process affected (PPA) and that its classification must be guided by a hydrogeologist; and >75% means the sample is definitely process-affected (PA). Values are assigned to each indicator based on dissolved concentration and then weighted according to the importance of the descriptor (Baker, 2000). Table 5.5 presents the results of the PA tree analysis and the index method.

	Data (mg/L)							Classification	
Sample Name	**Naph Acid**	**Cl**	**Na**	**Naph acids (mg/L)**	**Na^+: Cl^-**	**Na^+ (mg/L)**	**Weighting**	**Tree**	**Index**
ENV2000-2	2	7.6	95.8	0	60	20	45%	**Background**	**Background**
ENV91-7B Aug 2003	15	8.7	142	40	60	20	66%	**PPA**	**PA**
ENV91-7B Apr2003	18	7.8	161	40	60	20	69%	**PPA**	**PA**
ENV92-10B	37	9	167	80	60	20	86%	**PA**	**PA**
SP-02-FLT2-01	10	11.9	107	40	30	20	47%	**PPA**	**PPA**
SP-02-FLT2-02	19	14.3	113	40	30	20	46%	**PPA**	**PPA**
SP-02-FLT2-04	0	11	90	0	30	20	28%	**Background**	**Background**
SP-02-FLT2-05	29	14.7	216	80	60	40	92%	**PA**	**PA**
SP-02-FLT2-09	34	46.4	205	80	30	40	71%	**PPA**	**PPA**
SP-03-FLT2-01	0	3.8	32.8	0	30	20	29%	**Background**	**Background**
SP-03-FLT2-02	0	0.9	16.9	0	60	20	50%	**PPA**	**Background**
SP-03-FLT2-04	27	8	114	80	60	20	83%	**PA**	**PA**
SP-03-FLT2-05	26	9.1	139	80	60	20	83%	**PA**	**PA**
SP-03-FLT2-06	17	7.7	58.9	40	30	20	46%	**PPA**	**PPA**
WP-03-FLT2-1.01	20	16.8	81.8	80	30	20	63%	**PPA**	**PPA**
WP-03-FLT2-1.02	22	9.9	71.4	80	30	20	64%	**PPA**	**PPA**
WP-03-FLT2-1.03	23	9.6	146	80	60	20	83%	**PA**	**PA**
WP-03-FLT2-1.04	32	10	146	80	60	20	83%	**PA**	**PA**
WP-03-FLT2-2.02	44	8.5	135	120	60	20	102%	**PA**	**PA**
WP-03-FLT2-2.03	51	8.2		120	0	n/a	55%	**no sodium**	**
WP-03-FLT2-2.04	48	8.3	164	120	60	20	105%	**PA**	**PA**
WP-03-FLT2-2.05	40	8.1		120	0	n/a	55%	**no sodium**	**
WP-03-FLT2-2.06	34	8.4	125	80	60	20	83%	**PA**	**PA**
WP-03-FLT2-2.08	40	38		120	0	n/a	55%	**no sodium**	**
WP-03-FLT2-2.09	44	8	166	120	60	20	105%	**PA**	**PA**
WP-03-FLT2-2.10	43	8.2		120	0	n/a	55%	**no sodium**	**
WP-03-FLT2-2.11	45	8.1	157	120	60	20	104%	**PA**	**PA**
WP-03-FLT2-3.02	36	8.7	161	80	60	20	86%	**PPA**	**PA**
WP-03-FLT2-3.03	39	8.3	169	80	60	20	87%	**PPA**	**PA**
WP-03-FLT2-3.04	38	8.8	175	80	60	20	87%	**PPA**	**PA**
WP-03-FLT2-3.05	32	8.5	8.2	80	0	20	46%	**PPA**	**PPA**
WP-03-FLT2-3.06	18	8.7	120	40	60	20	64%	**PPA**	**PA**
WP-03-FLT2-3.07	17	8	113	40	60	20	64%	**PPA**	**PA**
WP-03-FLT2-4.02	3	5.9	53	0	30	20	29%	**Background**	**Background**
WP-03-FLT2-4.03	11	7	60.8	40	30	20	47%	**PPA**	**PPA**
WP-03-FLT2-4.04	20	10.3	114	80	60	20	80%	**PPA**	**PA**
WP-03-FLT2-4.06	20	9.2		80	0	n/a	36%	**no sodium**	**

Table 5.5: Results of the process-affected water decision tree and index method for the Southwest Aquifer samples (Suncor Energy Inc). PA means process-affected water and PPA means possibly process-affected water.

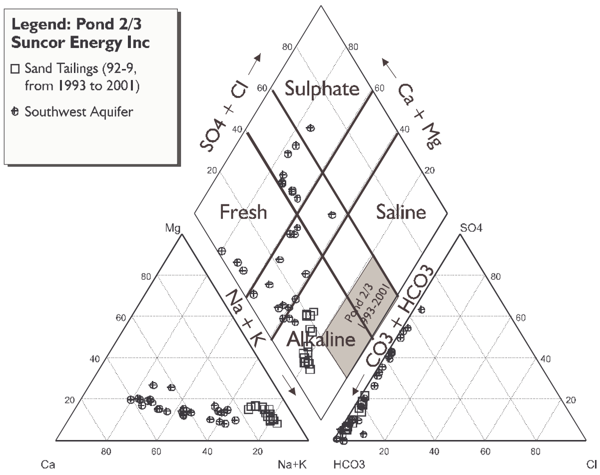


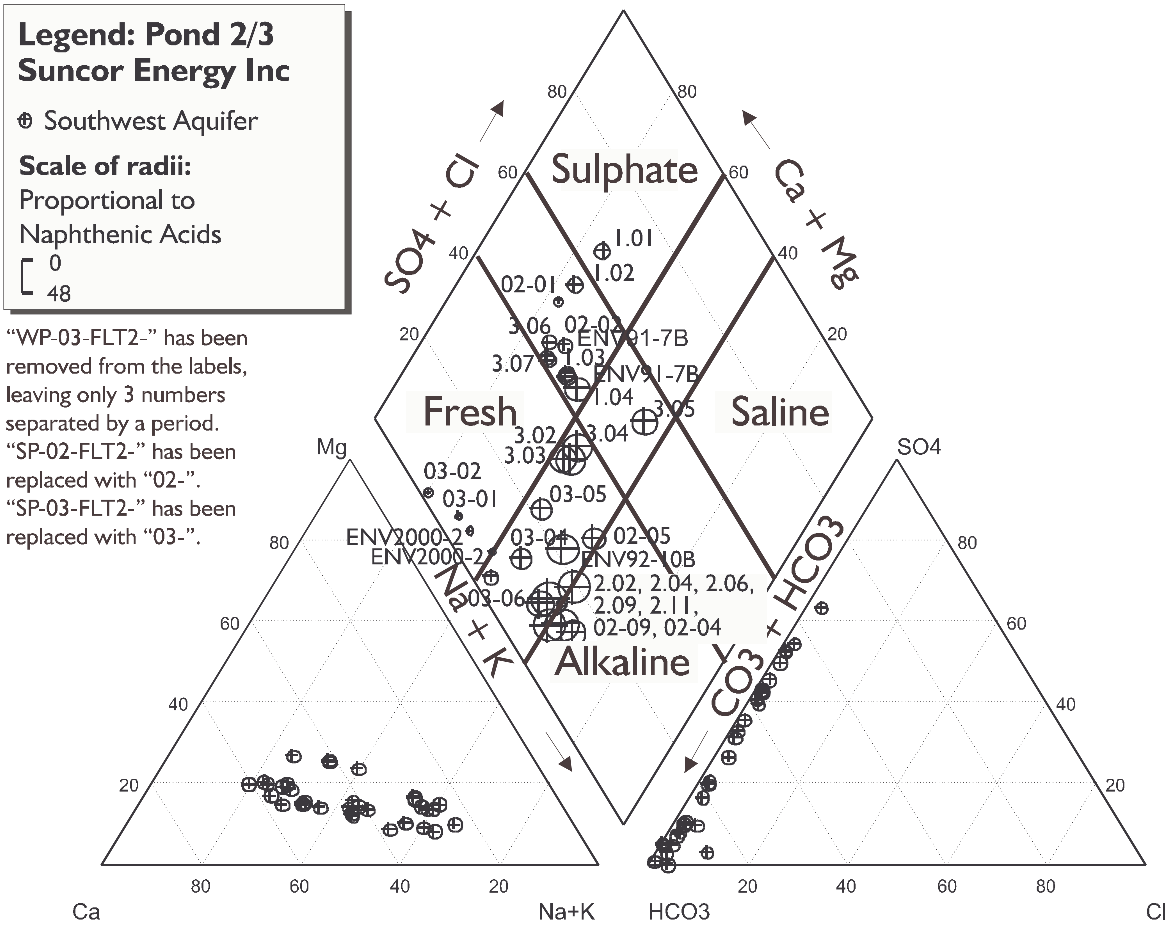
FIGURE 5.18: The distribution of sampling points of the Southwest Aquifer, Pond 2/3 and the sand tailings.

5.5.2.2 Piper Diagram

The Piper diagram plots the major groundwater ions as percentages of milliequivalents in two base triangles, one for cations and one for anions. The data points in the two triangles are projected onto a diamond shaped grid. The Piper diagram highlights sample clusters or systematic changes in composition due to mixing or hydrogeochemical reactions. A Suncor classification scheme distinguishes four groups according to the position the water sample plots on the Piper diagram (Figure 5.18).

This scheme has been successful in classifying the groundwater and surface water at Suncor, which generally correlate with the origin of the groundwater or surface water, or the processes affecting the groundwater along its flowpath. Other than a change in the extraction process in 1998 which increased sulfate concentrations, surface water from Pond 2/3 plots as alkaline water (Evison, 2002). Samples from ENV92-9, a shallow well screened in the tailings sands of Dyke 2W, also plots as alkaline (Figure 5.18).

The three samples geographically furthest from Pond 2/3 (SP-03-FLT2-01, -02 and ENV00-02) plot in the fresh water hydrogeochemical facies (Figure 5.19), suggesting that the process affected water has not reached these points. Classifying samples within the fresh facies as background water is reinforced by the low naphthenic acids concentration.



"WP-03-FLT2-" has been removed from the labels, leaving only 3 numbers separated by a period. "SP-02-FLT2-" has been replaced with "02-". "SP-03-FLT2-" has been replaced with "03-".

Figure 5.19: Relationship between hydrogeochemical facies and naphthenic acids concentration.

The classification of PA and PPA samples is more complicated. Along the base of Dyke 2W, WP-03-FLT2-1.01 (sample labelled 1.01) plots in the sulfate facies while SP-02-FLT2-09 (labelled 02-09) and WP-03-FLT2-2.02, -2.04 and -2.11 (labelled 2.02, 2.04 and 2.11) plot as alkaline. Sulfate reduction and variable sulfate input over time cause a wide "spread" of the samples that can be considered process affected. Since the only sample of sand tailings pore water (ENV92-9), as well as Pond 2/3, plot in the alkaline hydrogeochemical facies, then only samples that plot here were considered process affected. Samples that were neither fresh nor alkaline were classified as possibly process affected. Alkaline samples have the highest naphthenic acids concentration, although samples intermediate between the sulfate and alkaline facies may also have high NA concentrations.

5.5.2.3 Stable Isotopes

The Clark Hot Water Process mixes oil sands and water at an approximate temperature of 80°C, then the leftover water is dumped along with the sand and fine tailings into the holding ponds. The water may then become trapped in sand tailings pore spaces or be reused for processing. Heating leads to evaporation, which causes the water phase to become enriched in the heavier oxygen-18 and deuterium isotopes with respect to the isotope distribution in local precipitation. The main processes that affect oxygen and hydrogen isotopic composition of groundwater are phase changes such as evaporation and simple mixing at or below the surface (Sidle, 1998). If the isotope ratios for precipitation in an area are known, it is possible to fit a line to the data called the local meteoric water line (LMWL). Since process-affected water would be further evaporated than local precipitation, it would plot below and to the right of the LMWL. It may therefore be possible to identify groundwater that contains process-affected water.

While no historical data for Fort McMurray or the mine sites were found, there are two CNIP Climate Stations that bracket the mines, one to the north in Fort Smith, Northwest Territories, and one to the south in Edmonton, Alberta (IAEA, 2004). LMWLs were created for these two stations (Figure 5.20) using all the data points in the database. Then the groundwater samples from the SW Aquifer were plotted on the same graph (Table 5.6). The majority of the SW Aquifer data points plot below the two LMWLs, as expected for evaporated water. The line is a good fit (R^2=0.9518). The naphthenic acids concentration increases as the water becomes enriched in oxygen-18, suggesting that this line represents not a Suncor local meteoric water line but a mixing line between meteoric water infiltration and evaporated tailings sands pore water.

If this supposition is correct, then it is possible to use this graph to identify groundwater samples which are background, possibly process affected (PPA) and process affected (PA) (Table 5.9). The three samples near the LMWLs would be classified as background (Figure 5.20). WP-03-FLT2-4.02 plots on the Edmonton LMWL, and the naphthenic acids concentration is so low at 3 mg/L that the bubble is barely visible. This sample is also classified as background since the NA concentration falls within normal background range (Schramm et al., 2000). WP-03-FLT2-4.03 is considered to be possibly process-affected water. Two points in the cluster of high naphthenic acids concentration plot slightly higher than the others and so WP-03-

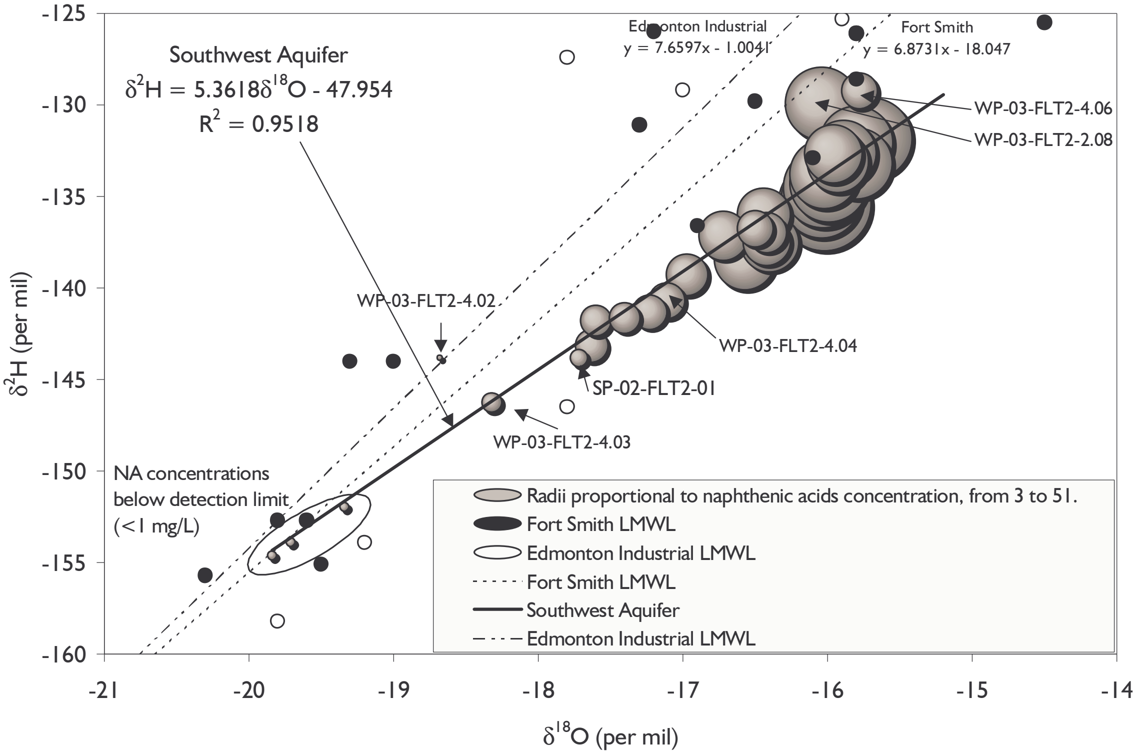


FIGURE 5.20: The stable isotope deuterium and oxygen-18 concentration in groundwater samples from the Southwest Aquifer relative to local meteoric water lines to the north (Fort Smith station) and south (Edmonton Industrial station).

FLT2-2.08 and WP-03-FLT2-4.06 are also classified as PPA. All other samples are considered to be process-affected.

5.5.2.4 Tritium

Since 1953, tritium levels in precipitation has been measured at several monitoring stations in central and western Canada (IAEA, 2004). The most complete data set was collected at the Ottawa station (1953-2001); but samples were also collected at the Edmonton Industrial station from 1961 to 1969, the peak time frame for atmospheric input from nuclear bomb testing. Partial tritium data from 1978 are also available for Wynyard, Saskatchewan and Fort Smith, Alberta. The data from these stations show a similar pattern for all locations (Figure 5.21). In 2001, the tritium levels ranged from 12.5 to 45 TUs and the average for the last five years of measurement

Sample	18O SMOW	2H	Lab Repeat	Sample	18O SMOW	2H	Lab Repeat
WP-03-FLT2-1.1	-16.50	-136.86	-136.68	WP-03-FLT2-3.5	-16.40	-136.94	-138.11
WP-03-FLT2-1.2	-16.42	-136.61	-137.34	WP-03-FLT2-3.6	-17.63	-142.51	-143.81
WP-03-FLT2-1.3	-16.97	-139.38	-139.20	WP-03-FLT2-3.7	-17.60	-141.99	-141.61
Lab Repeat	-17.03			WP-03-FLT2-3.8	-18.19	-144.81	-145.33
WP-03-FLT2-1.4	-15.96	-132.36	-132.99	WP-03-FLT2-4.2	-18.68	-144.22	-143.41
WP-03-FLT2-2.2	-16.04	-134.62	-135.53	WP-03-FLT2-4.3	-18.32	-147.12	-145.40
Lab Repeat				WP-03-FLT2-4.4	-17.11	-140.23	-141.18
WP-03-FLT2-2.3	-16.02	-135.13	-135.75	WP-03-FLT2-4.5	-16.99	-140.46	-140.30
WP-03-FLT2-2.4	-15.82	-132.83	-131.98	WP-03-FLT2-4.6	-15.78	-128.96	-129.54
WP-03-FLT2-2.5	-15.80	-131.54	-132.59	SP-02-FLT2-02	-17.23	-141.68	-140.96
WP-03-FLT2-2.6	-15.93	-132.92	-133.29	SP-02-FLT2-04	-19.34	-152.32	-151.62
WP-03-FLT2-2.7	-15.88	-134.11	-134.19	SP-02-FLT2-01	-17.72	-143.85	-143.81
Lab Repeat	-16.04			SP-02-FLT2-05	-16.44	-136.12	-135.84
WP-03-FLT2-2.8	-16.04	-129.51	-130.36	SP-02-FLT2-09	-16.57	-138.55	-138.32
WP-03-FLT2-2.9	-16.03	-135.02	-134.05	SP-03-FLT2-06	-17.40	-141.88	-141.38
WP-03-FLT2-2.10	-15.99	-134.19	-134.36	Lab Repeat			
Lab Repeat	-15.86			SP-03-FLT2-04	-16.72	-137.37	-136.92
WP-03-FLT2-2.11	-15.70	-131.27	-132.42	SP-03-FLT2-05	-16.42	-138.32	-136.65
WP-03-FLT2-3.2	-15.89	-131.16	-134.12	SP-03-FLT2-01	-19.71	-153.95	-153.82
WP-03-FLT2-3.3	-15.80	-132.94	-133.45	SP-03-FLT2-02	-19.84	-154.53	-154.68
WP-03-FLT2-3.4	-16.02	-134.34	-133.20	SP-03-FLT2-02D	-19.86	-154.89	-154.12

TABLE 5.6: Stable isotope concentrations in July 2003 ground water samples from Suncor Energy Inc.

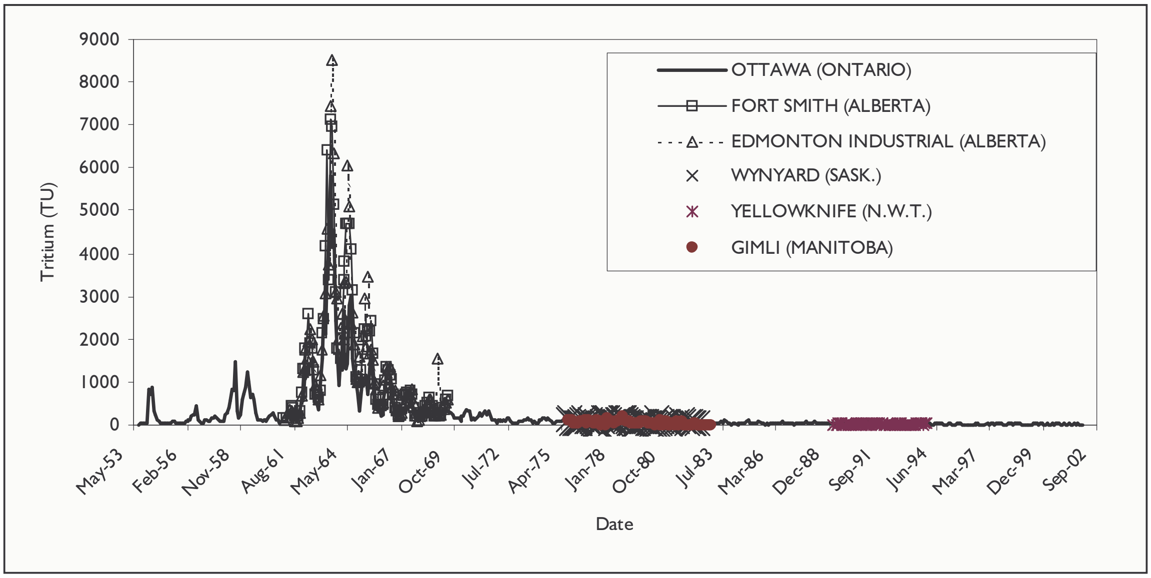


FIGURE 5.21: Historical tritium levels in precipitation in Ottawa, Ontario and various stations located near northern Alberta.

Sample	3H	Sample	3H	Sample	3H
WP-03-FLT2-1.1	18 +/- 8	WP-03-FLT2-2.10	27 +/- 8	WP-03-FLT2-4.5	16 +/- 8
WP-03-FLT2-1.2	27 +/- 8	WP-03-FLT2-2.11	25 +/- 8	WP-03-FLT2-4.6	20 +/- 8
WP-03-FLT2-1.3	21 +/- 8	WP-03-FLT2-3.2	30 +/- 8	SP-02-FLT2-02	28 +/- 8
WP-03-FLT2-1.4	27 +/- 8	WP-03-FLT2-3.3	25 +/- 8	SP-02-FLT2-04	14 +/- 8
WP-03-FLT2-2.2	18 +/- 8	WP-03-FLT2-3.4	23 +/- 8	SP-02-FLT2-01	26 +/- 8
Lab Repeat	23 +/- 8	Lab Repeat	21 +/- 8	SP-02-FLT2-05	21 +/- 8
WP-03-FLT2-2.3	27 +/- 8	WP-03-FLT2-3.5	22 +/- 8	SP-02-FLT2-09	18 +/- 8
WP-03-FLT2-2.4	22 +/- 8	WP-03-FLT2-3.6	30 +/- 8	SP-03-FLT2-06	25 +/- 8
WP-03-FLT2-2.5	20 +/- 8	WP-03-FLT2-3.7	30 +/- 8	Lab Repeat	19 +/- 8
WP-03-FLT2-2.6	22 +/- 8	WP-03-FLT2-3.8	13 +/- 8	SP-03-FLT2-04	17 +/- 8
WP-03-FLT2-2.7	19 +/- 8	WP-03-FLT2-4.2	13 +/- 8	SP-03-FLT2-05	34 +/- 8
WP-03-FLT2-2.8	22 +/- 8	WP-03-FLT2-4.3	7 +/- 8	SP-03-FLT2-01	<6 +/- 8
WP-03-FLT2-2.9	32 +/- 8	WP-03-FLT2-4.4	14 +/- 8	SP-03-FLT2-02	<6 +/- 8
				SP-03-FLT2-02D	<6 +/- 8

TABLE 5.7: Tritium levels for 2003 water samples from Suncor Energy Inc. Values are presented in tritium units (TUs).

(1996-2001) was 20±2 TUs.

Mining started in 1973 and tailings operations along Dyke 2W started in 1978 (AGRA, 1998). Unfortunately, except for the two piezometers geographically furthest from Dyke 2W, tritium levels in the Southwest Aquifer (Table 5.7) fall within the range found in both modern precipitation and decayed 1978, 1988 and 1998 values. It is not possible to distinguish between decayed samples that entered at different time periods (Table 5.8). This method allows the identification of two samples (SP-03-FLT2-01 and SP-03-FLT2-02) as pre-1952 water and therefore background. All other samples are unclassified.

5.5.2.5 Summary

Using the different classification methods, samples were classified as either background water, may contain process-affected water (PPA) and does contain process-affected water (PA) (Table 5.9). Figure 5.22 shows a plume of process-affected and possibly-process-affected groundwater extending at least to SP-02-FLT2-05.

5.5.3 Naphthenic Acids

The measured naphthenic acids concentrations vary from 0 to 51 mg/L along the two transects; ENV92-9, screened in sands tailings, has the highest NA concentrations at 72 mg/L (Figure 5.23). The naphthenic acids 10 mg/L contour line does not always

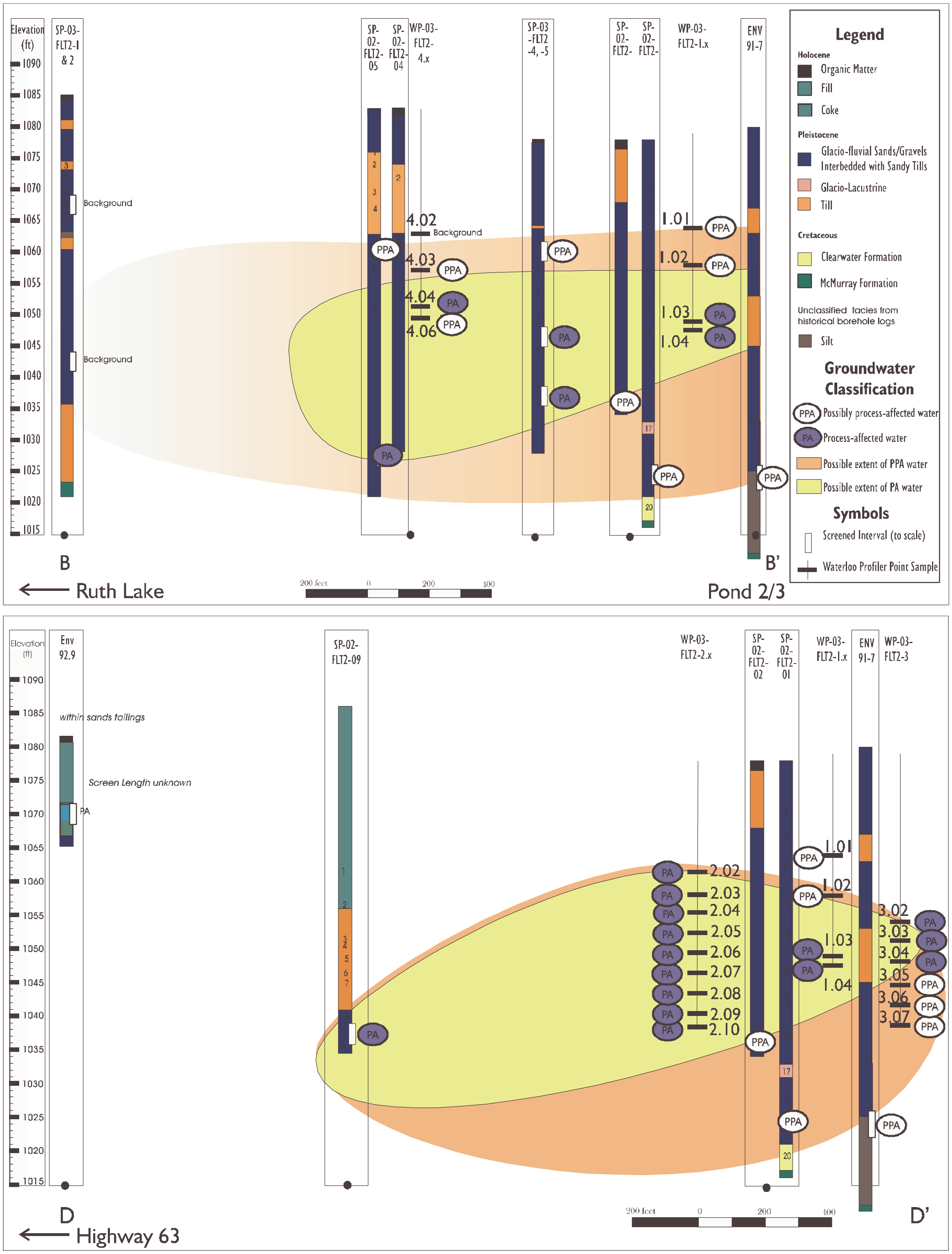


FIGURE 5.22: Distribution of process-affected water along section B-B' and D-D' near Pond 2/3.

	Observed Activity in Precipitation: 1978 (TU)		Calculated Activity in Ground Water: 2003 (TU)	
Station	Measured minimum	Measured maximum	Calculated minimum	Calculated maximum
Ottawa	36	135	9	33
Gimli, Manitoby	30	184	7	45
Wynward, Manitoba	34	173	8	43

	Observed Activity in Precipitation: 1988 (TU)		Calculated Activity in Ground Water: 2003 (TU)	
Station	Measured minimum	Measured maximum	Calculated minimum	Calculated maximum
Ottawa	23	61	10	26

	Observed Activity in Precipitation: 1998 (TU)		Calculated Activity in Ground Water: 2003 (TU)	
Station	Measured minimum	Measured maximum	Calculated minimum	Calculated maximum
Ottawa	10	36	8	27

Table 5.8: Tritium levels for 1978, 1988 and 1998.

include all the PA and PPA water, showing the complexity of classifying samples as process-affected.

5.5.4 Naphthenic Acids "Signature"

Samples were analyzed by the gas chromatograph-mass spectrometer method which allows a semi-quantitative characterization of the naphthenic acids present in a sample (St John et al., 1998). The relative proportions are usually shown in a graphical format after Holowenko *et al.* (2002). The bars represent the percentage of NAs in the mixture that can account for a given carbon number of a given Z family (a specific m/z value). The sum of all bars equals 100% and so the relative proportion of homologues is displayed (Holowenko *et al.*, 2002). The 3D graphs illustrate the distinct signatures that can be seen when naphthenic acids from different groundwater samples are analyzed.

Groundwater samples were collected in a line along the base of Dyke 2W (section D-D') and perpendicular to the dyke (section B-B'). Only one NA sample for detailed characterization was taken per vertical profile, indicated by an X in Figure 5.23.

Three processes were examined in the laboratory to determine their effect on the NA "signature": sorption, anaerobic biodegradation and aerobic biodegradation.

Sample ID	Weighted Indicator	Decision Tree	Piper	Stable Isotopes	Tritium	Final Classification
ENV2000-2	Background	Background	Background	*	*	Background
ENV91-7B Apr2003	PPA	PA	PPA	*	*	PPA
ENV91-7B Aug 2003	PPA	PA	PPA	*	*	PPA
ENV92-10B	PPA	PA	PPA	*	*	PPA
SP-02-FLT2-01	PPA	PPA	PPA	PA	unclassified	PPA
SP-02-FLT2-02	PPA	PPA	PPA	PA	unclassified	PPA
SP-02-FLT2-04	Background	Background	PPA	Background	unclassified	PPA
SP-02-FLT2-05	PA	PA	PPA	PA	unclassified	PA
SP-02-FLT2-09	PPA	PPA	PPA	PA	unclassified	PA
SP-03-FLT2-01	Background	Background	Background	Background	Background	Background
SP-03-FLT2-02	PPA	Background	Background	Background	Background	Background
SP-03-FLT2-04	PA	PA	PPA	PA	unclassified	PA
SP-03-FLT2-05	PA	PA	PPA	PA	unclassified	PA
SP-03-FLT2-06	PPA	PPA	PPA	PA	unclassified	PPA
WP-03-FLT2-1.01	PPA	PPA	PPA	PA	unclassified	PPA
WP-03-FLT2-1.02	PPA	PPA	PPA	PA	unclassified	PPA
WP-03-FLT2-1.03	PA	PA	PPA	PA	unclassified	PA
WP-03-FLT2-1.04	PA	PA	PPA	PA	unclassified	PA
WP-03-FLT2-2.02	PA	PA	PA	PA	unclassified	PA
WP-03-FLT2-2.03	*	*	*	PA	unclassified	PA
WP-03-FLT2-2.04	PA	PA	PA	PA	unclassified	PA
WP-03-FLT2-2.05	*	*	*	PA	unclassified	PA
WP-03-FLT2-2.06	PA	PA	PPA	PA	unclassified	PA
WP-03-FLT2-2.08	*	*	*	PPA	unclassified	PA
WP-03-FLT2-2.09	PA	PA	PPA	PA	unclassified	PA
WP-03-FLT2-2.10	*	*	*	PA	unclassified	PA
WP-03-FLT2-2.11	PA	PA	PA	PA	unclassified	PA
WP-03-FLT2-3.02	PA	PA	PPA	PA	unclassified	PA
WP-03-FLT2-3.03	PA	PA	PPA	PA	unclassified	PA
WP-03-FLT2-3.04	PA	PA	PPA	PA	unclassified	PA
WP-03-FLT2-3.05	PPA	PPA	PPA	PA	unclassified	PPA
WP-03-FLT2-3.06	PPA	PA	PPA	PA	unclassified	PPA
WP-03-FLT2-3.07	PPA	PA	PPA	PA	unclassified	PPA
WP-03-FLT2-4.02	Background	Background	*	Background	unclassified	Background
WP-03-FLT2-4.03	PPA	PPA	*	PPA	unclassified	PPA
WP-03-FLT2-4.04	PA	PA	*	PA	unclassified	PA
WP-03-FLT2-4.06	*	*	*	PPA	unclassified	PPA

*missing a chemical parameter

Table 5.9: Summary of water classification for Suncor Energy Inc. PA means process affected water and PPA refers to possibly process affected water.

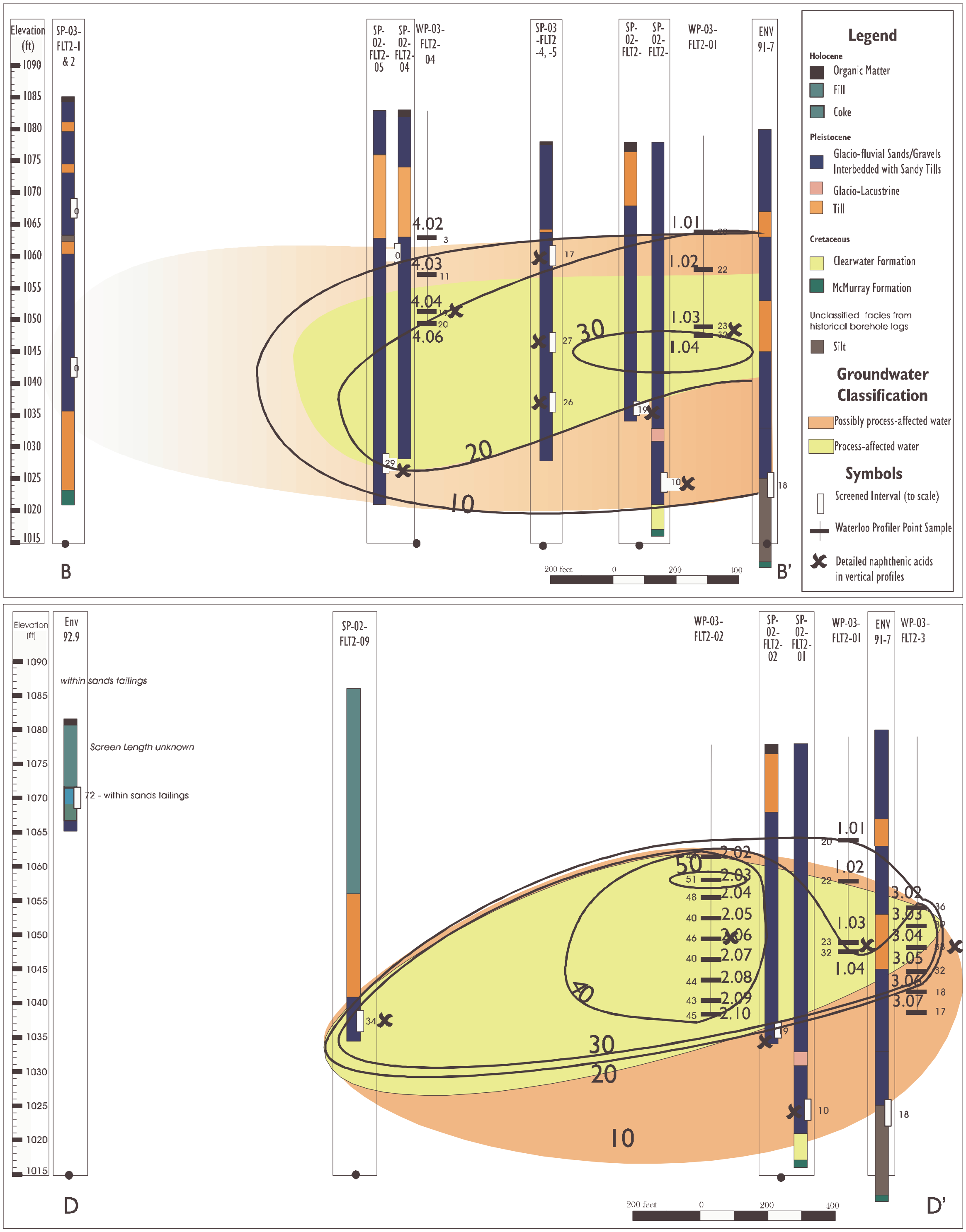


FIGURE 5.23: Distribution of naphthenic acids along the two profiling lines. Naphthenic acids contour lines are in mg/L.

While sorption may be responsible for some natural attenuation, under laboratory conditions this process caused no gross change in the distribution of NA homologues. Measurable anaerobic biodegradation could not be produced in the laboratory microcosms and so no "signature" shift is available. This leaves only one process for which a shift in "signature" was noted. The pattern change for aerobic biodegradation is a decrease in the relative proportion of the low molecular weight homologues in Group 1 ($C \leq 14$) and no change in the mid-weight homologues in Group 2 ($15 \leq C \leq 21$). Because the analytical results are given in percentages, a decrease in the relative proportions of one set of homologues must be accompanied by an increase in another, in this case Group 3 ($C \geq 22$).

A visual examination of the 3D graphs reveals that the homologue distributions in some samples appears to be different than others (Figures 5.26 to 5.36). In order to examine these differences more objectively, a t-test is applied to the results to see if one group from one sample is significantly different than the same group in another sample (Table 5.10).

Unlike the samples near the Muskeg River (Albian Sands), the relative proportions of NA homologues in Group 1 is never significantly different between different samples. Therefore, there is no "signature" shift indicative of aerobic biodegradation. Group 3 homologues do change significantly but Group 3 is more sensitive to being classified as significantly different than the other two groups. Group 1 has 22 homologues, group 2 has 50 and group 3 has 84. Since group 3 contains the majority of homologues and each homologue usually has such a low concentration, changes in relative proportion or analytical variations that would be minor considering the large relative proportions in the first two groups would lead to group 3 being classified as different.

5.5.5 Estimated Naphthenic Acid Concentrations

As with Albian Sands, a trendline was fit to naphthenic acids and conservative chemicals in order to predict decreases in NA concentration due to simple dispersion during groundwater flow. One common step in oil sand processing is the addition of NaOH, leading to sodium concentrations much greater than chloride concentrations. With any particular data set, the molar $Na^+:Cl^-$ ratio was a better fit than sodium alone. The equation of the correlation line of the molar $Na^+:Cl^-$ ratio of the background

		SP-02-FLT2-02	SP-02-FLT2-05	SP-02-FLT2-09	SP-03-FLT2-04	SP-03-FLT2-05	SP-03-FLT2-06	WP-03-FLT2-1	WP-03-FLT2-2	WP-03-FLT2-3	WP-03-FLT2-4
SP-02-FLT2-01	Group 1	0.77	0.93	0.84	0.46	0.42	0.36	0.53	**0.95**	0.84	0.82
	Group 2	0.15	0.08	0.11	0.14	0.43	0.64	0.45	0.21	0.25	0.17
	Group 3	**0.002**	**2.E-05**	**7.E-07**	**3.E-11**	**1.E-09**	**4.E-07**	**1.E-04**	**2.E-03**	**1.E-03**	**4.E-03**
SP-02-FLT2-02	Group 1		0.81	**0.96**	0.55	0.49	0.42	0.63	0.73	**0.99**	0.57
	Group 2		0.58	0.55	0.58	**0.98**	0.70	0.73	0.79	**0.98**	0.74
	Group 3		0.28	**0.06**	**0.0001**	**0.001**	**0.03**	0.48	**0.97**	**0.99**	0.74
SP-02-FLT2-05	Group 1			0.88	0.46	0.43	0.37	0.55	0.88	0.88	0.74
	Group 2			0.92	0.91	0.75	0.47	0.44	0.86	0.65	0.89
	Group 3			0.35	**0.001**	**0.01**	0.18	0.74	0.25	0.27	0.15
SP-02-FLT2-09	Group 1				0.57	0.49	0.42	0.63	0.79	**0.98**	0.66
	Group 2				**0.99**	0.70	0.44	0.43	0.80	0.61	0.82
	Group 3				**0.01**	0.07	0.62	0.23	**0.05**	**0.05**	**0.02**
SP-03-FLT2-04	Group 1					0.78	0.69	**0.99**	0.44	0.63	0.34
	Group 2					0.71	0.46	0.45	0.80	0.63	0.82
	Group 3					0.51	0.07	**0.001**	**0.00003**	**0.00003**	**0.00001**
SP-03-FLT2-05	Group 1						0.92	0.80	0.40	0.53	0.34
	Group 2						0.76	0.80	0.87	**0.99**	0.84
	Group 3						0.24	**0.01**	**0.0004**	**0.0005**	**0.0002**
SP-03-FLT2-06	Group 1							0.72	0.35	0.46	0.29
	Group 2							0.92	0.60	0.72	0.57
	Group 3							0.12	**0.02**	**0.02**	**0.01**
WP-03-FLT2-1	Group 1								0.51	0.67	0.42
	Group 2								0.61	0.75	0.57
	Group 3								0.44	0.47	0.29
WP-03-FLT2-2	Group 1									0.80	0.88
	Group 2									0.82	**0.97**
	Group 3									**0.96**	0.77
WP-03-FLT2-3	Group 1										0.686
	Group 2										0.787
	Group 3										0.723

Table 5.10: Results of the t-test analysis of the extracted and derivatized naphthenic acids from groundwater samples collected at Suncor Energy Inc. Group 1 is composed of carbon number 5 to 13, Group 2 has C14-C21 and Group 3=C22-C33. The numbers in red are considered to be significantly different ($P<0.05$).

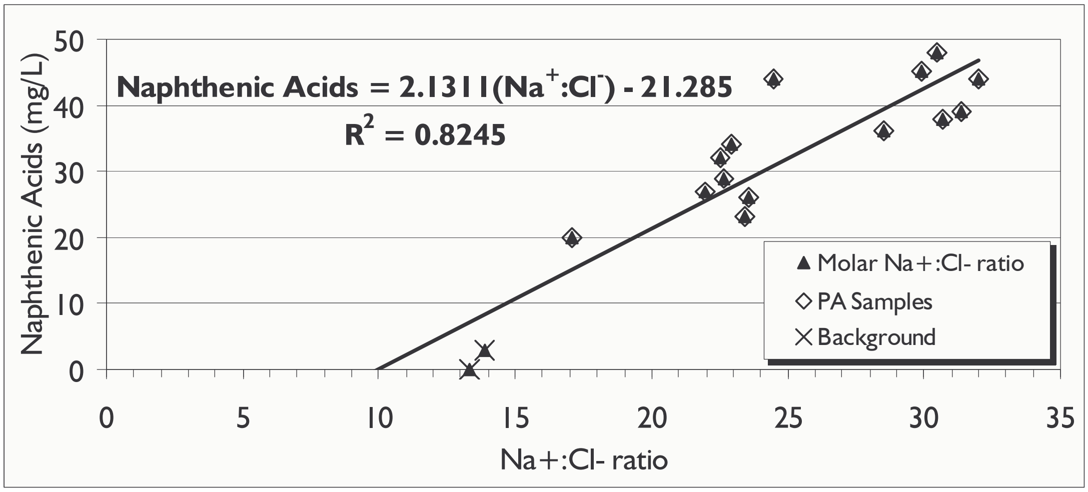


FIGURE 5.24: Correlation line for the molar Na:Cl ratio versus naphthenic acids at the Suncor Mine. Samples classified as PPA were not included in the data set.

and PA samples (no PPA samples) versus NA concentrations is (Figure 5.24):

$$\text{Naphthenic acids} = 2.1311 \times (\text{molar Na}^{+}\text{:Cl}^{-}) - 21.285 \qquad R^2{=}0.8245$$

The x-intercept of 10 makes sense since the dividing line between PA and PPA is 15. The inclusion of PPA samples in the data set decreases the R^2 to 0.6824.

There is no large change in chloride between background and PA water. Most values clustered about 10 mg/L with one sample much lower and one much higher. Therefore, dissolved chloride is not useful on its own.

This correlation assumes a one dimensional flow field, no retardation or attenuation and a single source. The complex geological setting, the presence of the natural wetland as well as the holding pond as possible sources and the muskeg which acts as a discharge zone (i.e. possible vertical flow) indicate that these assumptions may not be valid for this site and may explain the poor correlation when the PPA samples are included in the data set.

Because of the greater complexity of the Suncor plume, the most pessimistic uncertainty calculated in the Albian Sands chapter was used. The samples are considered to have a change in NA concentration within the range of normal analytical uncertainty if the relative standard deviation (RSD) between the measured and predicted concentrations was less than 34%. The majority of samples fall within this range

(Table 5.11). Of the five samples with RSD>34% and measured concentrations less than the predicted concentration, three (SP-03-FLT2-01 and -02, WP-03-FLT2-4.02) are background groundwater samples. SP-02-FLT2-04 is probably background, although it is officially classified as PPA. ENV91-7B should be examined for possible attenuation, especially since it is the only sample to plot away and above a 1 to 1 line of measured versus predicted naphthenic acids concentrations (Figure 5.25).

Three samples that showed a significant difference in the distribution of homologues, SP-02-FLT2-01, SP-02-FLT2-02 and WP-03-FLT2-1.04 all have a measured NA greater than predicted, which provides evidence against biodegradation.

5.5.6 Oxidation Reduction Conditions

There is strong evidence that the SW aquifer is strongly reducing (Tables 5.12). Not only the absence of dissolved oxygen but the presence of reduced nitrogen as ammonium, significant iron(II) and manganese(II) all point to a reducing environment.

5.6 Discussion

If the residual standard deviation between the predicted and measured concentrations was greater than 34%, the samples were considered to have a difference greater than can be accounted for by normal analytical variation. Five samples had measured concentrations less than the predicted concentration. Three of those are background groundwater samples: piezometers SP-03-FLT2-01 and -02 which are geographically distant and vertical profile WP-03-FLT2-4.02 which is near the water table or the bottom of confining unit. Piezometer SP-02-FLT2-04 is probably background, although it is officially classified as PPA. It is the sampling point with the greatest methane concentration, 10 mg/L. ENV91-7B should be examined for possible attenuation, especially since it is the only sample to plot away and above a 1 to 1 line of measured versus predicted naphthenic acids concentrations. The aqueous environment has progressed to iron and manganese reducing but not sulfate reducing or methanogenic. Of the thirty-four groundwater samples for Suncor, five had no sodium data and so were not considered in the previous analysis: WP-03-FLT2-4.06, WP-03-FLT2-2.10, WP-03-FLT2-2.08, WP-03-FLT2-2.05 and WP-03-FLT2-2.03.

Sample Name	Measured Naphthenic acids (mg/L)	Cl (mg/L)	Na (mg/L)	molar Na+:Cl-	Calculated Naphthenic Acids (mg/L)	RSD	Used In correlation
SP-03-FLT2-04	27	8	114	22.0	26	4%	X
WP-03-FLT2-2.11	45	8.1	157	29.9	42	4%	X
WP-03-FLT2-2.09	44	8	166	32.0	47	5%	X
SP-02-FLT2-05	29	14.7	216	22.7	27	5%	X
WP-03-FLT2-3.02	36	8.7	161	28.5	40	7%	X
WP-03-FLT2-2.04	48	8.3	164	30.5	44	7%	X
SP-03-FLT2-05	26	9.1	139	23.6	29	8%	X
WP-03-FLT2-3.04	38	8.8	175	30.7	44	10%	X
WP-03-FLT2-3.03	39	8.3	169	31.4	46	11%	X
WP-03-FLT2-1.04	32	10	146	22.5	27	13%	X
SP-02-FLT2-01	10	11.9	107	13.9	8	13%	
WP-03-FLT2-2.06	34	8.4	125	22.9	28	15%	X
WP-03-FLT2-1.03	23	9.6	146	23.5	29	16%	X
WP-03-FLT2-4.04	20	10.3	114	17.1	15	20%	X
WP-03-FLT2-3.06	18	8.7	120	21.3	24	20%	
WP-03-FLT2-2.02	44	8.5	135	24.5	31	25%	X
WP-03-FLT2-3.07	17	8	113	21.8	25	27%	
WP-03-FLT2-4.03	11	7	60.8	13.4	7	29%	
ENV91-7B Apr2003	18	7.8	161	31.8	47	63%	
WP-03-FLT2-4.02	3	5.9	53	13.9	8	66%	X
SP-02-FLT2-02	19	14.3	113	12.2	5	85%	
SP-03-FLT2-06	17	7.7	58.9	11.8	4	89%	
WP-03-FLT2-1.02	22	9.9	71.4	11.1	2	113%	
SP-03-FLT2-02	0	0.9	16.9	29.0	40	141%	
SP-02-FLT2-04	0	11	90	12.6	6	141%	
SP-03-FLT2-01	0	3.8	32.8	13.3	7	141%	X
SP-02-FLT2-09	34	46.4	205	6.8	-7	212%	
WP-03-FLT2-1.01	20	16.8	81.8	7.5	-5	243%	
WP-03-FLT2-3.05	32	8.5	8.2	1.5	-18	510%	

TABLE 5.11: The calculated naphthenic acids (NA) concentrations was the product of the correlation of measured total naphthenic acid versus the molar sodium:chloride ratio of the samples that were either background or definitely process-affected near Pond 2/3. The table is sorted by relative standard deviation (RSD).

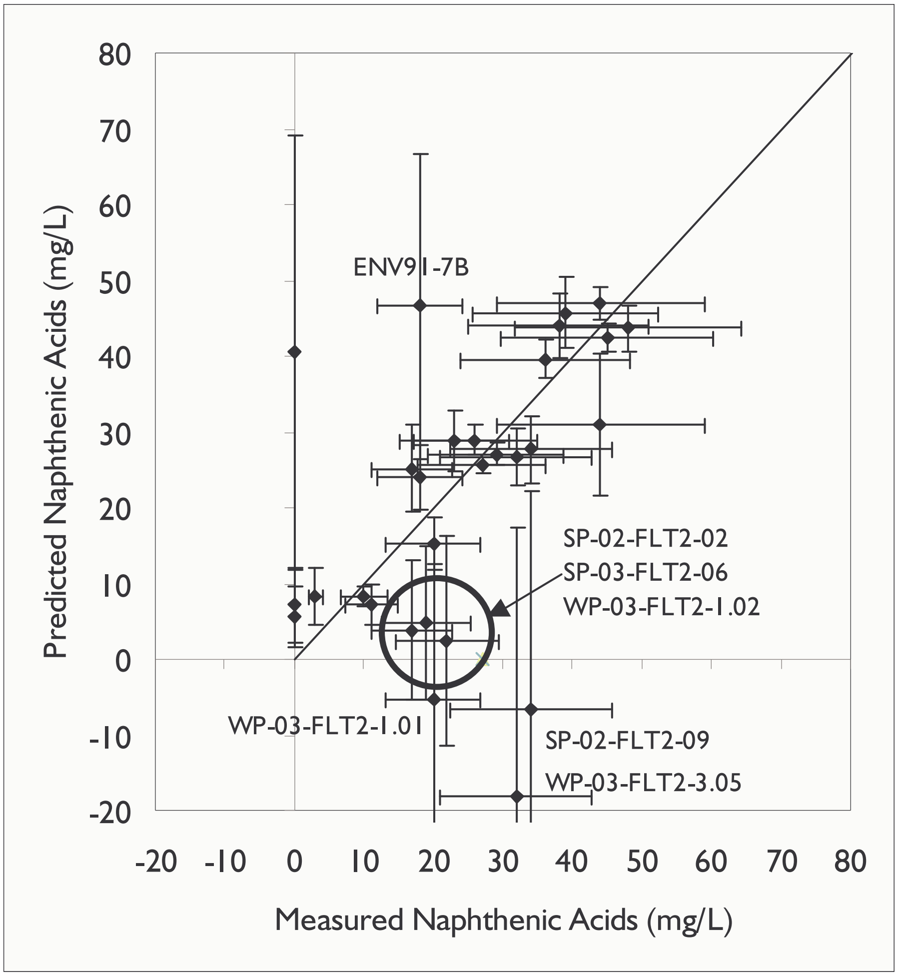


FIGURE 5.25: The measured naphthenic acids concentrations near Pond 2/3 plotted against the predicted concentrations. Horizontal error bars are the 34% relative standard deviation of the measured NA while the vertical error bars are one standard deviation of the measured/predicted values.

Sample Name	DO	NH4	NO3	NO2	Mn	Fe	SO4	CH4
ENV91-7B	0.28	1.15	0.006	0.008	0.232	0.32	462.00	0.028
SP-02-FLT2-01	0.08	0.59	<0.003	<0.003	2.45	0.38	544.00	0.016
SP-02-FLT2-02	0.1	0.55	<0.003	<0.003	1.13	0.03	349.00	0.016
SP-02-FLT2-04	0.1	0.16	0.012	<0.003	0.536	0.07	30.20	10.314
SP-02-FLT2-05	0.5	0.72	<0.003	0.016	0.29	4.72	203.00	0.000
SP-02-FLT2-09	0.1	0.93	ns	ns	0.339	0.26	19.80	0.000
SP-03-FLT2-01	0.03	0.92	<0.003	<0.003	0.217	0.04	6.90	0.000
SP-03-FLT2-02	0.2	0.2	<0.003	<0.003	0.098	<0.01	1.50	1.624
SP-03-FLT2-04	0.1	0.55	<0.003	<0.003	0.502	26.7	53.00	0.001
SP-03-FLT2-05	0.1	0.6	<0.003	0.006	0.247	0.03	133.00	0.008
SP-03-FLT2-06	0.35	0.32	<0.003	<0.003	1.26	0.26	0.10	1.922
WP-03-FLT2-1.01	0.14	ns	0.118	<0.003	21	80.5	507.00	0.021
WP-03-FLT2-1.02	0.13	ns	0.031	0.003	2.22	45.6	384.00	0.020
WP-03-FLT2-1.03	0.07	ns	0.035	<0.003	0.504	0.22	432.00	0.023
WP-03-FLT2-1.04	ns	ns	0.006	<0.003	0.417	0.07	402.00	0.023
WP-03-FLT2-2.02	0.12	ns	0.005	<0.003	0.666	2.02	79.80	0.063
WP-03-FLT2-2.03	ns	ns	<0.003	<0.003	ns	ns	64.50	ns
WP-03-FLT2-2.04	ns	ns	0.056	<0.003	1.47	28.4	53.90	0.031
WP-03-FLT2-2.05	0.1	ns	<0.003	<0.003	ns	ns	50.50	ns
WP-03-FLT2-2.06	0.13	ns	<0.003	<0.003	1.12	14.4	40.70	0.0186
WP-03-FLT2-2.07	ns	ns	<0.003	<0.003	1.14	11.8	42.20	0.0171
WP-03-FLT2-2.08	ns	ns	<0.003	<0.003	ns	ns	42.90	ns
WP-03-FLT2-2.09	0.19	ns	<0.003	<0.003	1.54	9.86	39.60	0.024
WP-03-FLT2-2.10	ns	ns	<0.003	<0.003	ns	ns	46.70	ns
WP-03-FLT2-2.11	0.17	ns	<0.003	<0.003	0.457	9.46	55.80	0.030
WP-03-FLT2-3.02	0.27	ns	<0.003	<0.003	0.29	0.04	256.00	0.002
WP-03-FLT2-3.03	0.2	ns	<0.003	<0.003	0.29	12.9	294.00	0.016
WP-03-FLT2-3.04	0.18	ns	<0.003	<0.003	0.44	13	332.00	0.001
WP-03-FLT2-3.05	ns	ns	<0.003	<0.003	0.05	0.55	613.00	0.002
WP-03-FLT2-3.06	0.2	ns	<0.003	<0.003	0.59	24.3	478.00	0.009
WP-03-FLT2-3.07	0.24	ns	<0.003	<0.003	0.52	0.07	414.00	0.006
WP-03-FLT2-4.02	ns	ns	<0.003	<0.003	0.262	0.37	2.10	0.000
WP-03-FLT2-4.03	ns	ns	<0.003	<0.003	0.506	0.3	0.30	1.103
WP-03-FLT2-4.04	ns	ns	0.007	<0.003	0.33	0.27	0.20	0.304
WP-03-FLT2-4.05	ns	ns	0.006	<0.003	0.32	0.13	0.20	0.553
WP-03-FLT2-4.06	ns	ns	<0.003	<0.003	ns	ns	0.90	ns

ns=no sample taken

Table 5.12: Concentrations of electron acceptors that can act as geochemical indicators of reduction-oxidation conditions at Pond 2/3. All values are given in mg/L.

Sample WP-03-FLT2-4.06 may be degraded. It plots with PA samples on the mixing line (Figure 5.24) but has a lower concentration than its neighbours. Since no sodium data are available, its classification as background, PPA or PA depends entirely on stable isotope data. The vertical profiling point WP-03-FLT2-4.04 and piezometer SP-02-FLT2-05 are downgradient of the piezometer nest SP-03-FLT2-04, -05 and -06 and the detailed NA characterization may indicate aerobic biodegradation between the two locations. However, concentrations are not lower than predicted. The vertical profile WP-03-FLT2-4.x as a whole is sulfate reducing, although only the PPA sample WP-03-FLT2-4.03 shows evidence of having evolved to methanogenic conditions with methane concentrations greater than 1 mg/L. Piezometer SP-02-FLT2-05 is strongly reducing and does show some sulfate reduction, although there is no methane production.

There are two or three areas with hydraulic highs. One area is at SP-03-FLT2-01 and -02, along the proposed flow path from Pond 2/3 to the potential surface receptor, Ruth Lake. Given the groundwater elevations, ground water flow towards Pond 2/3 from the hydraulic high at SP-03-FLT2-01 and -02 is possible. This interpretation is contradicted by the identification of a plume of process-affected water extending towards the hydraulic high. As well, the strong upward vertical gradient suggest that the area near SP-03-FLT2- is a discharge, not a recharge zone.

While hydraulic analysis indicates it is possible ground water has moved up to 1200m, chemical evidence does not support such migration. SP-03-FLT2-01 and -02 show no high concentrations of sodium and it is probable that the plume has not travelled the 550 m distance from Pond 2/3. It has reached the next nearest well, SP-02-FLT2-05 (210 m). The predicted and measured NA concentrations are very similar at this well. From this well, it appears as if the naphthenic acids front coincides with the conservative tracer front.

5.7 Conclusion

The electrical resistivity tomography survey was effective at differentiating between sand and gravel aquifer and clay till; the resistivity changed as the fines content changed. The clay content of the glaciofluvial aquifers meant that Archie's Law calculations to interpret changes in resistivity in terms of pore fluid chemistry was not valid.

The geology, ground water flow patterns and ground water chemistry are complex. Attempts to identify samples as having lower naphthenic acids concentration that expected led to contradictory results. There is no evidence of retardation or attenuation at this site.

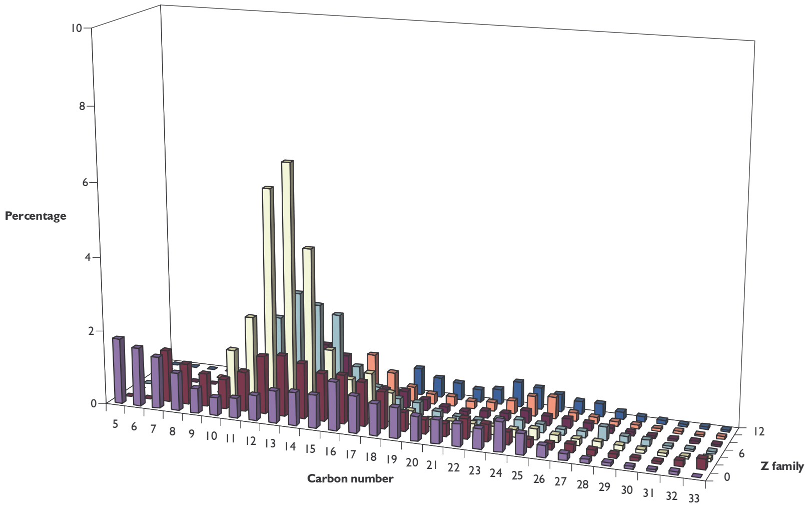


FIGURE 5.26: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample WP-03-FLT2-1.

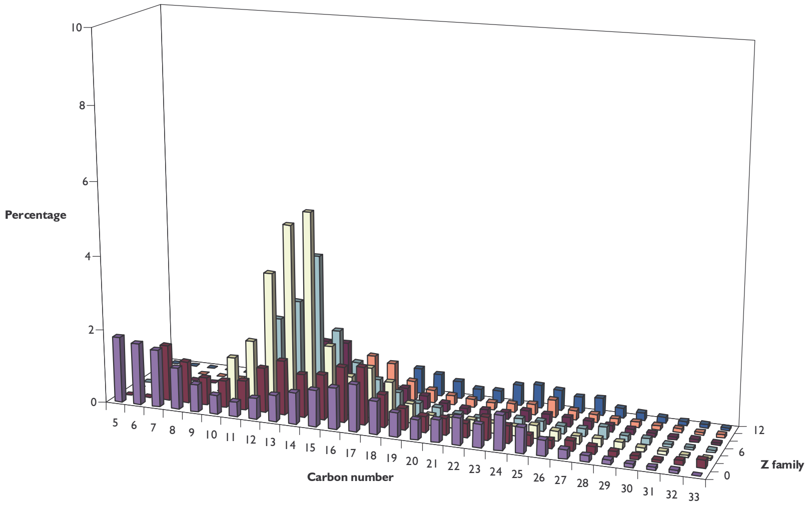


FIGURE 5.27: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample WP-03-FLT2-2.

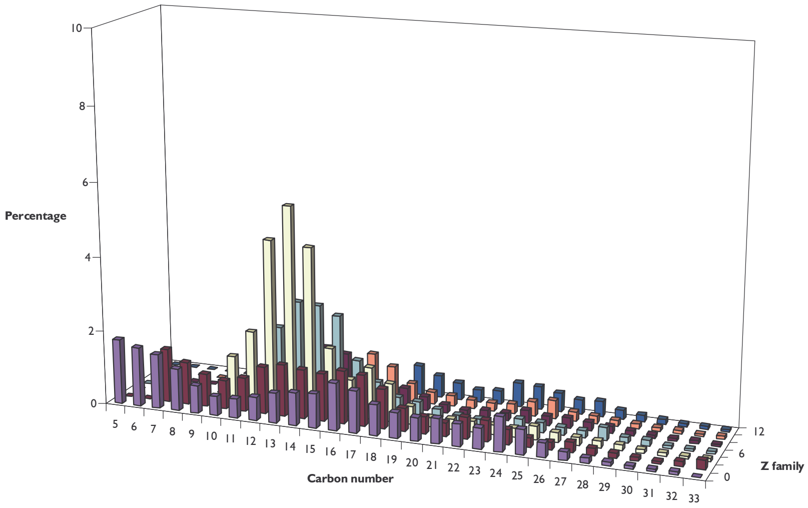


FIGURE 5.28: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample WP-03-FLT2-3.

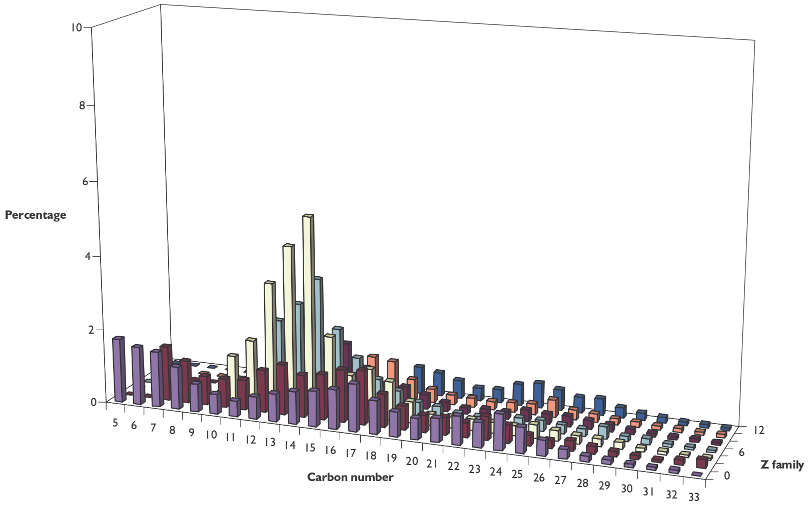


FIGURE 5.29: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample WP-03-FLT2-4.

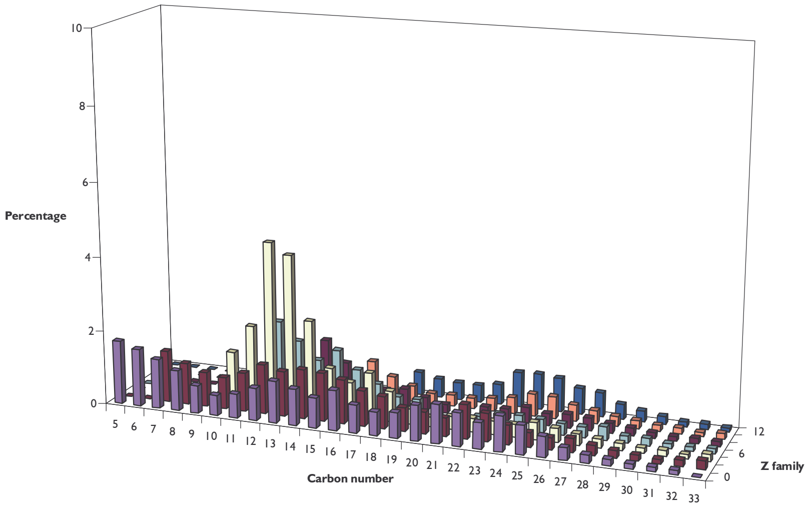


FIGURE 5.30: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample SP-02-FLT2-01.

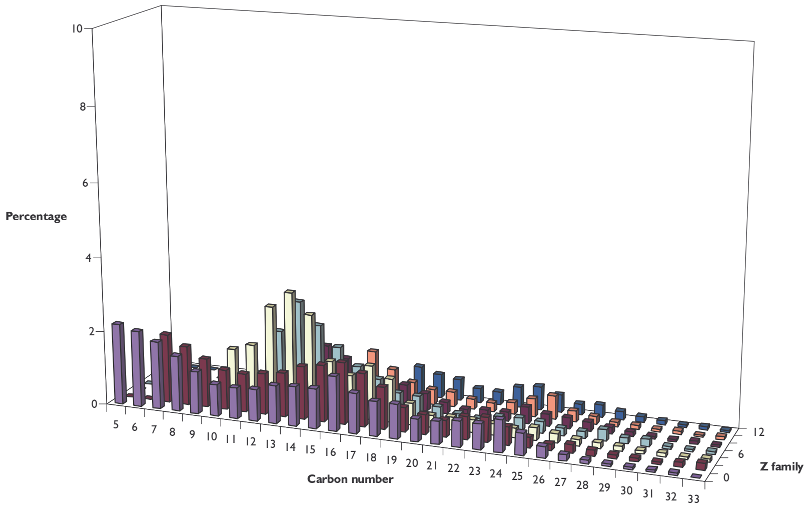


FIGURE 5.31: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample SP-02-FLT2-02.

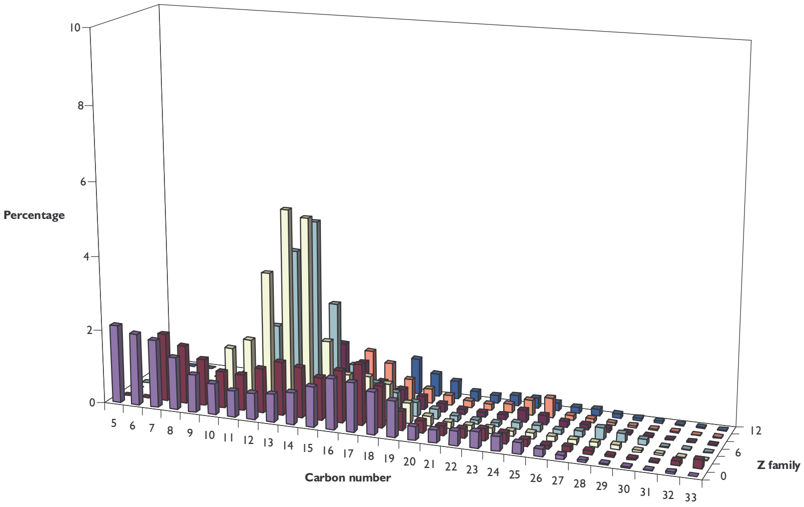


FIGURE 5.32: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample SP-03-FLT2-04.

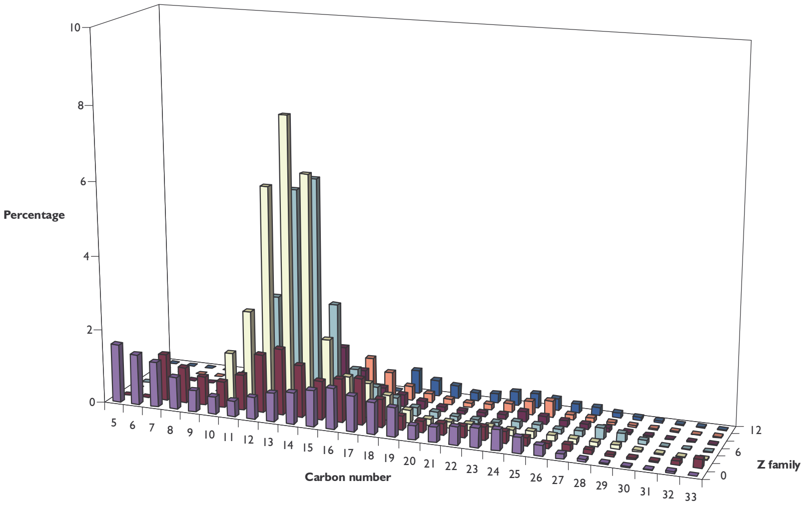


FIGURE 5.33: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample SP-03-FLT2-05.

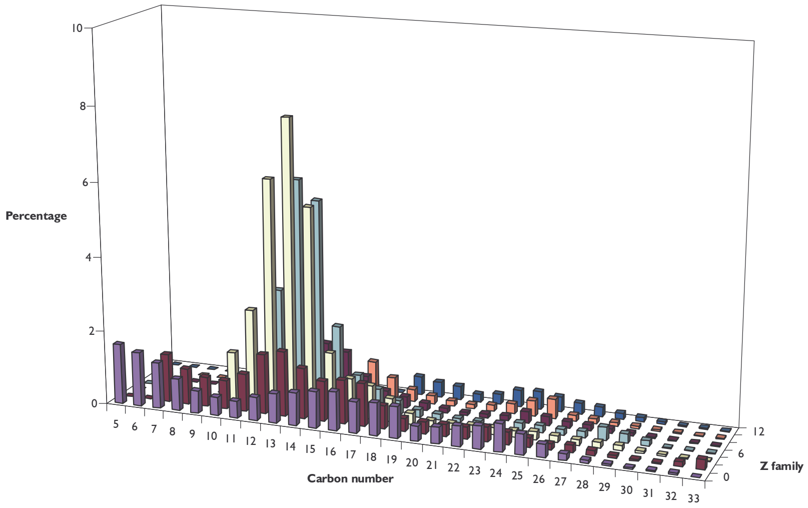


FIGURE 5.34: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample SP-03-FLT2-06.

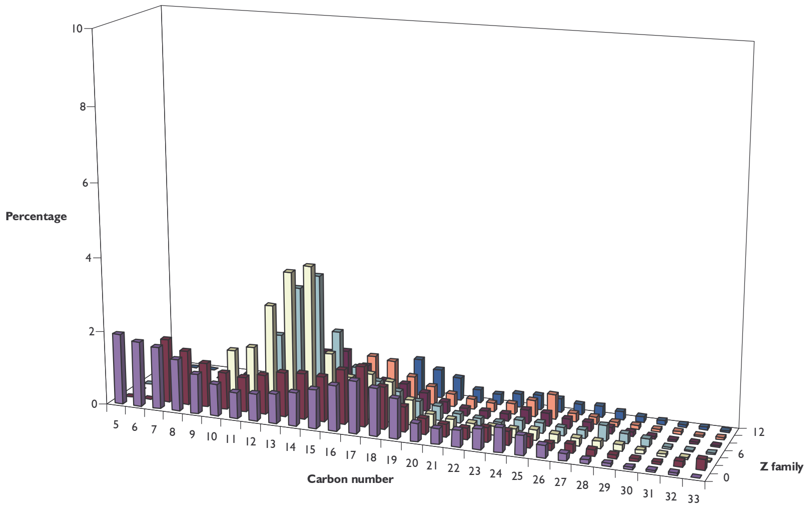


FIGURE 5.35: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample SP-02-FLT2-05.

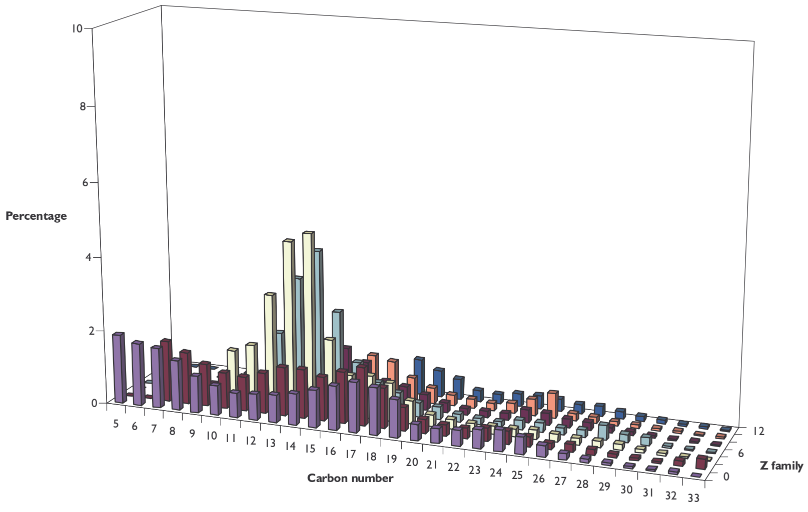


FIGURE 5.36: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample SP-02-FLT2-09.

Chapter 6

Mildred Lake Settling Basin

6.1 Location, Local Geology and Physiography

The Mildred Lake Settling Basin (MLSB), a Syncrude Canada Limited (Syncrude) holding pond, is located near the end of Highway 63 in northern Alberta, Canada (Figure 4.1). The MLSB is north of Fort McMurray (Figure 4.2), on the west side of the Athabasca River near Mildred Lake.

A description of the regional geology can be found in Chapter 4. The local geology east of the Mildred Lake Settling Basin consists of a shallow (maximum of 10 m) unconfined sand and gravel aquifer over till, Clearwater Formation or McMurray Formation (Figure 6.11). Some boreholes contained discontinuous glacio-lacustrine sediments interbedded between the glacio-fluvial sand and gravel facies. Chemical data, water levels and borehole logs for existing piezometers were supplied by Syncrude.

A contractor yard is located at the base of the tailings dyke. Between the contractor yard and the highway margin, the physiography is dry field or trees (Figure 6.1). The highway verge was dry on both sides. Topography is heavily influenced by man-made infrastructure and ground elevation varies by 4 metres (Figure 6.2).

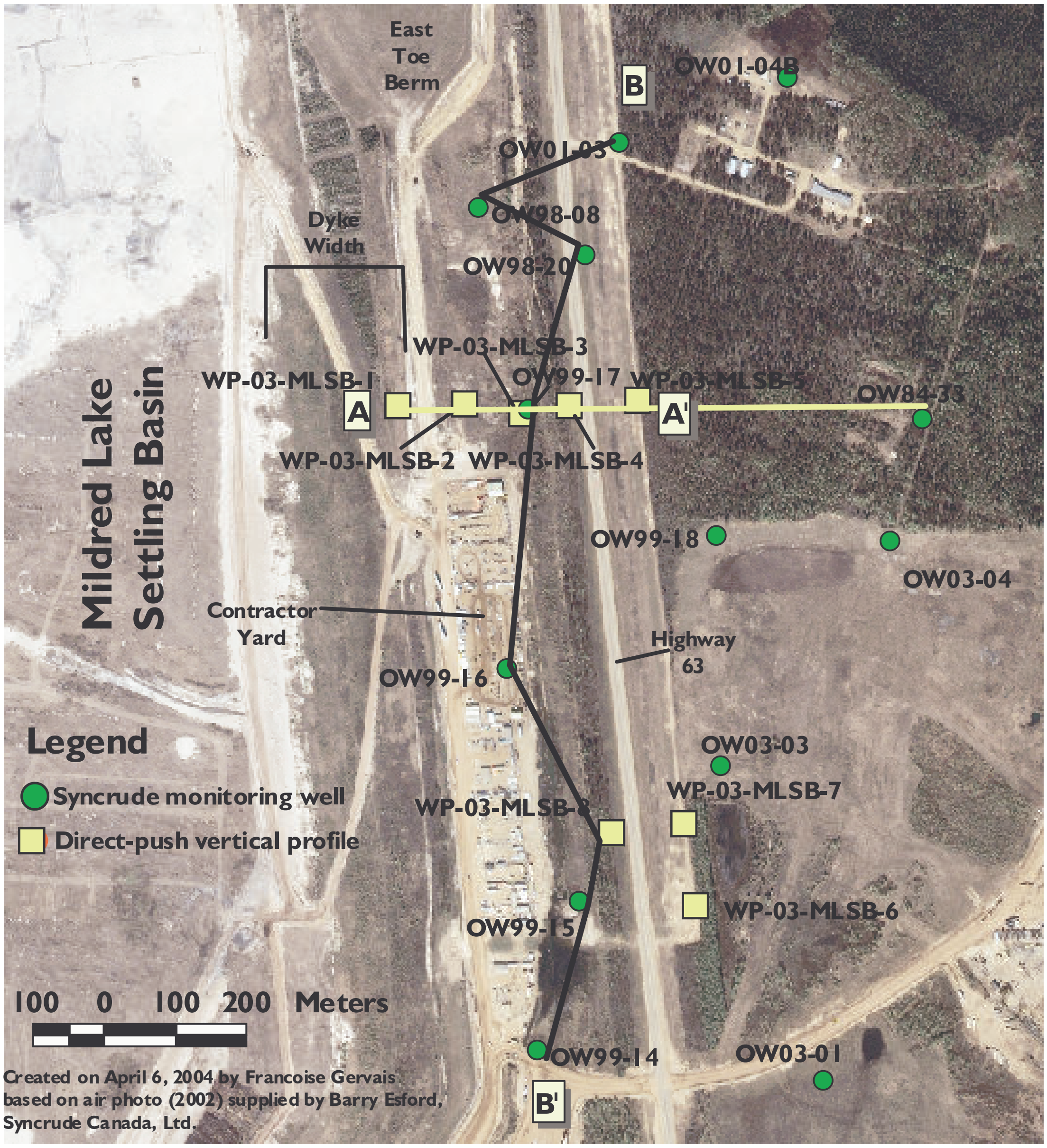


FIGURE 6.1: Air photo of the Mildred Lake Settling Basin, Syncrude Canada Ltd.

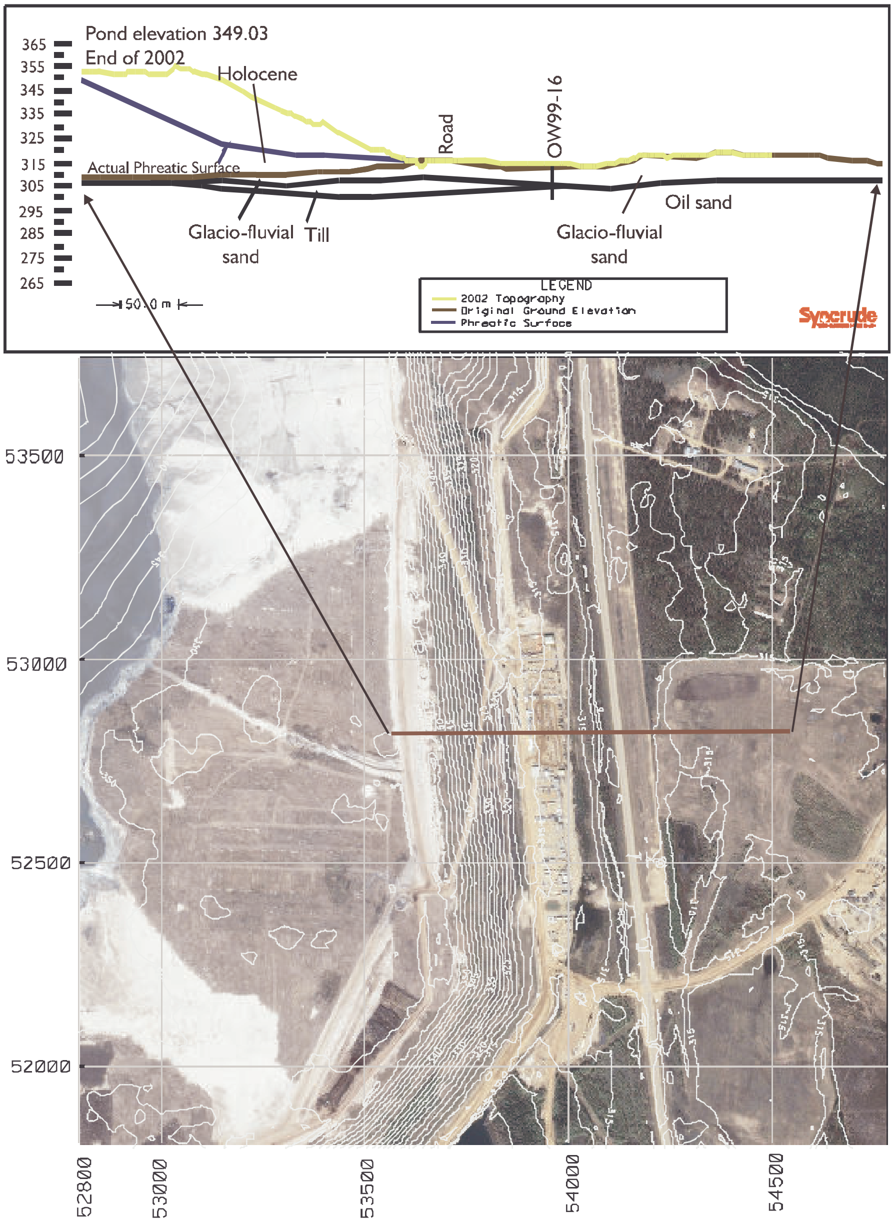


FIGURE 6.2: Topography near the Mildred Lake Settling Basin. Elevation contours are 2.5 intervals.

6.2 Previous Studies

6.2.1 Groundwater Flow Regime

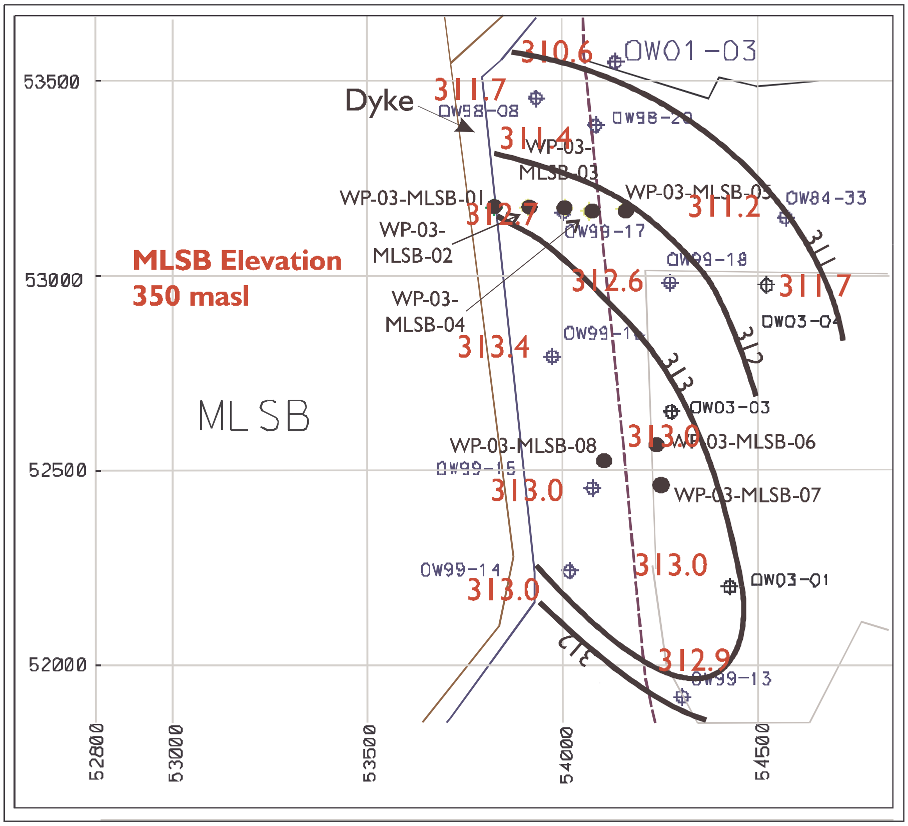
The MLSB was started in 1978. There is no indication of a direct hydraulic connection between the water in the MLSB holding pond and the surficial aquifer, although some seepage may occur. In some areas, a perimeter ditch receives water draining from within the dyke as well as precipitation and this is the likely source of the majority of the aquifer recharge (B. Esford, personal communication, April 13, 2004). Where the ditch is too shallow to act as a hydraulic low (not excavated below the water table) then ditch water enters the aquifer, contributing process affected water to the surficial aquifer. A topographic high in the perimeter ditch forms a groundwater divide, flowing north and south (Figure 6.3). At the time the field sampling was being organized, the monitoring well OW99-17 had the highest hydraulic head in the area and was presumably close to the recharge area.

The East Toe Berm, located north of the study site, was constructed in the spring of 1998 to provide extra storage space for the MLSB (Baker, 1999). An interceptor ditch was dug along the base of the East Toe Berm to provide a hydraulic low and reverse groundwater flow in the area, causing the contaminated water to move back toward the ditch. By 2001, the ditch was no longer controlling seepage and a new plume developed, affecting three wells immediately north of the study site: OW98-07, -21 and -22. These wells are not included in the cross-sections used in this study. To the south, the profiled glacio-fluvial sand and gravel facies pinches out and may mark the southern boundary of the surficial aquifer. Since OW99-12 may be screened in a separate aquifer than the one directly east of the MLSB, it was also excluded.

6.3 Methods

6.3.1 Site Preparation

In July 2003, the Syncrude site was profiled at 8 locations (Figure 6.1). Employees of Syncrude Canada Ltd. ensured all mine regulations regarding digging were observed and all buried utilities were properly located and marked. They also surveyed the drilling sites and coordinates were given in NAD83. Sampling stations were set up



Created on July 16, 2003 by Barry Esford, Syncrude using metric mine coordinate system. Modified by Francoise Gervais February 9, 2004.

⊕ Active Monitoring Wells
● Vertical Profile Locations
--- Highway 63
312.7 Water Elevation (masl)
311 Water table contours (masl)

FIGURE 6.3: Water table map at the east side of the Mildred Lake Settling Basin. Contour lines are based on July 2003 water level data.

either on the tailgate of a truck or on the drill rig. The sampling station was up-wind of any source of exhaust and wind blown contamination.

6.3.2 Sampling

As part of their regular sampling protocol, Syncrude collected samples from the wells in the area. In addition, they collected samples for detailed naphthenic acids analysis, which were sent to the Organic Geochemistry Laboratory at the University of Waterloo. The vertical profiles were collected by Waterloo Profiler. A solid-stem auger was used to drill to the top of the water table and then the profiler rods were advanced using a hydraulic hammer. The profiler was preassembled and field tested as per Appendix I, then decontaminated before the first sample and between each profiling location. The same appendix provides detailed decontamination, sampling, handling and shipping guidelines. Except for the field spike, the same decontamination and quality assurance measures as used at Albian Sands were followed (page 83).

Five of the vertical profiling locations were in an east-west line perpendicular to the eastern dyke of the MLSB. The other three profiling sites attempted to delineate the extent of the plume to the south. One high resolution profile was taken next to piezometer OW99-17; samples were taken every metre. The vertical resolution for the other profiles was 2 metres. Naphthenic acids and chloride were sampled at every depth, but other samples were taken only as flow permitted (Table 6.1). NA samples for detailed characterization were collected once per vertical profile. Field parameters were measured by probes in a flow-through cell and sample bottles were in line with the pump.

6.4 Results and Discussion

6.4.1 Process-Affected Water Identification

High concentrations of bicarbonate, sodium, chloride and NAs characterize process water, although the exact composition changes over time as the source of oil sand or processing changes. The groundwater samples were classified using three methods, one of which included NA as the primary criteria. Since biodegradation or sorp-

Chemical or Physical Parameter, Vertical Profiles	Priority
$Cl^{-} + SO_4^{2-} + NO_3^{1-} + NO_2^{1-}$	1
Total naphthenic acids	1
Major dissolved metal ions: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Fe^{2+}, Mn^{2+}	2
$^{18}O/^{2}H/^{3}H$	2
Detailed characterization of naphthenic acids	2
Field DO/pH/Electrical Conductivity (EC)	3
Aromatic hydrocarbons (C_6 - C_{12})	3
Alkalinity (HCO_3^{-}, CO_3^{2-}, OH^{-})+ pH + Laboratory EC	4
Methane	5

Table 6.1: Table of samples, and their priorities, collected by Waterloo Profiler at Syncrude Canada Ltd.

tion may have occurred, samples were also classified using two methods that were independent of naphthenic acids concentration.

6.4.1.1 MLSB Decision Tree

The primary criteria was NA concentrations greater than that found naturally. The NA concentration in the Athabasca River both up and downstream of the main oil sand deposits as well as in several tributaries in the deposit area did not exceed 1 mg/L (Schramm et al., 2000). At Suncor, the largest background concentration measured in the surficial glacial aquifer is 4 mg/L. The highest NA concentration measured in the Test Pit recharged in part by groundwater from the McMurray Basal Aquifer is 17 mg/L. Syncrude used NA concentrations greater than 30 mg/L; at Suncor, 40 mg/L was chosen as the dividing line between PPA and PA (Baker, 1999; Baker, 2000). The more pessimistic NA concentrations of 40 mg/L or more were used as the first criteria in this study.

Within the group of samples with NA>40 mg/L, chloride concentrations varied from 113 to 258 mg/L (Figure 6.5; Table 6.2) and dissolved sodium concentrations were greater than 250 mg/L. Water samples with naphthenic acid concentrations below the detection limit (1 mg/L) had dissolved chloride concentrations less than 65 mg/L and sodium concentrations were less than 20 mg/L.

It was therefore possible to classify water samples as process-affected (PA), possibly process-affected (PPA) or background (Table 6.6). As shown in Figure 6.4, any

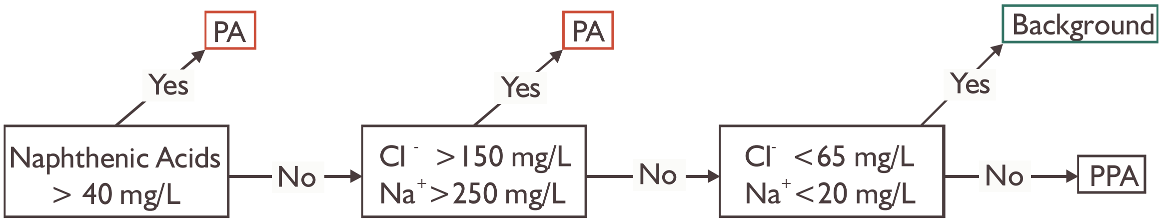


Figure 6.4: MLSB decision tree for groundwater identification.

sample with NA > 40 mg/L was considered PA. However, since sorption or biodegradation can change NA concentrations, conservative tracers were also considered.

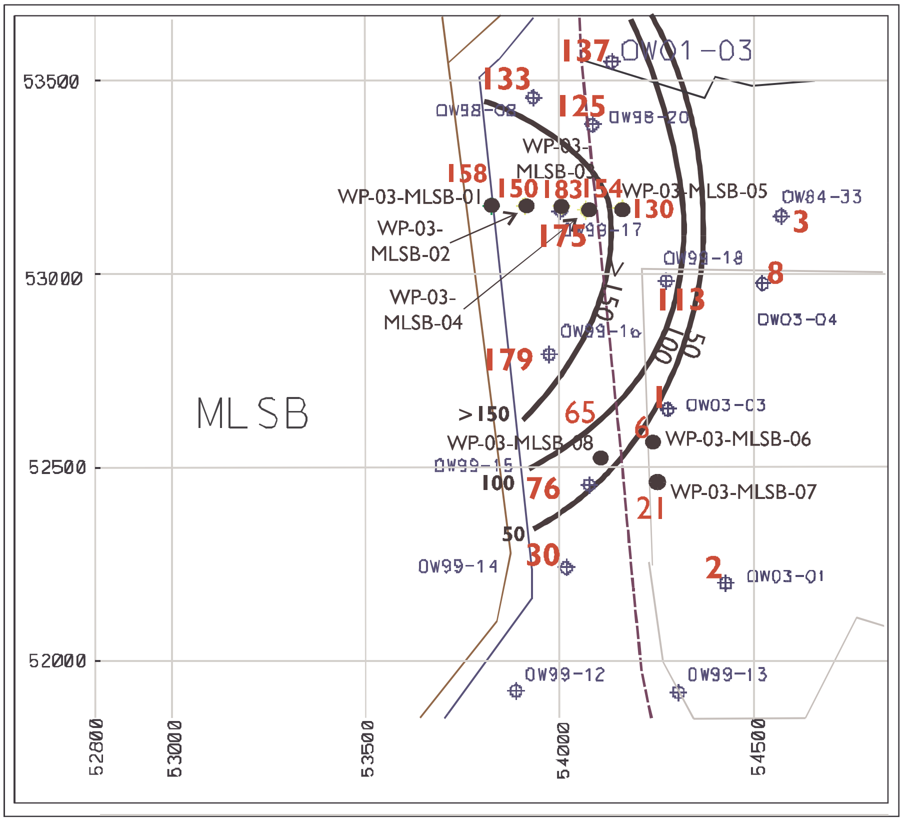
6.4.1.2 Piper Diagrams

Piper diagrams are used to see changes in groundwater chemistry over space or time, due to either interaction with geological material or mixing of different groundwater types *e.g.* contaminated water with background groundwater. Piper diagrams consists of two triangular diagrams which describe the relative compositions of cations and anions, and a diamond-shaped diagram that combines the compositions of the two.

When the Piper diagram for the MLSB was constructed (*AquaChem 3.70*), the groundwater samples were assigned symbols based on classifications determined by the MLSB decision tree. All samples which plotted within the "Fresh" hydrogeochemical facies (Figure 6.6) had been classified as background by the MLSB decision tree. As well, they fell within the range previously classified as background (Baker, 1999).

All samples previously classified as PA plotted within or near the edge of the alkaline facies; they also plotted within the range defined by Baker (1999). A more pessimistic division of Na+K at 50% was used. OW01-03, which had been classified as PPA, plots near the PA samples and, therefore, shares their classification.

Their position in the intermediate zone between the Fresh and Alkaline hydrogeochemical facies led four samples to be classified as PPA even though only two (OW99-15 and -18) had been classified as PPA by the MLSB decision tree. The other two PPA samples were WP-03-MLSB-2.02 and WP-03-MLSB-3.02. Since both samples were collected near the water table, the conflicting classification may be due



Created on July 16, 2003 by Barry Esford, Syncrude using metric mine coordinate system. Modified by Francoise Gervais February 9, 2004.

⌖ Active Monitoring Wells

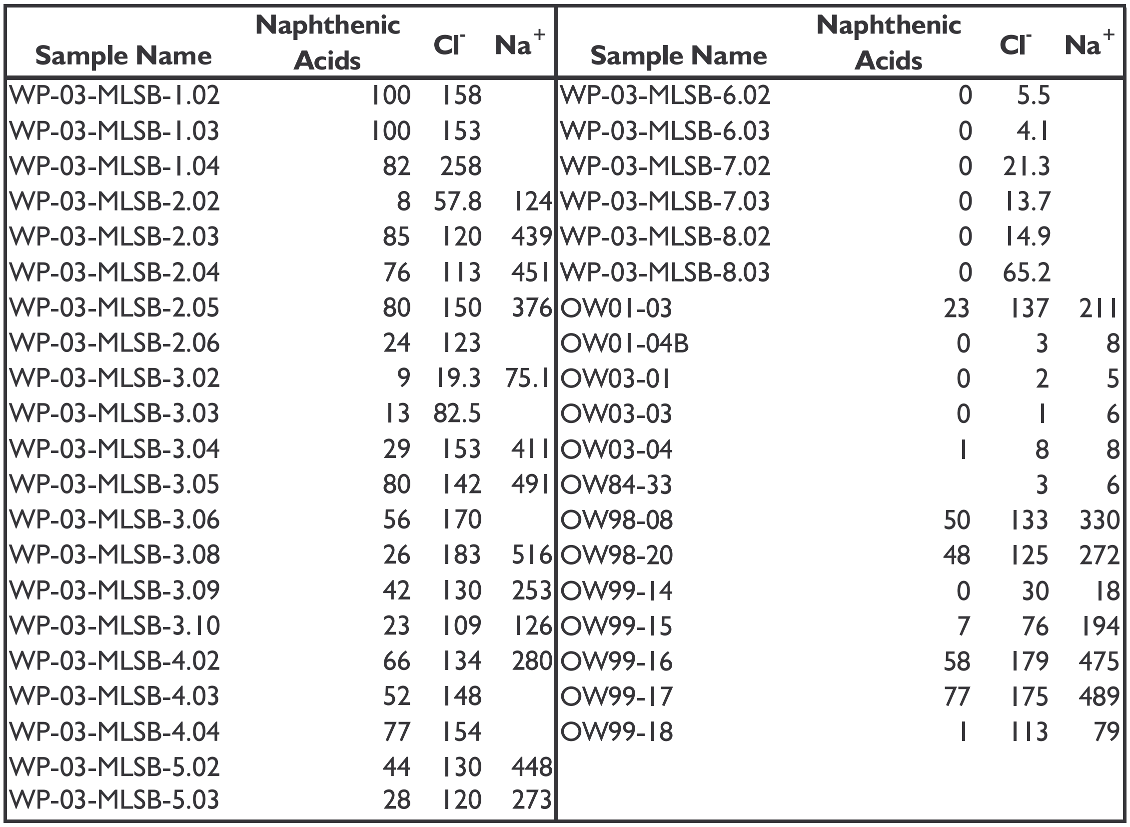
● Vertical Profile Locations

50 Contours of chloride concentration (50 mg/L)

--- Highway 63

312.7 Dissolved Chloride Concentrations (mg/L)

FIGURE 6.5: Distribution of chloride concentrations east of the MLSB, Syncrude Canada Ltd.



Sample Name	Naphthenic Acids	Cl$^-$	Na$^+$	Sample Name	Naphthenic Acids	Cl$^-$	Na$^+$
WP-03-MLSB-1.02	100	158		WP-03-MLSB-6.02	0	5.5	
WP-03-MLSB-1.03	100	153		WP-03-MLSB-6.03	0	4.1	
WP-03-MLSB-1.04	82	258		WP-03-MLSB-7.02	0	21.3	
WP-03-MLSB-2.02	8	57.8	124	WP-03-MLSB-7.03	0	13.7	
WP-03-MLSB-2.03	85	120	439	WP-03-MLSB-8.02	0	14.9	
WP-03-MLSB-2.04	76	113	451	WP-03-MLSB-8.03	0	65.2	
WP-03-MLSB-2.05	80	150	376	OW01-03	23	137	211
WP-03-MLSB-2.06	24	123		OW01-04B	0	3	8
WP-03-MLSB-3.02	9	19.3	75.1	OW03-01	0	2	5
WP-03-MLSB-3.03	13	82.5		OW03-03	0	1	6
WP-03-MLSB-3.04	29	153	411	OW03-04	1	8	8
WP-03-MLSB-3.05	80	142	491	OW84-33		3	6
WP-03-MLSB-3.06	56	170		OW98-08	50	133	330
WP-03-MLSB-3.08	26	183	516	OW98-20	48	125	272
WP-03-MLSB-3.09	42	130	253	OW99-14	0	30	18
WP-03-MLSB-3.10	23	109	126	OW99-15	7	76	194
WP-03-MLSB-4.02	66	134	280	OW99-16	58	179	475
WP-03-MLSB-4.03	52	148		OW99-17	77	175	489
WP-03-MLSB-4.04	77	154		OW99-18	1	113	79
WP-03-MLSB-5.02	44	130	448				
WP-03-MLSB-5.03	28	120	273				

Table 6.2: Data used in the MLSB decision tree. All values in mg/L.

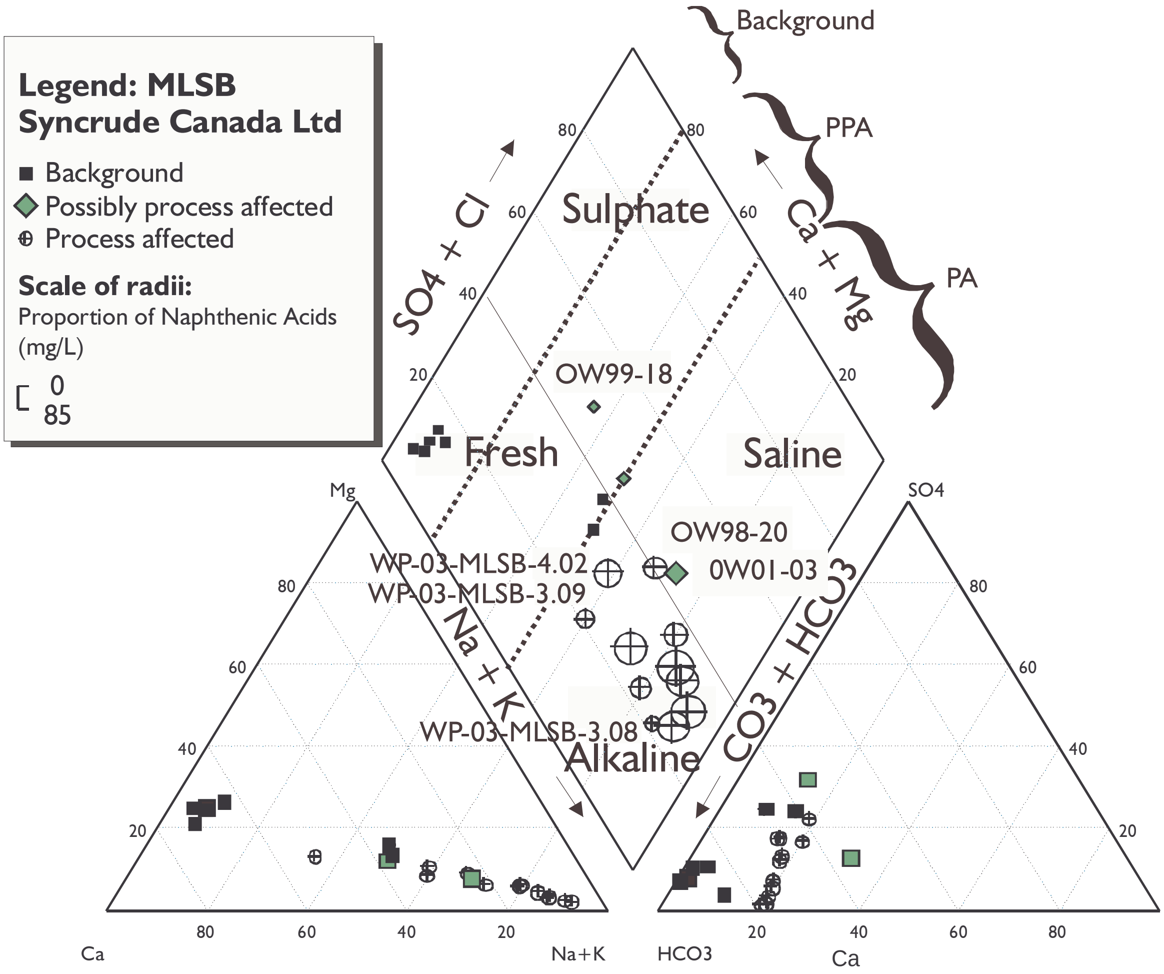


Figure 6.6: Hydrogeochemical facies at the Mildred Lake Settling Basin site.

to dilution; the different chemistry of rainwater infiltrating through the unsaturated zone; or aerobic biodegradation.

At the MLSB, pure process-affected water is very poor in calcium and magnesium ions (M. McKinnon, pers. comm, July 22, 2004). The PA and PPA samples appear to lie along a mixing line between zero Ca+Mg and the Fresh hydrogeochemical facies.

6.4.1.3 Molar Na:Cl Ratio

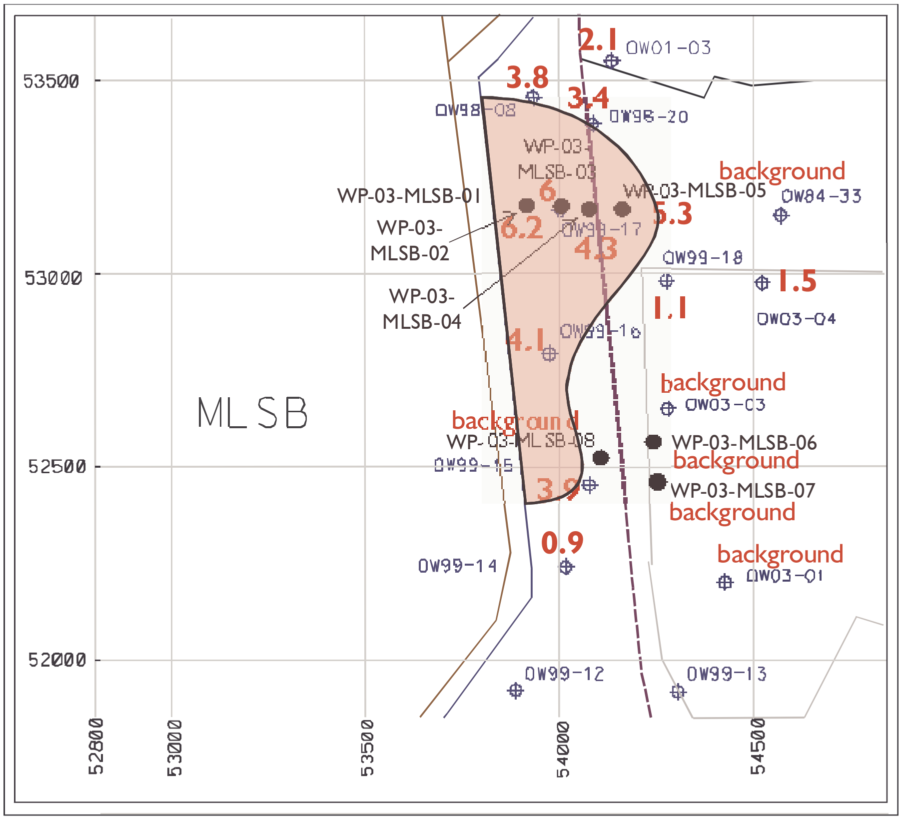
Because of the addition of NaOH during oil sand processing, the molar Na:Cl ratio is often greater than one. Since the source of oil sand varies over time, the ratio will change as the amount of NaOH which needs to be added changes. Ratios greater than 4 is often characteristic of pre-1990 process-affected water (M. McKinnon, pers. comm., July 22, 2004). A plume of pre-1990 water is extending eastward from the dyke. The apparent preferential flowpath in the northern section may be a function of greater sample density in that area. At the time the sampling trip was planned, OW99-17 was the hydraulic high in the area, not the monitoring well OW99-16 further south. This may account for the greater distance travelled by the plume in this area.

6.4.1.4 Stable Isotopes

Data for two local meteoric water lines (LMWL) which bracket Fort McMurray geographically are available. There is a station to the north in Fort Smith and one to the south in Edmonton (IAEA, 2004). Knowledge of the probable background stable isotope values is useful because process affected water will be depleted in the light hydrogen and oxygen isotopes. The oil sand is mixed with water at around 80°C before being disposed of in the holding ponds. This water is likely affected by evaporation which concentrates the heavy stable isotopes of hydrogen and oxygen in the residual water. Assuming that the groundwater samples collected within an aquifer volume impacted by PA water are a mixture of evaporated, process-affected water and local groundwater, a possible mixing line can be inferred from the groundwater data (Figure 6.8; Table 6.3). The samples that are most enriched in oxygen-18 are also some of the samples with the highest naphthenic acids concentration; the samples that are least enriched have low concentrations of naphthenic acids. This suggests that the stable isotope ratio results from mixing and does not represent a local meteoric water line reflecting specific precipitation events.

It was difficult to pump water from within the dyke and only deuterium was analyzed in these three samples. The three process-affected water samples had very similar δ^2H (-122.4±1%) and are similar to other high naphthenic acids samples, providing further evidence that the enriched samples are PA waters.

Most water samples for isotope analysis were taken within the aquifer volume believed to be impacted by PA water, so there are few samples to anchor the "background" end member of the mixing line. However, in northern Alberta, groundwater recharged from precipitation tends to have average annual $\delta^{18}O$ values from -20 to -17 per mil (IAEA, 2004) due to a combination of the continental and latitude effect. Overall, $\delta^{18}O$ values fluctuate seasonally from -36 to -10 per mil in precipitation.



Created on July 16, 2003 by Barry Esford, Syncrude using metric mine coordinate system. Modified by Francoise Gervais February 9, 2004.

⊕ Active Monitoring Wells

● Vertical Profile Locations

50 Contours of chloride concentration (50 mg/L)

--- Highway 63

2.7 Molar Na^+:Cl^- ratio

▨ Influence of Pre-1990 Process-affected Water

FIGURE 6.7: Distribution of molar Na:Cl ratio providing a characterization of of groundwater as pre- and post-1990. In the vertical profiles, the largest ratio was used.

Sample	18O SMOW	Lab Repeat	2H	Lab Repeat
WP-03-MLSB-1.02	no analysis requested		-120.37	-120.85
WP-03-MLSB-1.03	no analysis requested		-124.46	-123.35
WP-03-MLSB-1.04	no analysis requested		-122.35	-123.25
WP-03-MLSB-2.02	-17.21		-142.53	-140.82
WP-03-MLSB-2.03	-14.57		-125.15	-125.13
WP-03-MLSB-2.04	-14.75	-14.67	-123.91	-125.68
WP-03-MLSB-2.05	-14.38		-122.98	-123.91
WP-03-MLSB-3.02	-20.79		-162.10	-163.96
WP-03-MLSB-3.03	-17.78		-144.07	-144.02
WP-03-MLSB-3.04	-14.55	-14.56	-125.95	-126.92
WP-03-MLSB-3.05	-14.03		-123.33	-121.77
WP-03-MLSB-3.08	-13.93		-124.94	-123.47
(field dup of WP-03-MLSB-3.06)				
WP-03-MLSB-3.09	-15.43	-15.69	-131.43	-131.11
WP-03-MLSB-3.10	-15.83		-129.33	-130.88
WP-03-MLSB-4.02	-14.42		-123.72	-122.71
WP-03-MLSB-5.03	-16.14		-129.64	-128.53

TABLE 6.3: Stable isotope concentrations in July 2003 at Syncrude Canada Ltd.

There is some overlap between the MLSB groundwater samples and the samples from Edmonton and Fort Smith. Because of this, stable isotopes must be used in addition to other classification methods, not on their own. For example, we could reasonably draw a mixing line between the three data points WP-03-MLSB-3.09, WP-03-MLSB-3.10 and WP-03-MLSB-5.3. But overall, the samples with more than 40 mg/L NAs all plot within the same narrow area: $\delta^{18}O$ from -14 to -15.5 per mil and $\delta^{2}H$ from -120 to -135 per mil. The working hypothesis will be that if samples fall in this range, they are classified as PA.

Samples plot in three groups. The samples closest to the intersection with the Edmonton and Fort Smith LMWL can be considered background, two samples in the middle (including the sample which plots on the Fort Smith LMWL) are possibly process-affected while the most evaporated samples are considered to be process-affected water (Table 6.6). Two samples which plot in the PA section (WP-03-MLSB-3.08 and WP-03-MLSB-3.04) have low NA and will be examined for evidence of sorption or biodegradation. A plot of NA concentration against $\delta^{18}O$ (Figure 6.9) shows that WP-03-MLSB-3.08 and WP-03-MLSB-3.04 do not plot with other samples of like value, reinforcing the need to examine these sampling points.

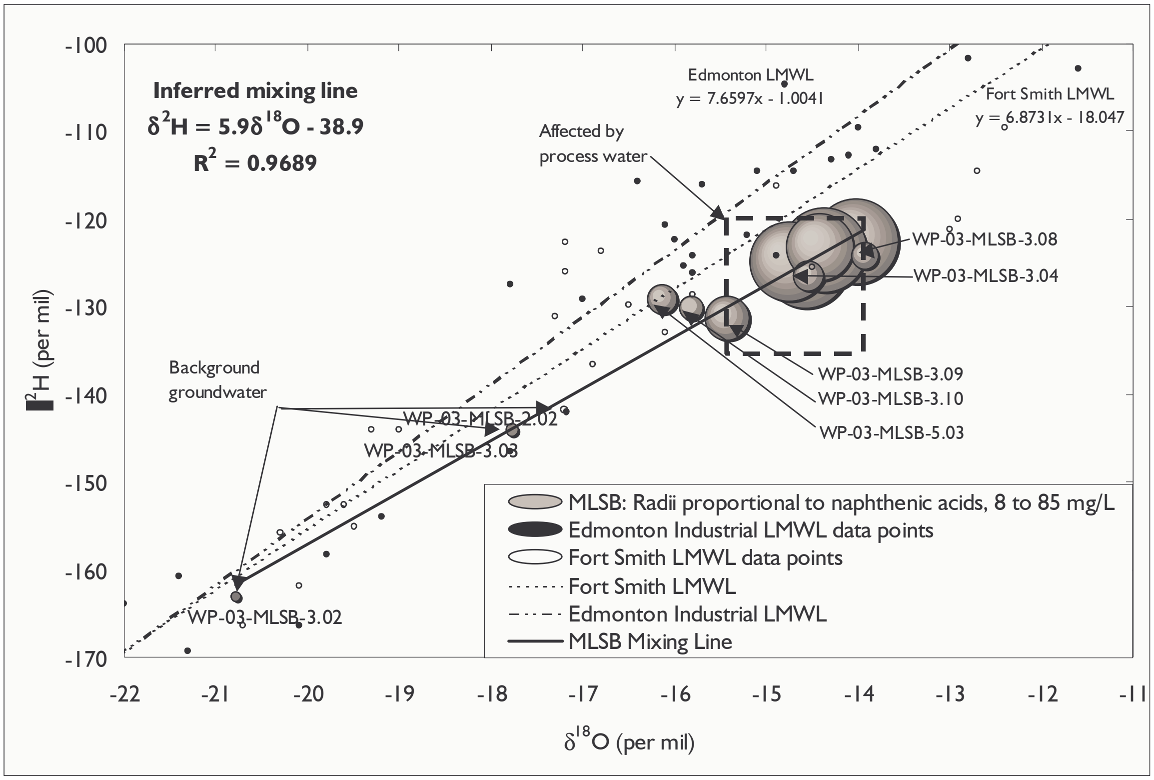


FIGURE 6.8: Possible mixing line between process-affected water and background groundwater samples from the Mildred Lake Settling Basin, relative to the local meteoric water lines to the north and south.

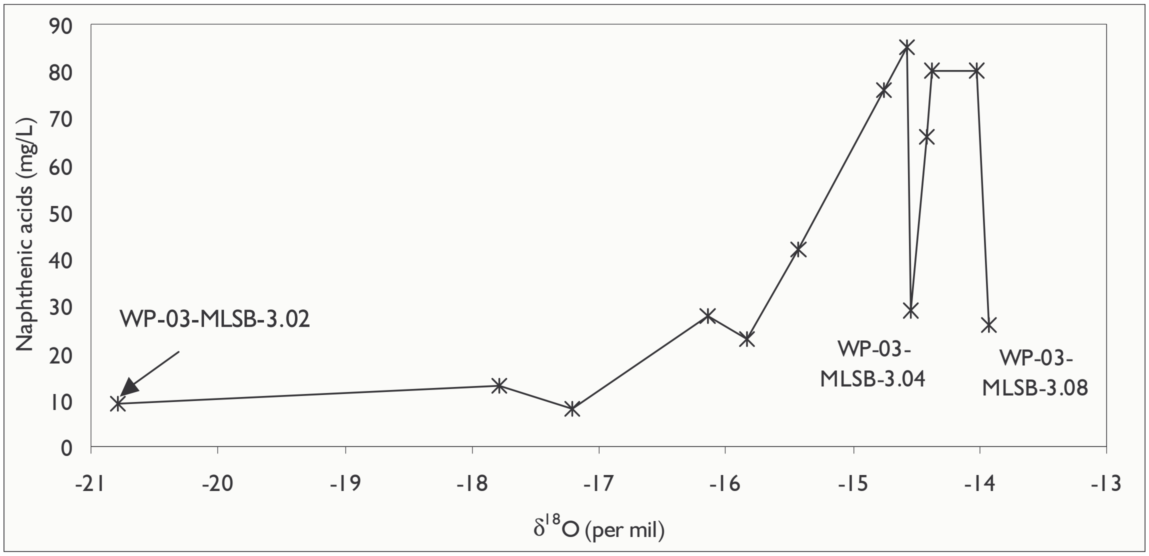


FIGURE 6.9: A comparison of naphthenic acids concentration and the heavy stable isotope oxygen-18 highlights the groundwater samples which have a different naphthenic acids concentration than other samples with similar oxygen-18.

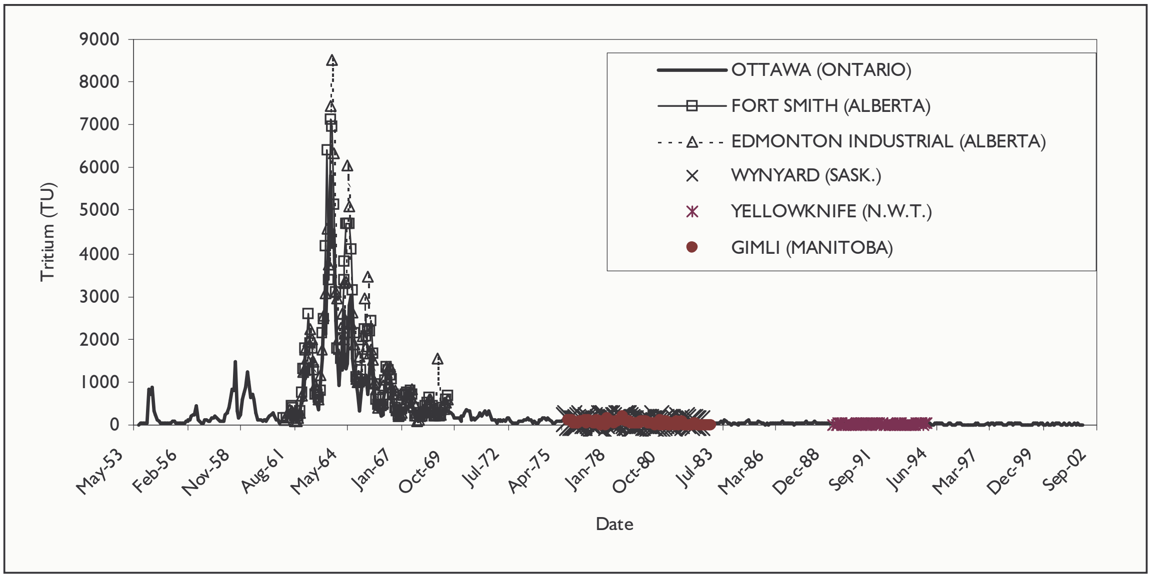


FIGURE 6.10: Historical tritium levels in precipitation in Ottawa, Ontario and various stations located near northern Alberta.

Station	Observed Activity in Precipitation: 1978 (TU)		Calculated Activity in Ground Water: 2003 (TU)	
	Measured minimum	Measured maximum	Calculated minimum	Calculated maximum
Ottawa	36	135	9	33
Gimli, Manitoby	30	184	7	45
Wynward, Manitoba	34	173	8	43

Station	Observed Activity in Precipitation: 1988 (TU)		Calculated Activity in Ground Water: 2003 (TU)	
	Measured minimum	Measured maximum	Calculated minimum	Calculated maximum
Ottawa	23	61	10	26

Station	Observed Activity in Precipitation: 1998 (TU)		Calculated Activity in Ground Water: 2003 (TU)	
	Measured minimum	Measured maximum	Calculated minimum	Calculated maximum
Ottawa	10	36	8	27

TABLE 6.4: Tritium levels for 1978, 1988 and 1998.

6.4.1.5 Tritium

Since 1953, tritium levels in precipitation has been measured at several monitoring stations in central and western Canada (IAEA, 2004). The most complete data set was collected at the Ottawa station (1953-2001). Partial tritium data from 1978 are also available for Wynyard, Saskatchewan and Fort Smith, Alberta. The data from all the stations show a similar pattern for all locations (Figure 6.10). In 2001, the tritium levels ranged from 12.5 to 45 TUs and the average for the last five years of measurement (1996-2001) was 20±2 TUs.

The sands tailings which were used to construct the dykes around the MLSB were deposited beginning in 1978. Unfortunately, groundwater tritium levels (Table 6.5) fall within the range found in both modern precipitation and decayed 1978, 1988 and 1998 values, so that it is not possible to distinguish between decayed samples that entered at different time periods (Table 6.4) and recent infiltration. Tritium was not used to classify samples.

6.4.1.6 Summary

Transect A-A' starts within the dyke and extends eastward towards OW84-33 located in background groundwater and downgradient of the dyke. Transect B-B' runs north-

Sample	Tritium (TU)	Lab Repeat
WP-03-MLSB-2.02	21 +/- 8	
WP-03-MLSB-2.03	19 +/- 8	
WP-03-MLSB-2.04	26 +/- 8	
WP-03-MLSB-2.05	24 +/- 8	
WP-03-MLSB-3.02	9 +/- 8	
WP-03-MLSB-3.03	21 +/- 8	
WP-03-MLSB-3.04	15 +/- 8	
WP-03-MLSB-3.05	23 +/- 8	
WP-03-MLSB-3.08	21 +/- 8	21 +/- 8
(field dup of WP-03-MLSB-3.06)		
WP-03-MLSB-3.09	25 +/- 8	
WP-03-MLSB-3.10	30 +/- 8	
WP-03-MLSB-4.02	22 +/- 8	
WP-03-MLSB-5.03	12 +/- 8	

TABLE 6.5: Tritium concentrations in 2003 groundwater samples from Syncrude Canada Ltd.

south along the base of the MLSB. Using the different classification methods, the different samples were labelled as background water, may contain process-affected water (PPA) or does contain process-affected water (PA) (Table 6.6; Figures 6.11 and 6.12). All of the samples collected along section A-A' were classified as PA or PPA with the exception of OW84-33. The southern end of B-B' is background but the rest of the groundwater samples were PA or PPA.

6.4.2 Naphthenic Acids

A plume of high naphthenic acids concentration extends outward from the MLSB with a high concentration core (Figures 6.13 and 6.14).

6.4.3 Estimated Naphthenic Acids Concentrations

The MLSB site has an abundance of conservative tracers to use in estimating changes in naphthenic acids concentrations due to simple mixing of PA water with background groundwater or meteoric water: dissolved chloride, dissolved sodium and the stable isotope deuterium (Figure 6.15). Three PA samples within the dyke anchor one end of the correlation line while background samples anchor the other. The best correlation was fair (R^2=0.7); and the predicted NA concentration was first calculated using dissolved sodium:

$$\text{Naphthenic Acids} = 0.1398 \times \text{Na}^+ - 1.492 \qquad R^2=0.7044$$

Sample ID	MLSB Decision Tree	Piper	Stable Isotopes	Final Classification	Comment
WP-03-MLSB-1.02	PA	*	*	PA	NA>40 mg/L
WP-03-MLSB-1.03	PA	*	*	PA	NA>40 mg/L
WP-03-MLSB-1.04	PA	*	*	PA	NA>40 mg/L
WP-03-MLSB-2.02	Background	PPA	Background	PPA	
WP-03-MLSB-2.03	PA	PA	PA	PA	NA>40 mg/L
WP-03-MLSB-2.04	PA	PA	PA	PA	NA>40 mg/L
WP-03-MLSB-2.05	PA	PA	PA	PA	NA>40 mg/L
WP-03-MLSB-2.06	PPA	*	*	PPA	
WP-03-MLSB-3.02	Background	PPA	Background	PPA	
WP-03-MLSB-3.03	PPA	*	Background	PPA	
WP-03-MLSB-3.04	PA	*	PA	PA	
WP-03-MLSB-3.05	PA	PA	PA	PA	NA>40 mg/L
WP-03-MLSB-3.06	PA	*	*	PA	NA>40 mg/L; dup of 3.08
WP-03-MLSB-3.08	PA	PA			field dup of WP-03-MLSB-3.06
WP-03-MLSB-3.09	PA	PA	PPA	PA	NA>40 mg/L
WP-03-MLSB-3.10	PPA	*	PPA	PPA	
WP-03-MLSB-4.02	PA	PA	PA	PA	NA>40 mg/L
WP-03-MLSB-4.03	PA	*	*	PA	NA>40 mg/L
WP-03-MLSB-4.04	PA	*	*	PA	NA>40 mg/L
WP-03-MLSB-5.02	PA	*	*	PA	NA>40 mg/L
WP-03-MLSB-5.03	PPA	*	PPA	PPA	
WP-03-MLSB-6.02	Background	*	*	Background	
WP-03-MLSB-6.03	Background	*	*	Background	
WP-03-MLSB-7.02	Background	*	*	Background	
WP-03-MLSB-7.03	Background	*	*	Background	
WP-03-MLSB-8.02	Background	*	*	Background	
WP-03-MLSB-8.03	Background	*	*	Background	
OW01-03	PPA	PA	*	PPA	
OW01-04B	Background	Background	*	Background	
OW03-01	Background	Background	*	Background	
OW03-03	Background	Background	*	Background	
OW03-04	Background	Background	*	Background	
OW84-33	Background	*	*	Background	
OW98-08	PA	PA	*	PA	NA>40 mg/L
OW98-20	PA	PA	*	PA	NA>40 mg/L
OW99-14	Background	Background	*	Background	
OW99-15	PPA	PPA	*	PPA	
OW99-16	PA	PA	*	PA	NA>40 mg/L
OW99-17	PA	PA	*	PA	NA>40 mg/L
OW99-18	PPA	PPA	*	PA	NA>40 mg/L

*missing one or more chemical parameters

Table 6.6: Summary of water classification for Syncrude Canada Ltd. PA means process-affected water and PPA refers to possibly process-affected water.

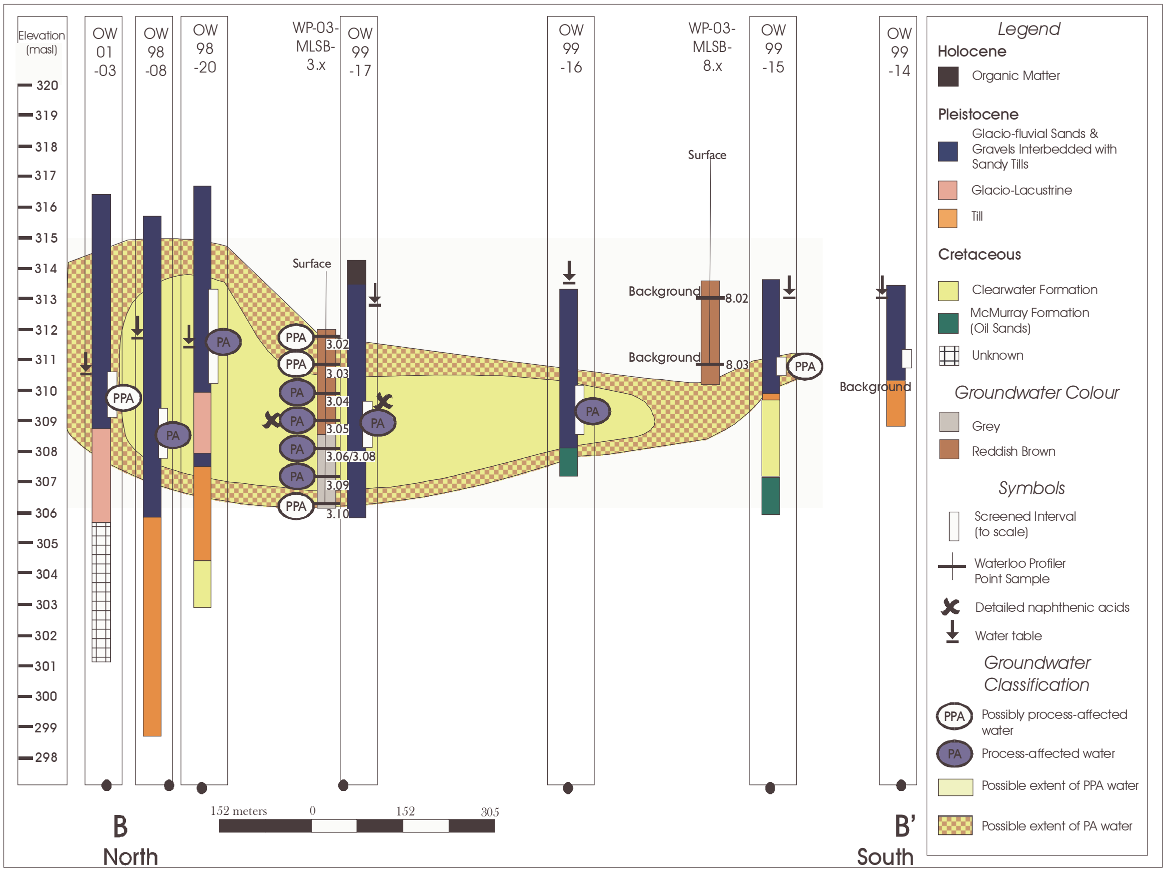


FIGURE 6.11: Cross-section B-B' parallel to the Mildred Lake Settling Basin dyke and south of the East Toe Berm, showing the extent of process-affected water in the surficial water table aquifer.

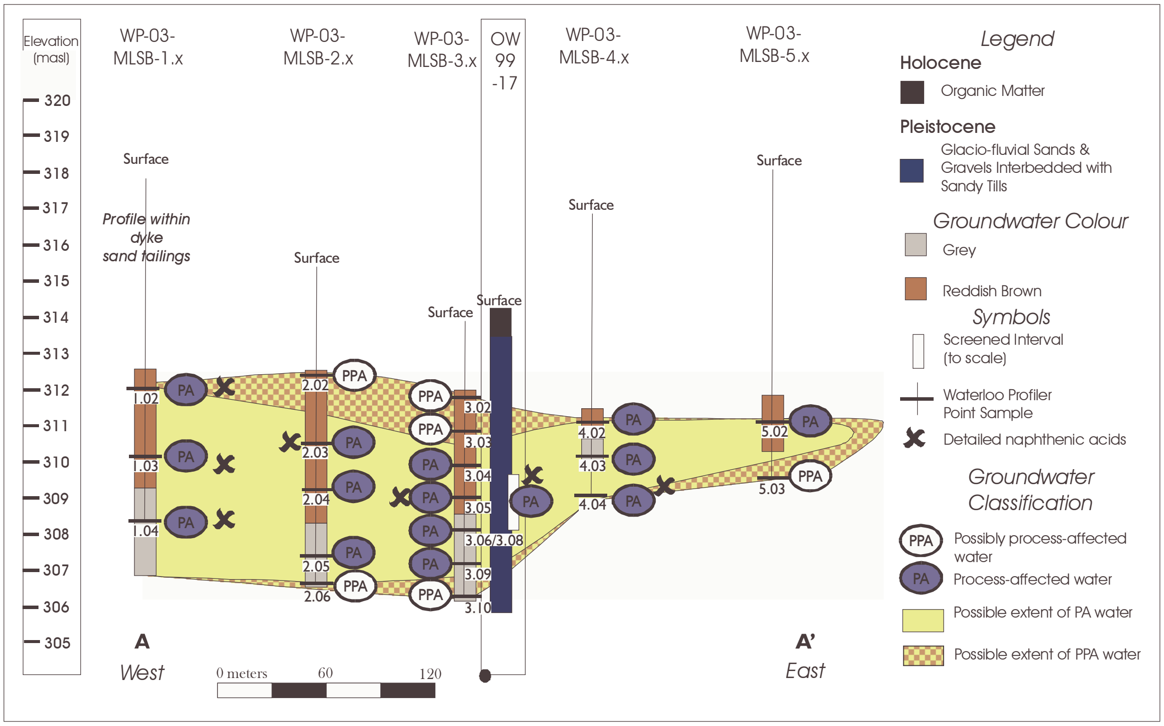


Figure 6.12: Cross-section A-A' perpendicular to the Mildred Lake Settling Basin dyke, showing the extent of process-affected water in the surfical water table aquifer.

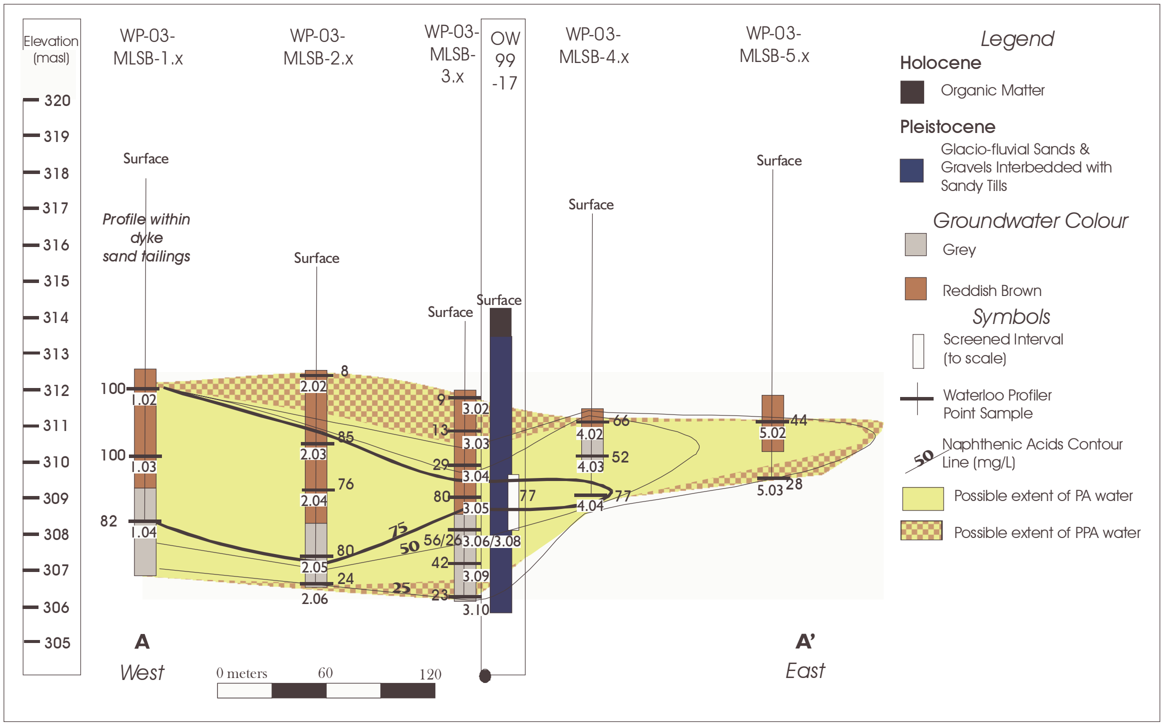


FIGURE 6.13: Cross-section A-A' showing the naphthenic acids concentrations.

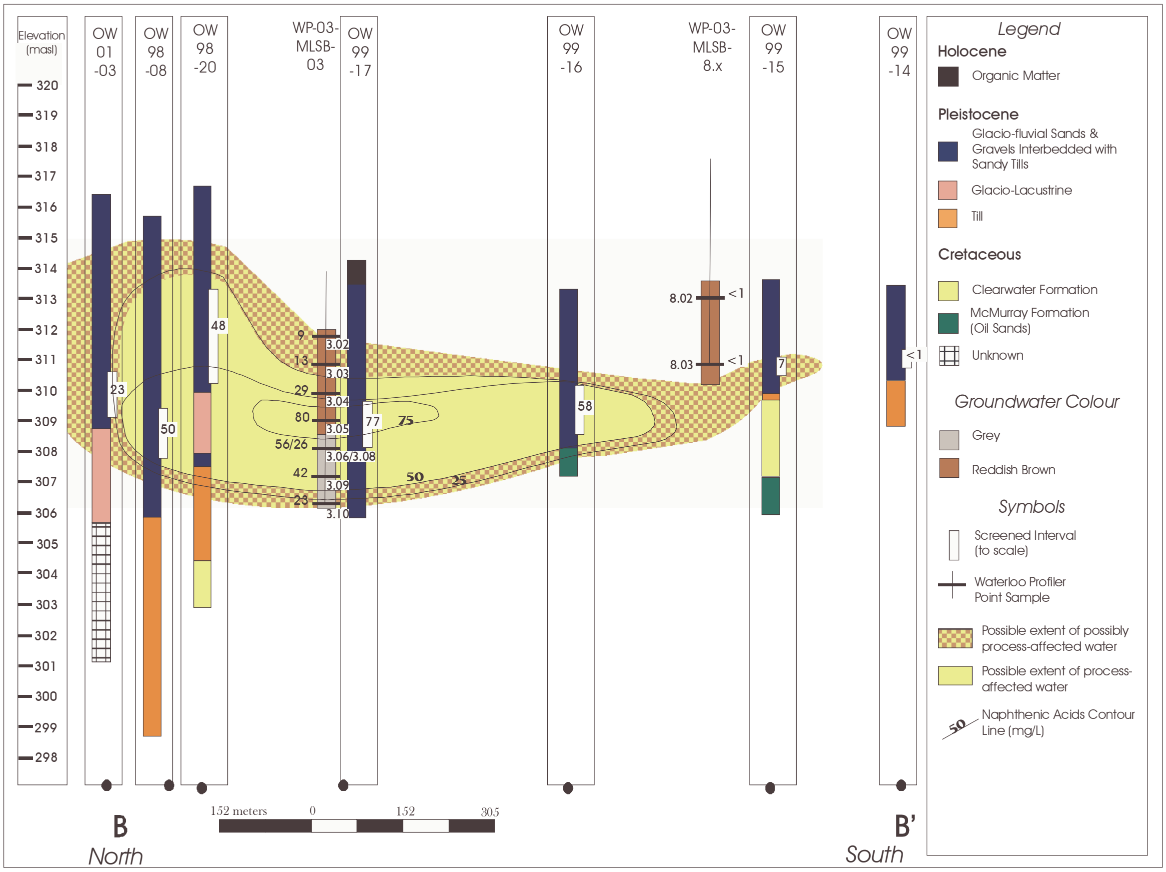


FIGURE 6.14: Cross-section B-B' showing the naphthenic acids concentrations.

Even though a chloride trendline did not have as good a fit to the data, more samples have chloride concentrations than sodium. The equations for dissolved chloride is:

$$\text{Naphthenic Acids} = 0.417 \times \text{Cl}^{-} - 6.3443 \qquad R^2=0.6738$$

These correlation lines did a fair job of estimating naphthenic acids concentrations (Table 6.7 and 6.8)

This correlation assumes a one dimensional flow field, no retardation or attenuation and a single source. Because of the shallow aquifer and no muskeg, the 1D assumption is considered valid. The hydraulic head distribution and molar Na:Cl ratio distribution allowed the delineation of a plume with a single source. The purpose of the correlation is to determine if retardation or attenuation occured, so this assumption is not valid. In order to make statements regarding NA removal, it is necessary to estimate the uncertainty in the measurements and calculations. The same uncertainty used at Albian Sands is applied here.

Using sodium, twelve of the twenty seven samples had a relative standard deviation (RSD) between measured and calculated concentrations of less than 16%; seven more had a high RSD simply because measured concentrations were at the method detection limit (1 mg/L). Four samples were overestimated, leaving six samples that were underestimated and may be attenuated: OW99-15, WP-03-MLSB-2.02, WP-03-MLSB-3.04, WP-03-MLSB-3.08, WP-03-MLSB-5.02 and WP-03-MLSB-5.03 (Table 6.7). At high concentrations, samples tended to be underestimated.

For chloride, eleven samples had measured values less than predicted values, including the four samples from the sodium correlation (Table 6.8): OW01-03, OW99-15, OW99-18, WP-03-MLSB-2.02, WP-03-MLSB-2.06, WP-03-MLSB-3.03, WP-03-MLSB-3.04, WP-03-MLSB-3.08 , WP-03-MLSB-3.10, WP-03-MLSB-5.03 and WP-03-MLSB-8.03. Samples with measured and predicted values near the method detection limit (1 mg/L) were not included in the list.

Another way of seeing which samples have NA concentrations which are higher or lower than expected is to plot the predicted and measured NA concentrations against each other (Figure 6.16). In this case, only three samples plot above the one to one line for sodium and may be affected by attenuation: WP-03-MLSB-5.03, WP-03-MLSB-5.02 and WP-03-MLSB-3.04. For chloride, only WP-03-MSLB-1.04 is clearly above the line. These will be examined in more detail later in the chapter.

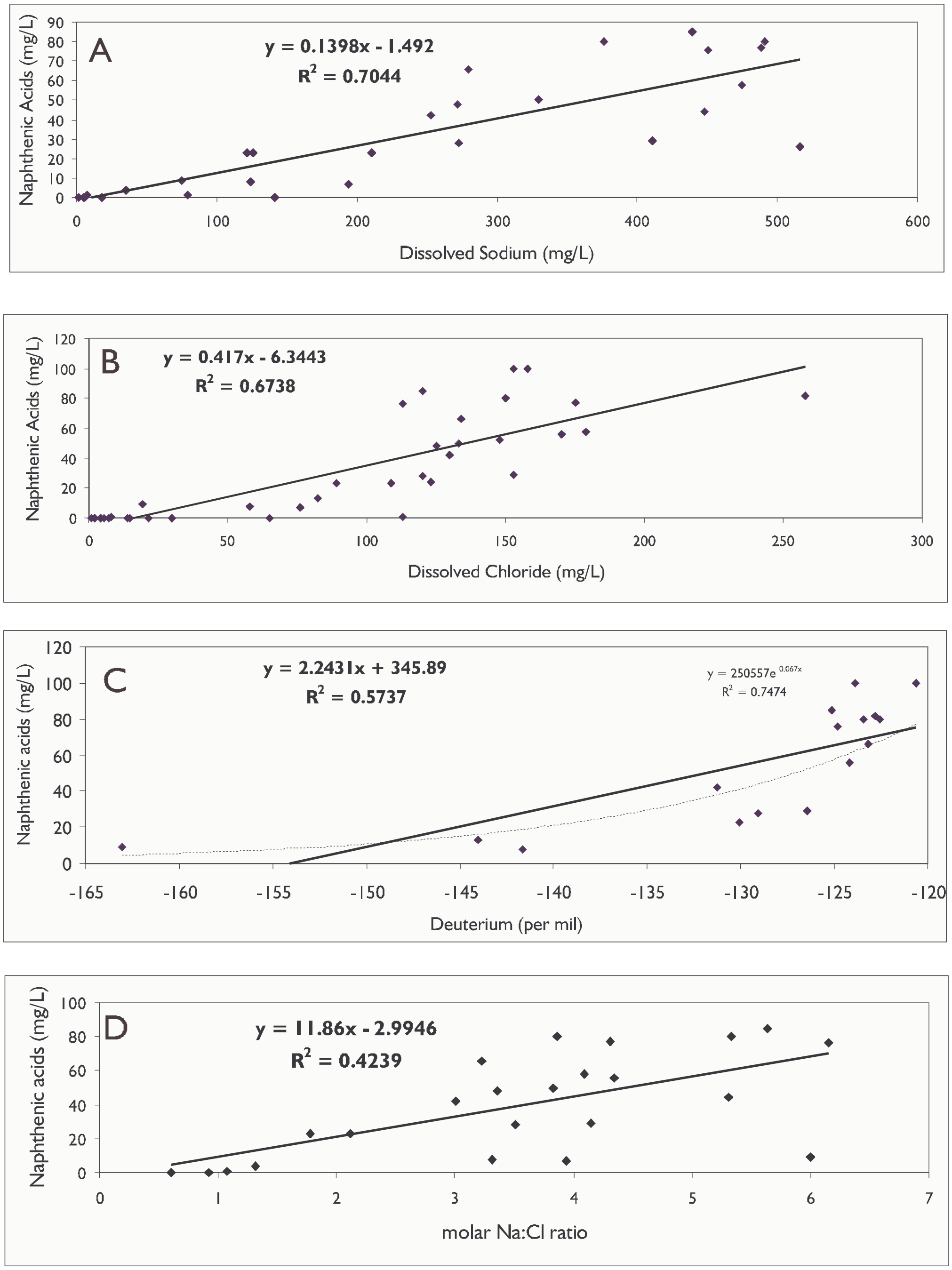


FIGURE 6.15: Relationship between the naphthenic acids concentration and A) dissolved sodium, B) dissolved chloride, C) deuterium and D) molar sodium:chloride ratio at the Mildred Lake Settling Basin.

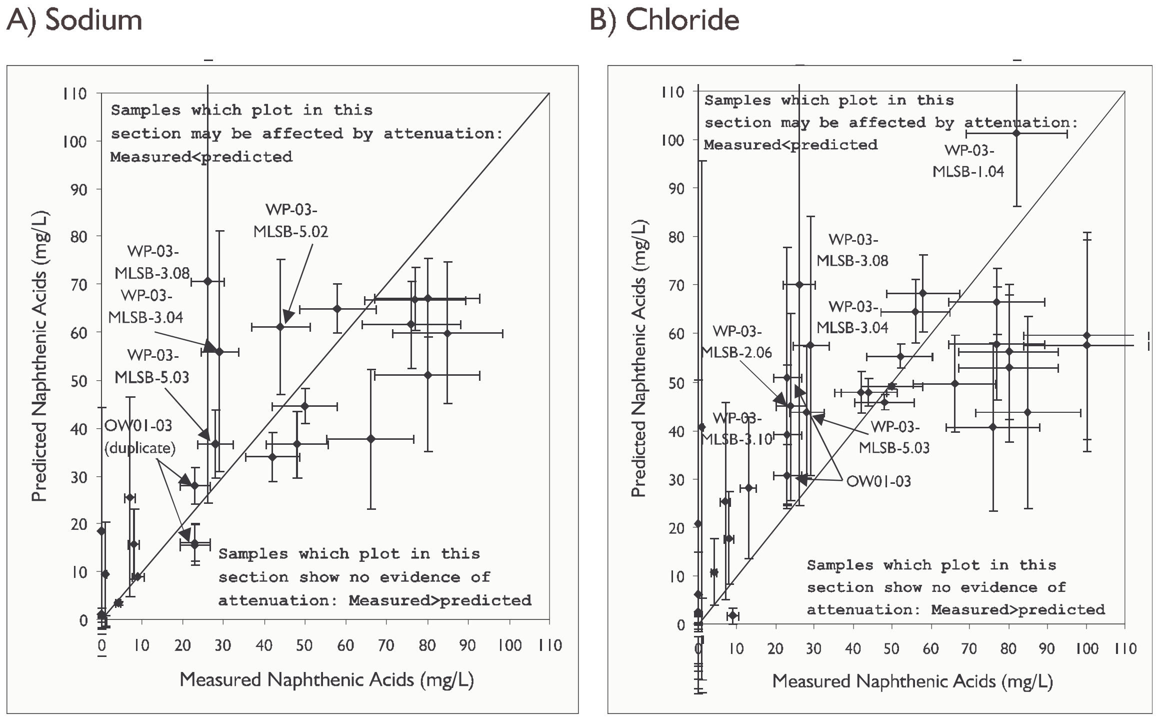


FIGURE 6.16: The measured naphthenic acids concentrations near the MLSB plotted against the concentrations estimated using sodium. Horizontal error bars are 16% residual standard deviation of the measured concentration while the vertical error bars are one residual standard deviation between the measured and predicted values.

Sample Name	Naphthenic Acid (mg/L)	Sodium (mg/L)	Estimated Naphthenic Acids	RSD
OW03-01	0	5	0	0%
OW03-03	0	6	0	0%
OW98-07	0	2	0	0%
WP-03-MLSB-3.02	9	75.1	9	0%
OW99-16	58	475	65	8%
OW98-08	50	330	45	8%
OW99-17	77	489	67	10%
OW98-22	4	35	3	11%
WP-03-MLSB-3.05	80	491	67	12%
OW01-03	23	211	28	14%
WP-03-MLSB-2.04	76	451	62	15%
WP-03-MLSB-3.09	42	253	34	15%
WP-03-MLSB-5.03	28	273	37	19%
OW98-20	48	272	37	19%
WP-03-MLSB-5.02	44	448	61	23%
WP-03-MLSB-2.03	85	439	60	25%
WP-03-MLSB-3.10	23	126	16	25%
OW01-03	23	122	16	27%
WP-03-MLSB-2.05	80	376	51	31%
WP-03-MLSB-4.02	66	280	38	39%
WP-03-MLSB-3.04	29	411	56	45%
WP-03-MLSB-2.02	8	124	16	47%
WP-03-MLSB-3.8	26	516	71	65%
OW99-15	7	194	26	81%
OW99-18	1	79	10	115%
OW99-14	0	18	1	141%
OW03-04	1	8	0	310%

Table 6.7: The estimated naphthenic acids concentration was the product of the correlation of measured total naphthenic acid versus dissolved sodium.

Sample Name	Naphthenic Acid (mg/L)	Chloride (mg/L)	Estimated Naphthenic Acids	RSD
OW03-04	1	8	-3	-282%
WP-03-MLSB-6.02	0	5.5	-4	-141%
WP-03-MLSB-7.03	0	13.7	-1	-141%
WP-03-MLSB-8.02	0	14.9	0	-141%
OW03-01	0	2	-6	-141%
OW03-03	0	1	-6	-141%
OW98-07	0	7	-3	-141%
WP-03-MLSB-6.03	0	4.1	-5	-141%
OW98-08	50	133	49	1%
OW98-20	48	125	46	3%
WP-03-MLSB-4.03	52	148	55	4%
WP-03-MLSB-5.02	44	130	48	6%
WP-03-MLSB-3.09	42	130	48	9%
WP-03-MLSB-3.06	56	170	65	10%
OW99-17	77	175	67	10%
OW99-16	58	179	68	12%
WP-03-MLSB-1.04	82	258	101	15%
WP-03-MLSB-4.04	77	154	58	20%
WP-03-MLSB-4.02	66	134	50	20%
OW01-03	23	89	31	20%
WP-03-MLSB-2.05	80	150	56	25%
WP-03-MLSB-3.05	80	142	53	29%
WP-03-MLSB-5.03	28	120	44	31%
WP-03-MLSB-1.02	100	158	60	36%
WP-03-MLSB-3.10	23	109	39	37%
WP-03-MLSB-1.03	100	153	57	38%
WP-03-MLSB-2.04	76	113	41	43%
WP-03-MLSB-2.06	24	123	45	43%
WP-03-MLSB-2.03	85	120	44	45%
WP-03-MLSB-3.04	29	153	57	47%
WP-03-MLSB-3.03	13	82.5	28	52%
OW01-03	23	137	51	53%
WP-03-MLSB-2.02	8	57.8	18	54%
WP-03-MLSB-3.08	26	183	70	65%
OW99-15	7	76	25	80%
WP-03-MLSB-3.02	9	19.3	2	96%
OW99-18	1	113	41	135%
WP-03-MLSB-7.02	0	21.3	3	141%
OW99-14	0	30	6	141%
WP-03-MLSB-8.03	0	65.2	21	141%

Table 6.8: The estimated naphthenic acids concentration was the product of the correlation of measured total naphthenic acid versus dissolved chloride.

There were two samples near the water table that were declared PPA: WP-03-MLSB-3.02 and WP-03-MLSB-2.02. The predicted NA for WP-03-MLSB-3.02 is exactly the same as the measured concentrations. Likely dilution by infiltrating rainwater is responsible for its PPA status. WP-03-MLSB-2.02, on the other hand, had a measured concentration less than half the predicted values. However, because of its large error bars, it is still considered to fall on the one-to-one line. Since no detailed NA analysis was done on this sample, it is not possible to confirm that aerobic biodegradation is responsible for the difference between measured and predicted values.

Of the four samples with methane greater than 100 μg/L (Figure 6.17), WP-03-MSLB-3.09, -3.10 and -5.03 had more NA than predicted using sodium while WP-03-MSLB-3.08 had lower NA than predicted. The predicted concentrations using chloride are somewhat contradictory to the sodium results, showing that WP-03-MSLB-3.08, -3.10 and -5.03 all have lower measured NA than predicted. All four samples discussed in this paragraph fall within the methanogenic zone. The coexistence of lower than expected NAs and methanogenic groundwater may be coincidence cause by groundwater transport of methane or may be real. Methanogenesis of NAs has not been seen in the laboratory but may be see in the field because of longer residence times.

6.4.4 Naphthenic acids “Signature”

Samples were collected along two transects, one along the base of the MLSB East Dyke (BB’) and one perpendicular to the dyke (AA’). The “signature” is derived by placing the analytical results of the abundance of specific ions corresponding to naphthenic acids (Holowenko et al., 2002) into a matrix of Z number vs carbon number and then plotted (Figures 6.19 to 6.30). A visual examination of the 3D graphs leads to the conclusion that the relative proportions of bicyclic homologues C11-C17 (where C means carbon number) is higher outside the dyke than within along section A-A’ (Figure 6.18) and most of B-B’. This is probably due to a general decrease in the relative proportions of the other homologues. In the microcosms, aerobic biodegradation showed an 8% decrease for five bicyclic homologues, C12 to C16. The increase in these homologues outside the dyke follows the opposite pattern.

The t-test analysis (page 6) resulted in no significant differences in Group 1 or 2 between any samples (Table 6.9). Group 3 ($C \geq 22$) is sometimes significantly different. However, as previously mentioned in the microcosm chapter, Group 3 is more sensitive

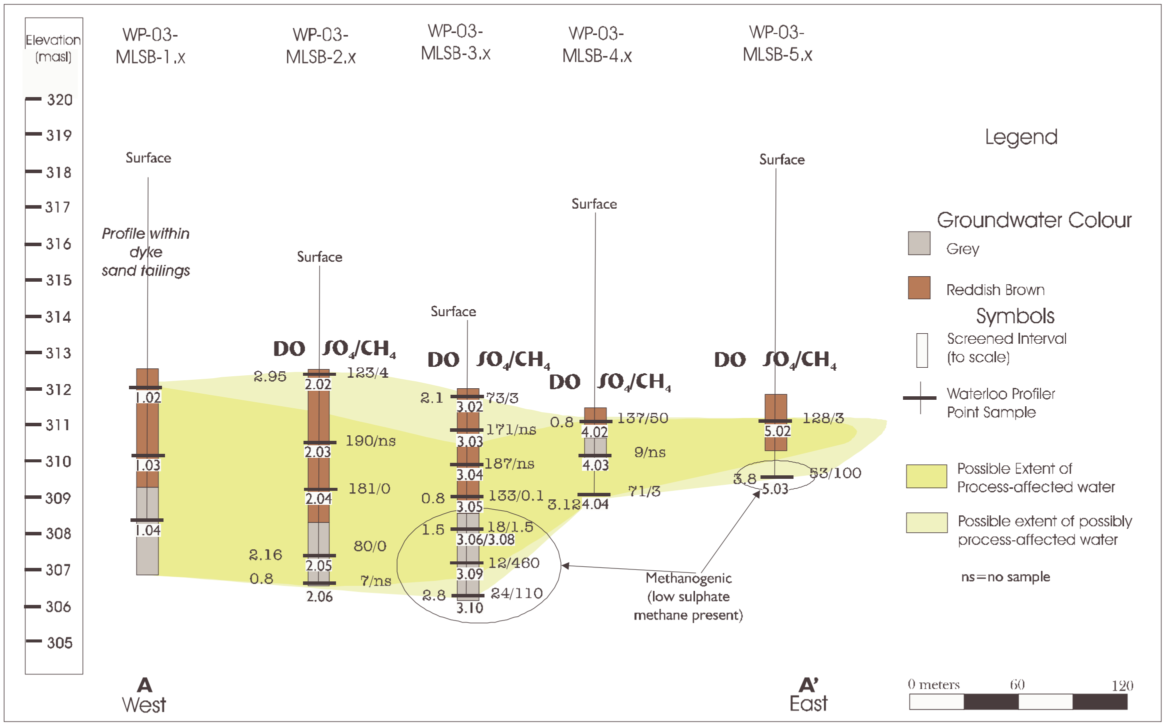


FIGURE 6.17: Chemical redox indicators dissolved oxygen (mg/L), sulfate (mg/L) and methane (ug/L) in the vertical profiles along section A-A'.

to analytical or random error than the other two groups. The changes in the Z=-4 family are probably not enough to affect the t-test results for Group 1 and 2 since the changes are distributed between the two groups and the relative concentrations are so large. The three samples within the dyke are not different from each other nor are they significantly different from WP-03-MLSB-4.04 and OW99-17. Since the aerobic biodegradation "signature" is a decrease in the relative proportions of group 1 (with an resulting increase in the relative proportions of Group 3), then it is probable that little or no biodegradation occurred in these particular samples.

Three samples which were subjected to NA characterization show evidence of NA loss (section 6.4.3): WP-02-MLSB-1.4, OW01-03 and OW99-15. In other words, they had measured NA concentrations significantly lower than concentrations predicted using the conservative indicator of process-affected water chloride. (Note: chloride was used even if the correlation was not as good because not all samples had sodium data.) The three samples are distributed evenly along the transect BB' - one in the middle and one at either end. None of the samples are significantly different in any group and show no evidence of aerobic biodegradation.

The laboratory assessment of retardation consisted of batch equilibration at three different concentrations. Sorption was higher at higher concentrations, within the range found at this site. Because of the high NA concentrations, the MLSB site was the only site were significant sorption was a possibility. At higher concentrations, the measured NA tended to be higher than predicted by the sodium-NA correlation line, strong evidence against attenuation. Another possible line of investigation was the detailed NA analysis "signature". In the lab, sorption experiments resulted in no strong overall change in homologue distribution. However, a relative decrease in the proportion of bicyclic naphthenic acids was noted. There was no change in the NA "signature" in any of the field samples. There was an increase in the relative proportion of the bicyclic NAs (Figure 6.18) in the aquifer, which is the opposite trend from what is seen in the isotherms. There is no visible attenuation of the NA plume due to sorption.

6.5 Recommendations

The MLSB decision tree can be expanded. In the MLSB, pure process-affected water has extremely low dissolved calcium and magnesium concentrations. If the

		WP-02-MLSB-1.3	WP-02-MLSB-1.4	WP-02-MLSB-2.3	WP-02-MLSB-3.5	WP-02-MLSB-4.4	OW01-03	OW98-08	OW98-20	OW99-17	OW99-16	OW99-15
WP-02-MLSB-1.2	Group 1	0.81	0.67	0.66	0.56	0.86	0.92	0.74	0.58	**0.98**	**0.97**	**0.97**
	Group 2	0.70	0.80	**0.97**	0.91	0.90	0.90	0.93	0.70	0.91	0.80	0.54
	Group 3	0.35	0.08	0.09	**0.03**	0.87	0.414	0.54	**0.01**	0.67	0.31	**0.03**
WP-02-MLSB-1.3	Group 1		0.43	0.76	0.62	0.66	0.73	0.84	0.32	0.85	0.86	0.82
	Group 2		0.91	0.74	0.88	0.64	0.83	0.83	**0.96**	0.84	0.94	0.76
	Group 3		0.35	**0.01**	**0.002**	0.28	**0.95**	0.13	0.11	0.672	0.91	0.21
WP-02-MLSB-1.4	Group 1			0.44	0.42	0.84	0.77	0.50	0.92	0.67	0.66	0.62
	Group 2			0.81	0.94	0.73	0.92	0.91	0.89	0.91	**0.98**	0.72
	Group 3			**0.002**	**0.001**	0.07	0.35	**0.03**	0.58	0.22	0.42	0.90
WP-02-MLSB-2.3	Group 1				0.79	0.57	0.62	0.94	0.38	0.70	0.70	0.67
	Group 2				0.90	0.94	0.89	0.91	0.73	0.90	0.81	0.61
	Group 3				0.58	0.13	**0.02**	0.30	**0.0001**	**0.05**	**0.01**	**0.0002**
WP-02-MLSB-3.5	Group 1					0.51	0.53	0.75	0.39	0.58	0.58	0.57
	Group 2					0.83	**0.99**	**0.98**	0.86	**0.99**	0.93	0.75
	Group 3					**0.04**	**0.01**	0.12	**0.00002**	**0.02**	**0.002**	**0.00002**
WP-02-MLSB-4.4	Group 1						0.94	0.64	0.76	0.84	0.83	0.82
	Group 2						0.81	0.84	0.64	0.83	0.73	0.51
	Group 3						0.34	0.66	**0.01**	0.57	0.25	**0.02**
OW01-03	Group 1							0.68	0.70	0.90	0.89	0.88
	Group 2							**0.98**	0.82	**0.99**	0.91	0.67
	Group 3							0.18	0.11	0.73	0.87	0.22
98-08	Group 1								0.45	0.77	0.77	0.75
	Group 2								0.82	**0.99**	0.90	0.69
	Group 3								**0.003**	0.33	0.12	**0.01**
98-20	Group 1									0.59	0.58	0.52
	Group 2									0.82	0.92	0.83
	Group 3									0.06	0.15	0.62
99-17	Group 1										**0.99**	**1.00**
	Group 2										0.91	0.69
	Group 3										0.60	0.12
99-16	Group 1											**1.00**
	Group 2											0.77
	Group 3											0.28

Table 6.9: Results of the t-test analysis of the extracted and derivatized naphthenic acids from MLSB. Group 1 is composed of carbon number 5 to 13, Group 2 has C14-C21 and Group 3=C22-C33. The numbers in red are considered to be significantly different ($P<0.05$).

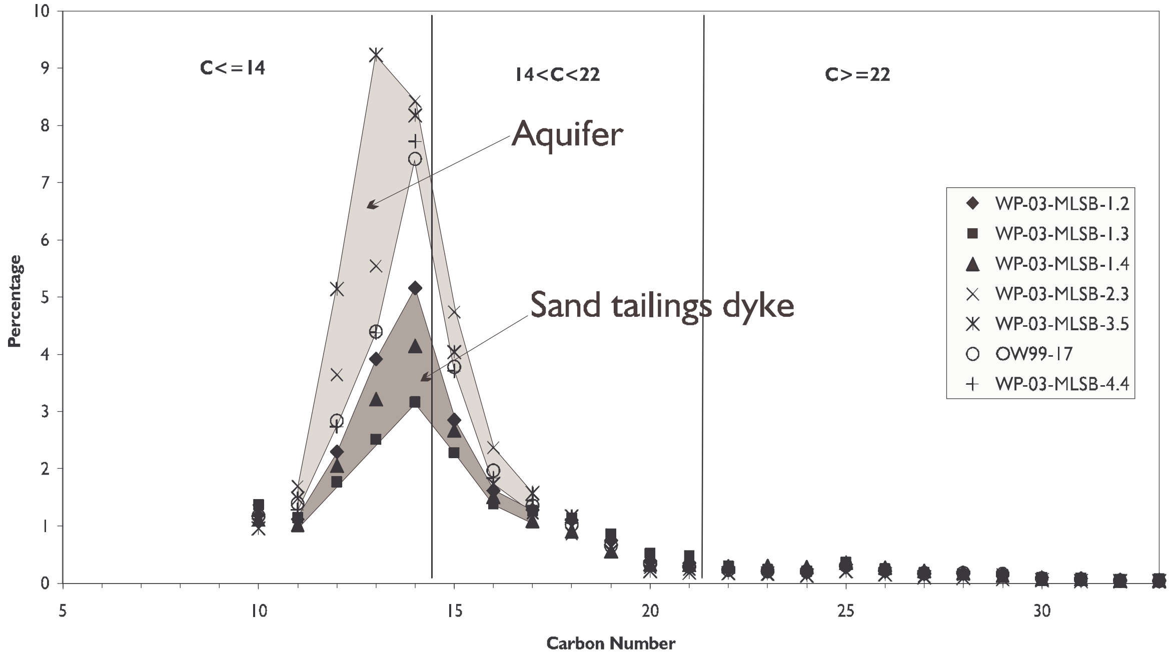


FIGURE 6.18: Variations in the relative concentrations of the various ions in the Z=-4 homologous family (2 rings) along section A-A'.

Ca^{2+}+Mg^{2+}:HCO_3^- ratio is $\leq$0.1, then the sample is relatively pure PA water (M. McKinnon, pers. comm., July 22, 2004). The stable isotopes ^{10}B and ^{11}B may provide another tracer (M. McKinnon, pers. comm., July 22, 2004).

6.6 Summary and Conclusion

In July 2003, 5 vertical profiles in a straight line transect were taken from the base of the Mildred Lake Settling Basin (MLSB) through monitoring well OW99-17 towards OW84-33 (Figure 6.1). Process-affected water was found within all five vertical profiles and many of the wells (Figure 6.11 and 6.12). This plume of high NA water had a high concentration core (Figure 6.13 and 6.14).

The two monitoring wells OW99-16 and OW99-18 are perpendicular to one of the water elevation contour lines. The horizontal gradient is 0.7 m and the approximate horizontal distance is 360 m. Assuming a porosity (η) of 0.30 and a hydraulic conductivity (K) between 10^{-1} to 10^{-3} cm/s, then V=K(i/η) ranges from 0.006 to 0.6 m/day. Section A-A' is 250 m long. Taking that as a minimum plume length,

Sample ID	Groundwater Classification	Stable Isotope	Sodium Correlation Line	Chloride Correlation Line	Sodium 1:1 Line	Chloride 1:1 Line
WP-03-MLSB-1.04	PA		n/a	n/a	n/a	X
WP-03-MLSB-2.02	PPA		X	X		
WP-03-MLSB-2.06	PPA		n/a	X	n/a	
WP-03-MLSB-3.03	PPA		n/a	X	n/a	
WP-03-MLSB-3.04	PA	X	X	X	X	
WP-03-MLSB-3.08	PA	X	X	X		
WP-03-MLSB-3.10	PPA			X		
WP-03-MLSB-5.02	PA		X		X	
WP-03-MLSB-5.03	PPA		X	X	X	
WP-03-MLSB-8.03	Background		n/a	X	n/a	
OW99-15	PPA		X	X		
OW99-18	Background			X		
OW01-03	PPA			X		

Table 6.10: Summary of samples which may have undergone attenuation.

then the plume could have been travelling from 1.2 to 120 years. However, since the holding pond was established in 1978, then the travel time is 1.2 to 26 years.

Two samples collected near the water table, WP-03-MLSB-2.02 and WP-03-MLSB-3.02, had conflicting classifications which could have been caused by dilution, the different chemistry of rainwater infiltrating through the unsaturated zone, or aerobic biodegradation. Within the range of uncertainty used, both samples plotted close to the one to one line of the measured versus predicted NA graph, indicating that dilution could be solely responsible for the low NA concentrations.

Various correlations between napththenic acid concentrations and conservative tracers were used to locate samples, and therefore locations that may contain NA which have been attenuated (Table 6.10). Four samples plotted above the sodium and/or chloride one-to-one lines and may be affected by attenuation: WP-03-MLSB-1.04, WP-03-MLSB-5.03, WP-03-MLSB-5.02 and WP-03-MLSB-3.04. WP-03-MLSB-3.04 plotted within the PA range for stable isotopes and had NA values lower than samples with similar $\delta^{18}O$ values. Of the four samples within a methanogenic zone, WP-03-MLSB-5.03 and WP-03-MLSB-3.08 and WP-03-MSLB-3.10, had lower measured NA concentrations than predicted. These four samples (WP-03-MLSB-5.03, WP-03-MLSB-3.08, WP-03-MSLB-3.10 and WP-03-MLSB-3.04) should be examined for evidence of sorption or biodegradation in future work.

There is no explanation why WP-03-MSLB-1.04 and WP-03-MLSB-5.02 plot above the one-to-one lines.

The “signature” derived by detailed naphthenic acids analysis showed no change in Group 1, therefore, for the points measured, no aerobic biodegradation can be seen. However, most samples that had NA concentrations lower than expected based on conservative tracers were not analyzed.

There are indications that some samples had lower than expected NA concentration, based on conservative tracers of PA water. However, most of these samples were not subjected to NA characterization and there is no definitive evidence that the naphthenic acids plume is attenuated by either biodegradation or sorption at the MLSB site. This should be followed in future studies.

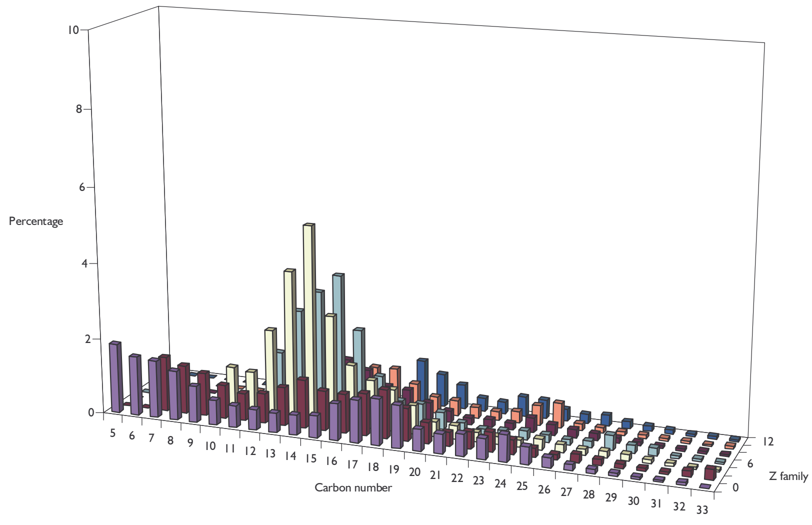


FIGURE 6.19: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample WP-03-MLSB-1.2.

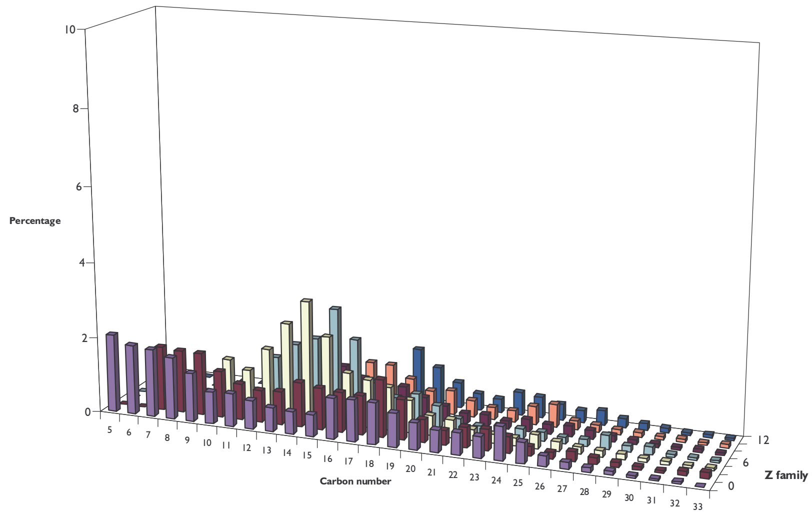


FIGURE 6.20: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample WP-03-MLSB-1.3.

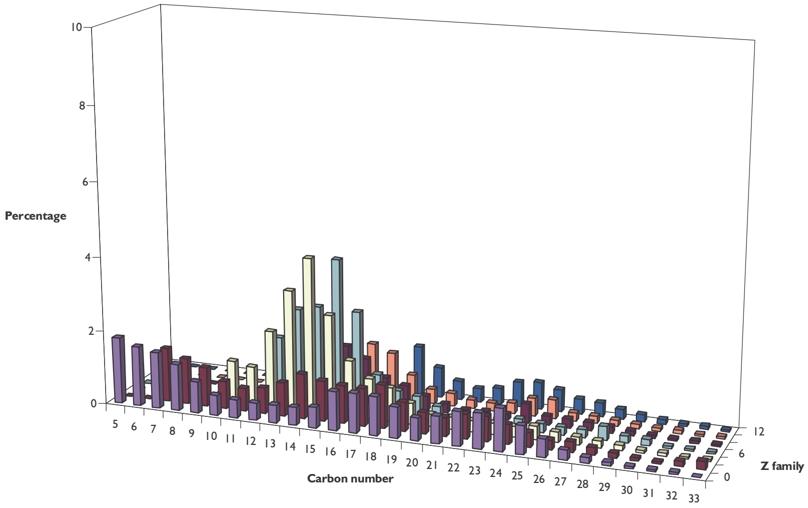


FIGURE 6.21: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample WP-03-MLSB-1.4.

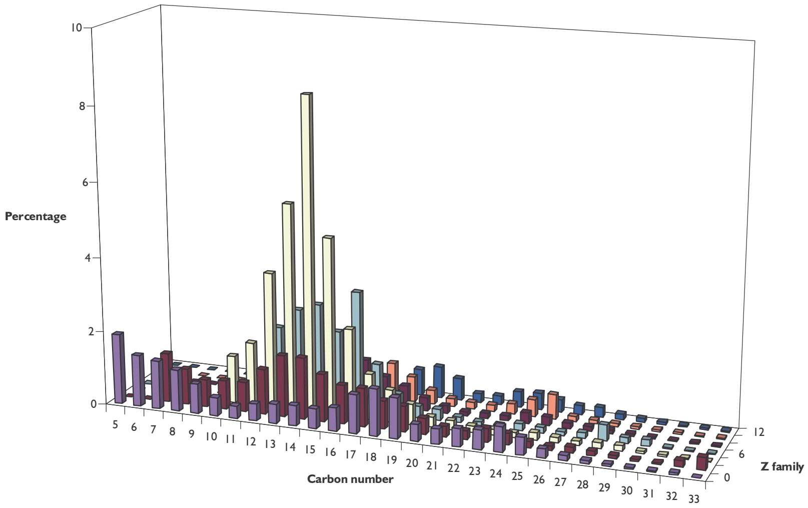


FIGURE 6.22: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample WP-03-MLSB-2.

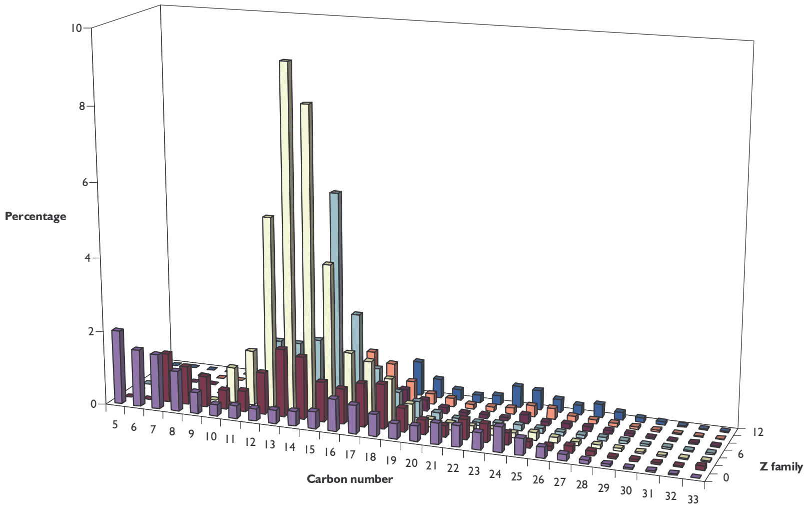


FIGURE 6.23: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample WP-03-MLSB-3.

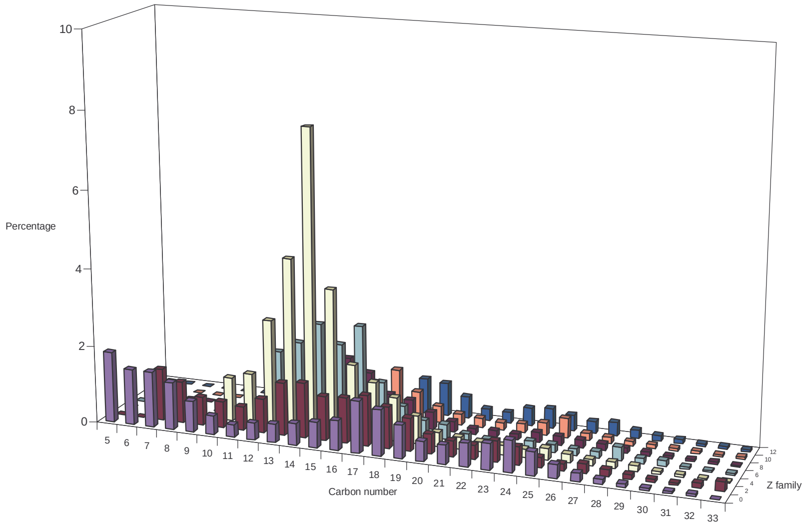


FIGURE 6.24: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample WP-03-MLSB-4.

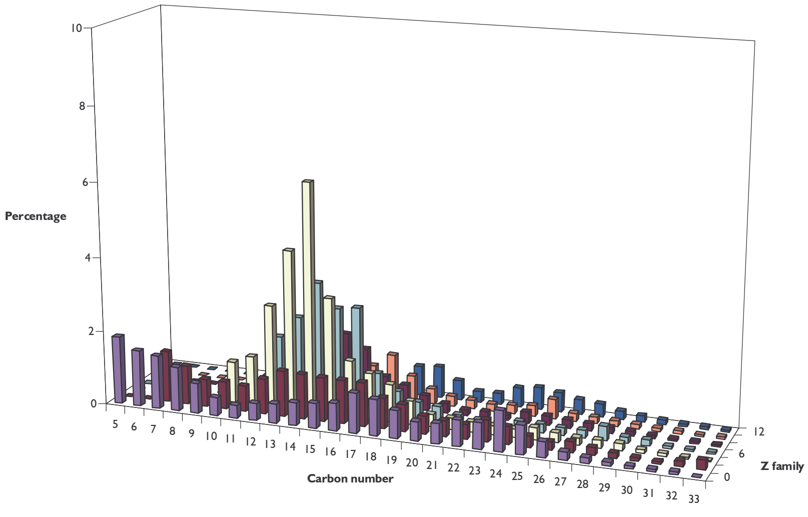


FIGURE 6.25: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample OW01-03.

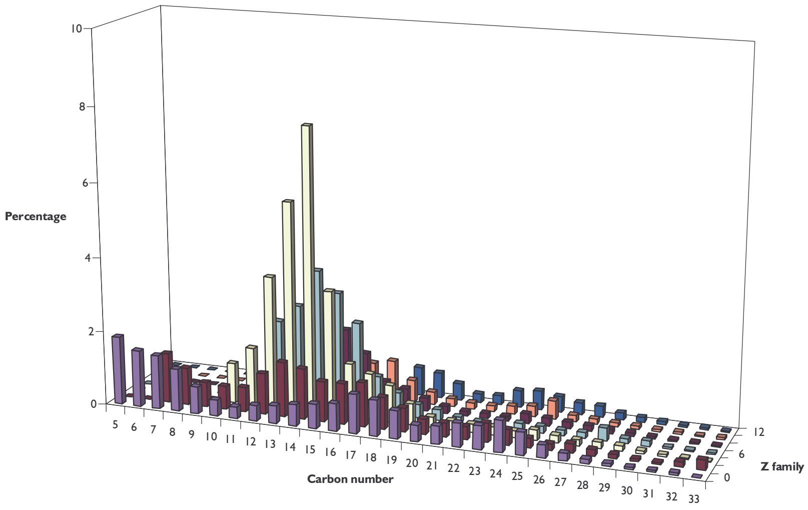


FIGURE 6.26: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample OW98-08.

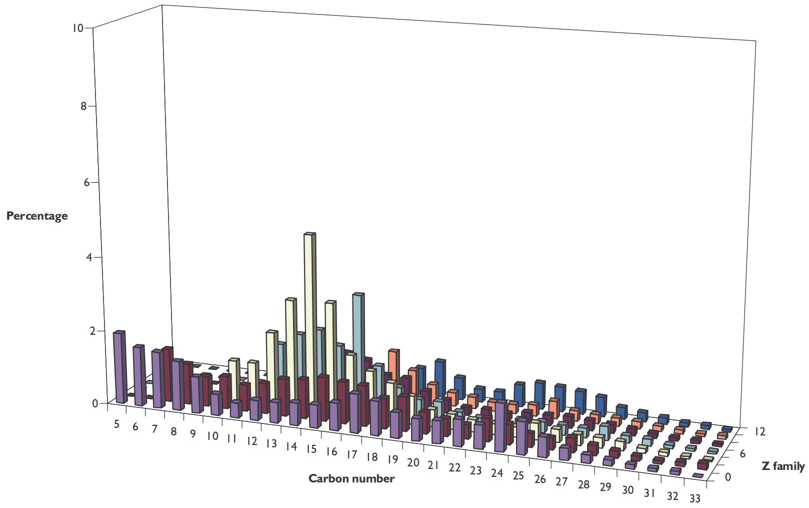


FIGURE 6.27: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample OW98-20.

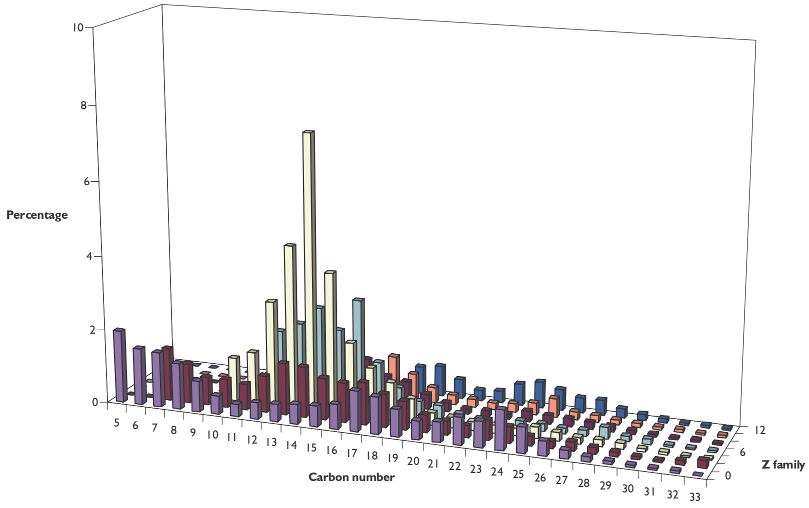


FIGURE 6.28: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample OW99-17.

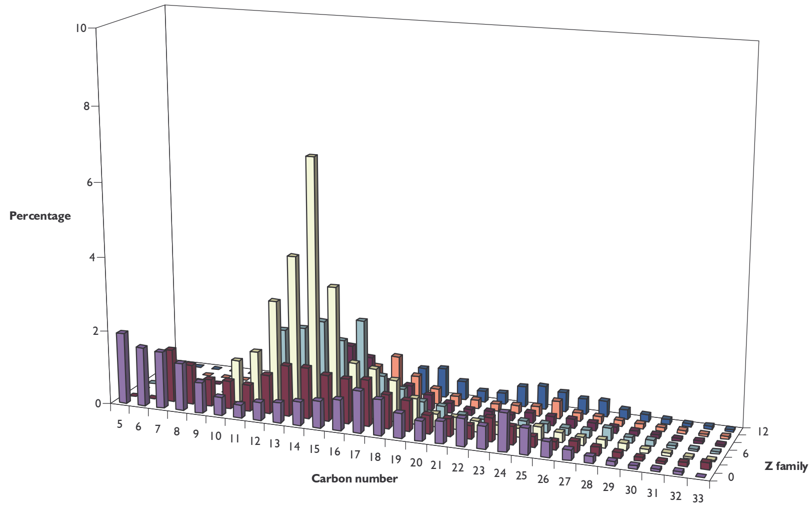


FIGURE 6.29: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample OW99-16.

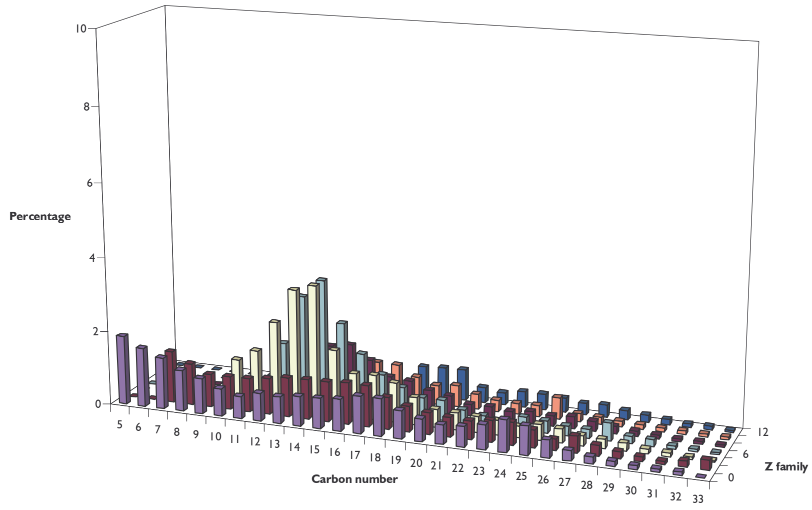


FIGURE 6.30: The distribution of carbon numbers and Z families of naphthenic acids extracted and derivatized from groundwater sample OW99-15.

Chapter 7

Final Summary and Conclusions

The objectives of the research program are:

1. To evaluate the potential for attenuation of naphthenic acids in surficial sand aquifers as they travel via groundwater to potential surface water receptors, and
2. To identify the principal physical, chemical, or biological processes responsible for attenuation.

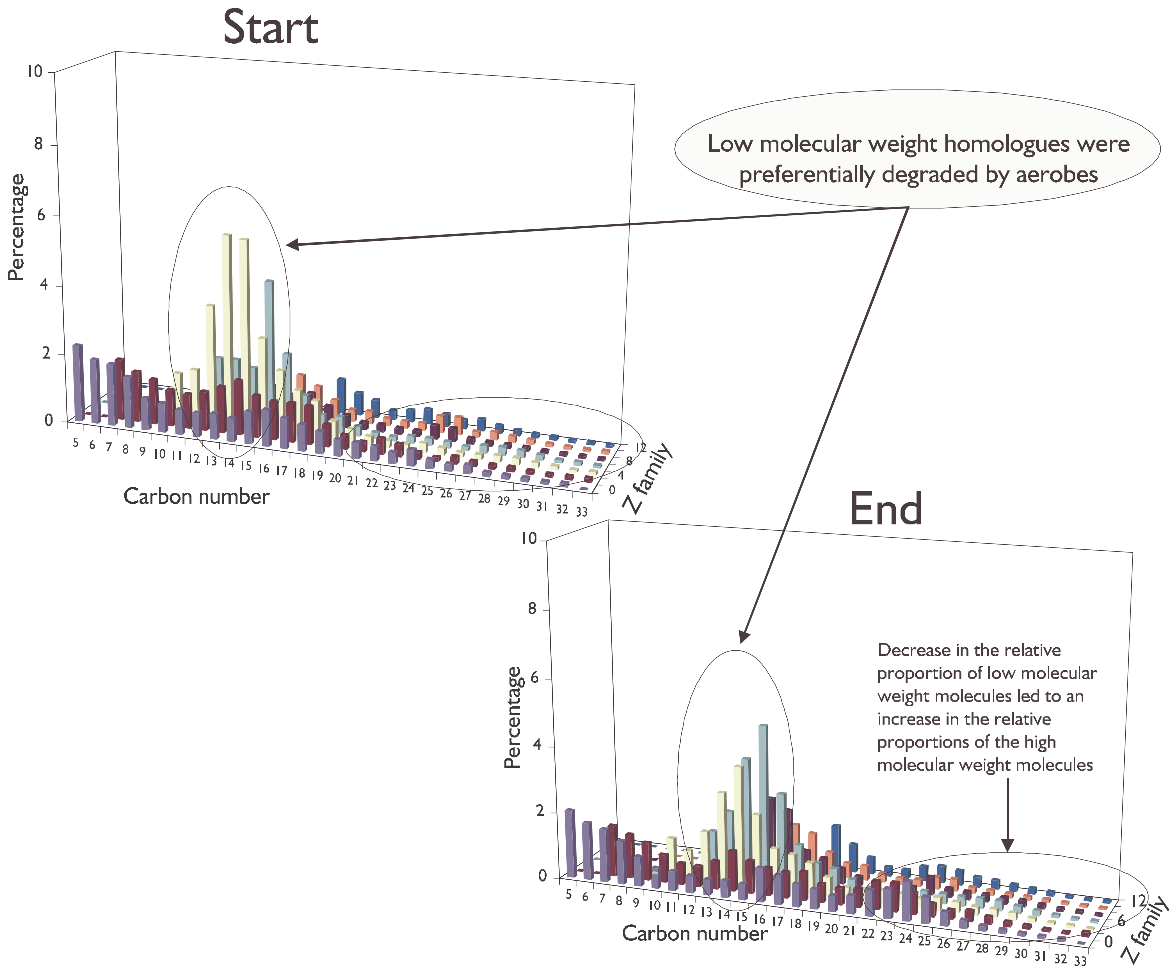
In order to accomplish this, both laboratory and field studies were designed and carried out. The laboratory studies assessed the relative role of sorption and biodegradation as potential mechanisms of naphthenic acids attenuation.

7.1 Laboratory Assessment

7.1.1 Biodegradation

7.1.1.1 Aerobic

Aerobes from aquifer material degraded 60% of the naphthenic acids over 182 days. There was an initial lag time of at least two weeks. Once biodegradation started, the majority of mass was lost over a five-week period, although biodegradation probably continued until the experiment was terminated. Previous studies found that aerobic biodegradation using microbial communities from tailings ponds favoured removal of



Low molecular weight homologues were preferentially degraded by aerobes

Decrease in the relative proportion of low molecular weight molecules led to an increase in the relative proportions of the high molecular weight molecules

Figure 7.1: The low molecular weight homologues where preferentially degraded by aerobes in the micocosms.

low molecular weight naphthenic acids (Clemente et al., 2004) and this pattern seems to remain consistent for the communities in the geological material (Figure 7.1). The bicyclic and tricyclic naphtenic acids with carbon number 12 to 14 seem to be most susceptible to aerobic biodegradation. These results show the potential for rapid, limited biodegradation in aerobic aquifer systems and display a change in homologue distribution which may characteristic of this process.

Recommendation The relative proportions of homologues for each carbon number/Z number combination in Control C, Aerobic microcosms, day 1 was substracted from the stock naphthenic acid UW456. The greatest apparent change occurred in

Carbon number	Z number 4	6	8
11	-0.6		
12	-0.5	-0.5	
13	2.4	1.1	
14	5.3	3.3	
15	2.0	4.7	1.5
16	-0.9	0.6	1.6
17	-0.5		

Table 7.1: The results of the subtraction of the relative proportion of homologue in one of the contols from the stock naphthenic acids derived from the Mildred Lake Settling Basin.

the bicyclic, tricyclic and tetracyclic NAs with carbon numbers between 11 and 17. Table 7.1 shows the homologues which changed by 0.5% or more. Unfortunately, the ground water sample was not analyzed before use. The bicyclic naphthenic acids (Z=-4) with carbon number 12-16 were the only molecules that showed a proportional decrease greater than 0.5%. This group contains homologues whose proportions were both potentially increased and decreased by the UW456, so the effect of t he stock is uncertain. More microcosms should be run using pure groundwater.

7.1.1.2 Anaerobic

There was no measurable decrease in naphthenic acids concentration over six months in anaerobic microcosms. There was microbial activity; by day 63, bottles were becoming sulfate reducing. The next time bottles were sacrificed (day 91), methane was measured and found to be present in measurable quantities (up to 1 mg/L). Mass balance calculations indicated that not all dissolved organic carbon in the ground water had been converted to methane. It is probable that the microbes which degrade the organic matter to provide acetate and hydrogen gas for the methanogens simply did not need to use the naphthenic acids as electron acceptors as yet.

Naphthenic acid surrogates are capable of being biodegraded under reducing conditions (Holowenko et al., 2000) but there may be a substantial lag time between the introduction of naphthenic acids into an anaerobic aquifer and the beginning of mass loss. Process-affected water plumes in ground water systems provide the opportunity to look at biological and chemical processes over a longer period of time than is usually possible in the laboratory. Other organic groundwater contaminants have substantial lag times before anaerobic biodegradation occurs. For example, lag times of up to 300 days under anaerobic conditions have been measured for both BTEX (Nales et al., 1998) and MTBE (Finneran & Lovley, 2001). Even though no naphthenic acids were metabolized in the anaerobic microcosms, the microcosms were allowed to proceed for only six months. Methanogenesis should be further investigated as a potential minor mechanism for biodegradation.

Recommendations One line of evidence for, or against, anaerobic biodegradation of naphthenic acids may be to determine if the methane found within plumes are of thermocatalytic and biological sources by examining their isotopic signature.

7.1.2 Retardation

Sorption may be a significant attenuation process. Batch equilibration experiments are a common method of determining a solid-water partitioning coefficient (Kd), especially for organic acids whose sorptive abilities are dependent upon several site specific conditions.

Several of the carboxylated cycloalkanes used as surrogates had Kd values similar to the stock, as well as similar Freundlich isotherms, indicating they may be good naphthenic acids surrogates. The Freundlich isotherms were concave up, indicating that sorption capacity increased as the solute concentration increased, a pattern sometime seen with surfactants (Schwarzenbach et al., 1993). However, even when solute concentrations were as high as 130 mg/L, mass loss did not exceed 15%. With Kd values in the range of 10^{-1} to 10^{-3} mL/g, sorption is not expected to be a major retardation process. On the other hand, the solubility of the surrogates increased as ionic strength increased, suggesting that hydrophobic sorption is not the dominant sorption process (Peng et al., 2002).

There was no perceptible change in the 3D signature. Changes in NA ”signature” in groundwater systems were then attributed to biodegradation. Retardation in glacio-fluvial sands (porosity of 0.3, bulk density of 1.5 g/mL) ranged from 1.2 to 2.6.

Sorption is a possible minor retardation mechanism in glacial aquifers. However, the small change in mass in the batch reactors and the lack of signature change in homologue distribution means that this mechanism cannot be conclusively identified at any of the three field sites.

7.1.2.1 Recommendations

Any sorption isotherm for naphthenic acids should have the same pH and ionic strength in all reactors. Various clays and their cation exchange capicities should be investigated as possible sorbents of naphthenic acids in the saline plumes.

7.2 Field Studies

Even though the chemicals of interest remain the same, each site is unique. The environmental mobility of organic acids with a polar, water-soluble group attached to a non-polar, water-insoluble hydrocarbon chain, which may be present in groundwater as both ionized and protonated species, has been less thoroughly studied than nonpolar organics. Therefore, site-specific investigations may provide the most reliable information for their transport characteristics and possible intrinsic remediation. Ground water samples were collected at all three of the active oil sand mines north of Fort McMurray.

7.2.1 Southwest Aquifer, Pond 2/3

The Southwest aquifer on the Suncor Energy Inc lease had the most complex geology and hydrogeology, composed of an upper water table aquifer and a semi-confined lower aquifer, both of which have a different areal extent. There are three possible sources of PA water at this site. Pore water from Dyke 2W, PA water from Pond 2/3 and seepage water pumped to the wetland between the dyke and the start of the transect. There is a plume of process-affected water at the base of Pond 2/3. However, the evidence for attenuation is contradictory and no conclusions can be drawn from this site.

7.2.1.1 Recommendation

The Suncor mixing line falls below the local meteoric water line and shows a clear trend of increasing naphthenic acids concentration with increasing stable isotope depletion. The use of the stable isotopes ^{18}O and ^{2}H should be explored as conservative tracers, since the fit between the stable isotope oxygen-18 and naphthenic acids was better than the line used in this thesis with all PPA samples removed.

7.2.2 Mildred Lake Settling Basin

A second plume is located at the base of the east dyke of the Mildred Lake Settling Basin (MLSB). The geology and hydrogeology in the immediate area of the plume is much simpler than Suncor. Over the past two years, only one hydraulic high was measured, although it moved slightly southward from one year to the next. The geology of the area is well known, a shallow (maximum of 10 m) unconfined glacio-fluvial sand and gravel aquifer interbedded with glacio-lacustrine facies. The aquifer was underlain by till, Clearwater Formation (shale) or McMurray Formation (oil sand). The source of the oil sand changed after 1990. This required a change in processing which led to a different molar Na:Cl ratio than another plume immediately to the north. It was possible to identify one plume extending eastward from the dyke, in a relatively simple glacio-fluvial aquifer, with a single source.

The transect, with 5 sampling locations, starts within the dyke itself and travels outward at a right angle to the dyke. Because of the high naphthenic acids found within and near the outside edge of the dyke, it was possible that sorption might be substantial enough to be distinguished. Unfortunately, because of low K_d values and the lack of 3D signature, any retardation is not dramatic enough to be teased apart from the effects of dispersive dilution.

The signature derived by detailed naphthenic acids analysis showed no change in Group 1, therefore, for the points measured, no aerobic biodegradation can be seen. However, most samples that had NA concentrations lower than expected based on conservative tracers were not analyzed.

There are indications that some samples had lower than expected NA concentration, based on conservative tracers of PA water. Three of those samples included chemical indicators of highly reducing chemical environments, down to methanogenic. The field data is consistent with methanogenesis, but the lab and field results don't agree. However, most of these samples were not subjected to NA characterization and there is no definitive evidence that the naphthenic acids plume is attenuated by either biodegradation or sorption at the MLSB site. This should be followed in future studies.

7.2.2.1 Recommendations

As well as the previous recommendation regarding methanogenesis, two other recommendations are proposed. Boron isotopes may provide yet another tool in identifying process-affected water mixed with groundwater at Syncrude Canada Ltd (M. McKinnon, pers. comm., July 22, 2004). Boron is a common element and minor or trace constituent in all natural surface and subsurface aquatic systems. There is a large relative mass difference between the two stable B isotopes, ^{10}B and ^{11}B, leads to a wide range of ^{11}B/^{10}B variations in nature. Boron sources tend to have diagnostic signatures which makes in an important stable isotope tracer when trying to differentiate between natural and anthropogenic sources (Barth, 2000).

In the MLSB, pure process-affected water has extremely low dissolved calcium and magnesium concentrations. If the Ca^{2+}+Mg^{2+}:HCO_3^- ratio is $\leq$0.1, then the sample is relatively pure PA water (M. McKinnon, pers. comm., July 22, 2004).

7.2.3 Muskeg River Mine Test Pit

The source of naphthenic acids at the Muskeg River Mine site (Albian Sands Energy Inc) is different than the other two plumes. These naphthenic acids were not solubilized from oil sands by an industrial process, but slowly dissolved *in situ* from oil sand over time. Because the source concentration is not as high as process-affected water, the contrast between process-affected water mixed with ground water and background ground water is not as dramatic. On the positive side, the linear correlation between dissolved naphthenic acids and sodium had a fit good fit (R^2=0.91). In addition, the delineation between background and plume is easy to make because of the highly saline source.

The sample nearest the river, downgradient of that other samples between itself and the source shows the “signature” consistent with aerobic biodegradation. This pattern — decrease in Group 1, no change in Group 2, increase in Group 3 — was observed in the lab for aerobic biodegradation. The measured NA concentration is lower than the predicted concentration for this point. At the concentrations measured, sorption is probably minimal. As well, sorption does not change the “signature” so that the changes in relative proportion can be attributed solely to aerobic biodegradation.

7.3 Summary

The purpose of this thesis was to identify the principal physical, chemical, or biological processes responsible for attenuation. Dispersive dilution due to advective flow is a physical process which is a strong contributor to attenuation in naphthenic acids. Sorption may cause some retardation of naphthenic acids, but more study is required to determine if physical, chemical or electrostatic sorption processes dominate and how this can be adapted into a remediation solution. Finally, there is strong field and laboratory evidence suggesting that aerobic biodegradation will occur in aerobic aquifers. Anaerobic biodegradation cannot yet be ruled out under field conditions, but is not considered a major contributor to attenuation.

The 3D bar graph showing the relative distribution of naphthenic acid homologues can provide a "signature" to help identify aerobic biodegradation in groundwater systems. Since sorption caused no change in the distribution of homologues, any change in signature consistent with aerobic biodegradation was attributed to aerobic biodegradation.

Three plumes were examined for evidence of attenuation of naphthenic acids via biodegradation. The Muskeg River Mine site shows good evidence of field biodegradation. The evidence at the MLSB is not definitive while the evidence for the Southwest Aquifer is contradictory.

Appendix A

Microcosms and Biodegradation of Naphthenic Acids

For FRANCOISE GERVAIS

(by Marianne VanderGriendt)

START DATE: AEROBIC – JULY 2, 2003; ANAEROBIC – JULY 8, 2003

A.1 Introduction

Laboratory experiments were designed to study the microbiologically mediated fate of naphthenic acids (NA) under both aerobic and anaerobic conditions. A matrix of static microcosms was prepared using Suncor site core material and groundwater. The collected groundwater contained some NA, but was supplemented with stock NA and inorganic nutrients (modified Bushnell Haas medium).

Concentrations of total NA (FTIR method) were monitored at each sampling times, while detailed "signature" NA (GC/MS-Fedorak method), Ph, dissolved oxygen, sulfate, and methane measurements were taken intermittently over the course of the experiment.

A.2 Materials and Methods

A.2.1 Core Material:

As per Francoise's soil/core chart. All cores were flushed into the anaerobic chamber, emptied, thoroughly mixed and repackaged into tight sealing mason jars. Core material used for the anaerobic experiment remained in the chamber, while core material required for the aerobic experiment was removed from the chamber and stored at 4°C.

A.2.2 Groundwater:

Collected by Francoise from the Suncor site (ENV91-7B) and stored at 4◦C until required for experimental set up.

A.3 Experimental Design and Procedure

All equipment used during the set up was sterilized and aseptic technique was employed throughout the experiment. Aerobic microcosms were assembled within the sterile air flow cabinet, while anaerobic microcosms were assembled within the anaerobic chamber.

Microcosm design consisted of 3 types of microcosms: They were Controls, Actives and Positive Controls (Table A.1 in triplicate, with eight sets each (sampling times), under both aerobic and anaerobic conditions, for a total of 144 microcosms.

In advance of the microcosm set up, appropriate amounts of aquifer material were weighed into each microcosm (Table 1). Control microcosms were sterilized by autoclaving on 3 successive days (days 1, 2, and 4 for 1 hour each day). During the experimental set up, the addition of either sodium azide (aerobic) or mercuric chloride (anaerobic) was made to control microcosms to help render them abiotic (metabolic poison -see below). Positive Control microcosms received 10 μl additions of both palmitic (hexadecanoic) acid and 3-cyclohexanepropionic (CHPA) acid in methylene chloride (see be.lw). The methylene chloride was allowed to evaporate off before groundwater addition was made to the microcosm. ENV91-7B groundwater

Type	Condition	Bottle Size (L)	Ground -Water (mL)	MBH	Soil (g)	Soil Treatment	NA (mg/L)	Palmitic Acid (mg/L)	CHPA (mg/L)
Control	Aerobic	1	375	yes	50	Autoclaved + Sodium Azide	30		
Control	Anaerobic	0.5	375	yes	49	Autoclaved + Sodium Azide	30		
Active	Aerobic	1	375	yes	50	none	30		
Active	Anaerobic	0.5	375	yes	49	none	30		
Positive Control	Aerobic	1	375	yes	50	none	30	10	10
Positive Control	Anaerobic	0.5	375	yes	49	none	30	10	10

Note: triplicate for each type, eight sets for each type

CHPA = 3-cyclohexanepropionic acid

MBH = Modified Bushnell Haas Medium

Table A.1: Microcosm Design

contained approximately only 15 mg/L NA and had to be supplemented with MLSB-derived NA, to a final concentration of 30mg/L NA, and pH ed to around neutrality (see below).This addition occurred on the day preceding the set up. Also, anaerobic microcosm groundwater was purged (overnight) with prepurified nitrogen to a dissolved oxygen concentration of 0.8 mg/L. Once the groundwater was prepared MBH addition (see below) was made to the groundwater carboys, and aliquots of 375 ml of were added to each of the microcosms. Microcosms were capped with Teflon lined caps and incubated at room temperature. Anaerobic microcosms were incubated in the anaerobic chamber.

A.3.1 Sampling Procedure:

During sampling a 50 ml ground glass syringe, fitted with a Teflon tip, was used to draw groundwater out of the microcosms. Care was taken not to disturb the sediment in the microcosm. Both aerobic and anaerobic microcosms were sampled for Dissolved Oxygen and pH (20ml), Total NA – (FTIR method -100ml-acidified to pH less than 2 with 1:1 sulfuric acid), and Detailed NA (GC-MS method - 200ml acidified to pH less than 2 with 1:1 sulfuric acid). Anaerobic microcosms were also sampled for sulfate (10ml refrigerated/frozen) and occasionally methane (15ml in ground glass syringe). Sampling times are:

Aerobic

- Day 1 (set 1) – July 3, 2003
- Day 8 (set 2)– July10, 2003 (samples decanted instead of drawn off)
- Day 14 (set 3) – July 16, 2003
- Day 43 (set 4) – Aug 14, 2003
- Day 57 (set 5) – Aug 28, 2003
- Day 83 (set 6) – Sept 23, 2003
- Day 140 (set 7 + 3 pos con set 8) – Nov 19, 2003 (changed extraction slightly – took separate samples for total NA and detailed NA and acidified them separately – rinsed bottle with methylene chloride)

Anaerobic

- Day 1 (set 1) – July 8, 2003
- Day 7 (set 2) – July 15, 2003
- Day 37 (set 3) – Aug 14, 2003
- Day 63 (set 4) – Sept 9, 2003
- Day 91 (set 5) – Oct 7, 2003 (pos con A extracted differently – total microcosm extracted –soil and all
- Day 142 (set 6) – Nov 27, 2003 (changed extraction slightly – took separate samples for total NA and detailed NA and acidified them separately – rinsed bottle with methylene chloride)

Due to the insolubility of palmitic acid and CHPA, 4 extra positive control bottle/microcosms (2 aerobic and 2 anaerobic) were prepared in the same way as the other positive controls, but without soil. These microcosms were used to obtain initial total NA concentration of the positive control groundwater. For the NA analysis, methylene chloride was added directly to the bottle/microcosm to enable extraction of the chunks of palmitic acid and CHPA that would not dissolve into the water (normally, during sampling, water is siphoned off of the microcosm – chunks may be left behind). Only 2 bottles were analyzed initially (1 aerobic and 1 anaerobic) and concentrations of 53.5 and 51.9 mg/L, respectively, of total NA were reported.

A.4 Addition of Metabolic Poison

Sodium Azide Addition to the aerobic microcosms:

Added 4ml of a 10 % solution of sodium azide per microcosm (50g soil/375 ml groundwater)

Mercuric Chloride Addition to the anaerobic microcosms:

Added 2ml of a 4% solution of mercuric chloride per microcosm (49g soil/375ml groundwater)

(J.T. Trevors, Journal of Microbiological Methods. 26 (1996) 53-59)

A.5 Addition of Positive Controls

Positive Control Additions of Palmitic Acid and 3-cyclohexanepropionic (CHPA) acid:

Required the addition of 10mg/L of Palmitic Acid:

10mg/L = 3.75mg/375ml (per microcosm)

Made stock of 0.3g per 3ml of methylene chloride

Add 37.5 μl of this stock to each microcosm

(0.3g/3ml) * 0.0375ml = 0.00375g or 3.75mg added to each microcosm

Required the addition of 10mg/L of 3-cyclohexanepropionic acid:

10mg/L = 3.75mg/375ml (per microcosm)

3.75mg/0.998density = 3.7575mg

Made stock of 0.3g per 3ml of methylene chloride

Add 37.575 μl of this stock to each microcosm

(0.3g/3ml) * 0.037575g = 0.0037575g or 3.7575 mg Added to each microcosm

Leave bottle cap off and allow the methylene chloride to evaporate away.

A.6 Groundwater Preparation

Groundwater used was ENV91-7B (it contained approximately 15 mg/L NA)

A stock solution, UW 456– MLSB 2001 NA (615mg/L), was used to add additional NA (up to 30mg/L) to the groundwater.

Aerobic NA spiked groundwater:

Required 2 carboys of water, one with 19L and the other with 9.4 L

Added 15mg/L of stock solution UW 456-MLSB 2001.

V1C1=V2C2, V=volume, C=concentration

X(615mg/L)=(19L)(15mg/L)

X=0.463L or Add 463ml to the 19L carboy

The smaller 9.4 L carboy received 229.3 ml

Groundwater was pH with Hcl to about 7.2 and allowed to stir overnight.

Final ph was 7.32 (large carboy) and 7.44 (small carboy)

Anaerobic NA spiked groundwater:

Required 2 carboys of nitrogen purged groundwater, one with 18.5L and the other with 9.4L

Added 15mg/L of stock solution UW 456-MLSB 2001

V1C1=V2C2, V=volume, C=concentration

X(615mg/L)=(18.4L)(15mg/L)

X=0.451L or Added 451ml to the 19L carboy

The smaller 9.4 L carboy received 229.3 ml

Groundwater was pH with HCl to about 7.2 and allowed to purge with nitrogen and stir overnight.

Final ph was 7.35 (large carboy) and 7.37 (small carboy)

After purging, the groundwater was transferred to smaller 4L bottles and flushed into the anaerobic chamber.

A.7 Addition of Nutrients

Modified Bushnell Haas Medium (MBH) consisted of per L: K2HPO4, 1.0g; KH2PO4, 1.0g; NH4NO3, 1.0g; MgSO4*7H2O, 0.2g; Cacl2*2H2O, 0.02g; Fecl3, 0.005g; distilled H2O, 1000mls and pH to 7.0 (modified from Mueller et.al. 1991. ES and T, 25:1045-1055)

Application rate 10ml per microcosm (375ml)

The following quantities of MBH were added to the groundwater 1-2 hours before dispensing.

Added 506.5 ml of MBH to 19L of groundwater (Aerobic)

Added 493.5 ml of MBH to 18.5L of groundwater (Anaerobic)

Added 250.5 ml of MBH to 9.4L of groundwater (Aerobic/Anaerobic)

A.8 Microcosm Chemical Results

Anaerobic		**Control A**	**Control B**	**Control C**	***Control Average***	***Standard Deviation***	***RSD***
Day 1	**pH**	----------	----------	----------	----------	----------	
	SO_4 (mg/L)	469.0	464.2	456.5	463.233	6.306	1%
	Total NA	23.6	33.2	24.2	27.000	5.378	20%
Day 7	**pH**	----------	----------	----------	----------	----------	
	SO_4 (mg/L)	414.6	476.6	447.5	446.233	31.019	7%
	Total NA	26.3	23.5	23.7	24.500	1.562	6%
Day 37	**pH**	7.46	7.47	7.48	7.47	0.0084	0%
	dO (mg/L)	0.8	0.6	0.8	0.73	0.1155	16%
	SO_4 (mg/L)	478.8	479.7	470.8	476.433	4.899	1%
	Total NA	21.7	21.6	22.8	22.033	0.666	3%
Day 63	**pH**	7.38	7.41	7.41	7.4	0.0173	0%
	dO (mg/L)	1	0.9	0.7	0.9	0.1528	18%
	SO_4 (mg/L)	477.70	489.50	467.50	478.23	11.01	2%
	Total NA	24.5	24.8	23.7	24.333	0.569	2%
Day 91	**pH**	7.44	7.46	7.44	7.45	0.0115	0%
	dO (mg/L)	1.3	1.1	1.1	1.2	0.1155	10%
	SO_4 (mg/L)	659.1	474.9	457.9	530.633	111.580	21%
	CH_4 (mg/L)	2.85	1.99	3.85	2.898	0.933	32%
	Total NA	18.6	17.9	31.8	22.767	7.831	34%
Day 142	**pH**	7.46	7.54	7.48	7.49	0.0416	1%
	dO (mg/L)	1.7	1.6	1.6	1.63	0.0577	4%
	SO_4 (mg/L)	458.9	477.3	467.8	468.000	9.202	2%
	CH_4 (mg/L)	1.25	2.94	2.60	2.264	0.897	40%
	Total NA	24.5	25.3	23.2	24.333	1.060	4%
Day 182	**pH**	7.33	7.4	7.41	7.38	0.0436	1%
	dO (mg/L)	1.1	1	1.4	1.2	0.2082	18%
	SO_4 (mg/L)	447.9	472.1	462.1	460.700	12.161	3%
	CH_4 (mg/L)	4.63	5.30	7.30	5.742	1.387	24%
	Total NA	24.5	25.8	25.6	25.300	0.700	3%

TABLE A.2: Chemical characteristics of anaerobic microcosm controls

		Active A	Active B	Active C	*Active Average*	*Standard Deviation*	*RSD*
Day 1	**pH**	----------	----------	----------	----------	----------	
	SO_4 (mg/L)	467.4	460.9	459.4	462.567	4.252	1%
	Total NA	16.7	16.5	15.5	16.233	0.643	4%
Day 7	**pH**	----------	----------	----------	----------	----------	
	SO_4 (mg/L)	481.9	472.1	546.6	500.200	40.481	8%
	Total NA	24.2	24.4	26.2	24.933	1.102	4%
Day 37	**pH**	7.85	7.83	7.94	7.87	0.0586	1%
	dO (mg/L)	0.5	0.5	0.8	0.60	0.1732	29%
	SO_4 (mg/L)	459.5	462.1	464.7	462.100	2.600	1%
	Total NA	18.4	20.0	26.3	23.135	4.182	18%
Day 63	**pH**	7.91	7.97	7.99	7.96	0.0416	1%
	dO (mg/L)	1.6	1.3	1.2	1.4	0.2082	15%
	SO_4 (mg/L)	463.90	465.40	469.20	466.17	2.73	1%
	Total NA	24.2	26.6	24.2	25.400	1.386	5%
Day 91	**pH**	8.33	8.16	7.96	8.15	0.1852	2%
	dO (mg/L)	1.1	1	1	1.0	0.0577	6%
	SO_4 (mg/L)	78.8	453.0	541.8	357.853	245.746	69%
	CH_4 (mg/L)	126.88	1.59	1.18	43.215	72.453	168%
	Total NA	21.0	22.3	25.9	24.100	2.538	11%
Day 142	**pH**	8.01	8.72	8.12	8.28	0.3821	5%
	dO (mg/L)	1.5	1.1	0.7	1.10	0.4000	36%
	SO_4 (mg/L)	486.7	25.2	442.0	317.970	254.521	80%
	CH_4 (mg/L)	2.95	0.68	3.62	2.416	1.544	64%
	Total NA	29.6	32.5	27.2	29.850	2.654	9%
Day 182	**pH**	7.68	8.02	8.63	8.11	0.4814	6%
	dO (mg/L)	1.3	1.2	1.3	1.3	0.0577	5%
	SO_4 (mg/L)	2.13	0	309.6	103.910	178.136	171%
	CH_4 (mg/L)	1013.27	401.09	2.45	472.271	509.156	108%
	Total NA	34.5	32.5	32.0	32.250	1.323	4%

Table A.3: Chemical characteristics of active anaerobic microcosms

		Positive Control A	Positive Control B	Positive Control C	*Positive Control Average*	*Standard Deviation*	*RSD*
Day 1	**pH**	----------	----------	----------	----------	----------	
	SO_4 (mg/L)	498.5	463.2	465.8	475.833	19.673	4%
	Total NA	16.7	16.5	15.5	16.233	0.643	4%
Day 7	**pH**	----------	----------	----------	----------	----------	
	SO_4 (mg/L)	460.9	480.4	474.1	471.800	9.951	2%
	Total NA	23.7	17.6	23.1	21.467	3.362	16%
Day 37	**pH**	8.03	8.44	7.91	8.13	0.2779	3%
	dO (mg/L)	0.9	0.8	0.8	0.85	0.0707	8%
	SO_4 (mg/L)	439.5	367.5	421.8	409.600	37.518	9%
	Total NA	17.1	18.7	20.6	18.800	1.752	9%
Day 63	**pH**	8.41	8.61	7.82	8.28	0.4107	5%
	dO (mg/L)	0.6	0.4	0.7	0.7	0.0707	11%
	SO_4 (mg/L)	48.75	43.07	428.50	173.44	220.91	127%
	Total NA	32.3	19.0	22.6	24.617	6.900	28%
Day 91	**pH**	8.01	8.74	8.12	8.29	0.3936	5%
	dO (mg/L)	0.8	0.5	0.7	0.8	0.0707	9%
	SO_4 (mg/L)	no sample	67.2	398.3	155.167	234.123	151%
	CH_4 (mg/L)		2.23	0.94	1.585	0.910	57%
	Total NA		23.4	27.3	25.350	2.758	11%
Day 142	**pH**	8.42	8.8	7.7	8.31	0.5587	7%
	dO (mg/L)	1.5	0.7	0.7	1.10	0.5657	51%
	SO_4 (mg/L)	198.5	23.1	9.9	77.146	105.302	136%
	CH_4 (mg/L)	5.58	8.63	53.72	31.173	31.885	102%
	Total NA	32.7	33.0	30.9	32.183	1.118	3%
Day 182	**pH**	8.63	9.04	8.84	8.84	0.2050	2%
	dO (mg/L)	1.2	1.0	0.9	1.1	0.2121	20%
	SO_4 (mg/L)	10.93	58.1	267.8	108.633	136.737	126%
	CH_4 (mg/L)	311.66	290.05	2.71	146.380	203.177	139%
	Total NA	34.7	31.8	36.4	34.100	3.253	10%

TABLE A.4: Chemical characteristics of positive control anaerobic microcosms

Aerobic Microcosms		**Control A**	**Control B**	**Control C**	***Control Average***	***Standard Deviation***	***Relative Standard Deviation***
Day 1	**pH**	----------	----------	----------	----------	----------	----------
	Total NA	27.1	27.8	25.5	26.800	1.179	4%
Day 9	**pH**	----------	----------	----------	----------	----------	----------
	Total NA	19.9	20.7	21.95	20.850	1.033	5%
Day 14	**pH**	7.91	7.92	7.96	7.93	0.0265	0%
	Total NA	29.0	26.7	28.1	27.923	1.137	4%
Day 44	**pH**	7.87	7.85	7.84	7.85	0.0153	0%
	dO (mg/L)	8.2	7.6	8.2	8.0	0.3464	4%
	Total NA	23.2	23.3	24.2	23.567	0.551	2%
Day 58	**pH**	8.01	8.25	8.18	8.15	0.1234	2%
	dO (mg/L)	7.1	8.16	8.24	7.8	0.6363	8%
	Total NA	23.0	28.9	23.7	25.200	3.223	13%
Day 84	**pH**	7.71	8.39	7.9	8.00	0.3509	4%
	dO (mg/L)	7.91	8.23	8.06	8.1	0.1601	2%
	Total NA	27.1	26.7	27.0	26.943	0.214	1%
Day 141	**pH**	7.75	8.51	8.16	8.14	0.3804	5%
	dO (mg/L)	8.4	8.7	8.5	8.5	0.1528	2%
	Total NA	28.4	29.8	28.9	29.033	0.709	2%

TABLE A.5: Chemical characteristics of control aerobic microcosms

Aerobic Microcosms		**Active A**	**Active B**	**Active C**	***Active Average***	***Standard Deviation***	***Relative Standard Deviation***
Day 1	**pH**	----------	----------	----------	----------	----------	----------
	Total NA	23.5	17.4	18.5	19.800	3.251	16%
Day 9	**pH**	----------	----------	----------	----------	----------	----------
	Total NA	14.1	17.3	17.6	16.333	1.940	12%
Day 14	**pH**						
	Total NA	22.8	27.1	32.0	29.570	4.624	16%
Day 44	**pH**	7.42	7.48	7.34	7.41	0.0702	1%
	dO (mg/L)	5.9	6.7	6	6.2	0.4359	7%
	Total NA	16.1	15.8	12.5	14.150	1.997	14%
Day 58	**pH**	7.71	8.02	7.59	7.77	0.2219	3%
	dO (mg/L)	7.67	7.77	7.41	7.6	0.1858	2%
	Total NA	15.7	17.7	15.7	16.700	1.155	7%
Day 84	**pH**	8.43	7.25	8.3	7.99	0.6470	8%
	dO (mg/L)	7.77	5.12	7.78	6.9	1.5329	22%
	Total NA	15.2	13.6	14.0	13.815	0.828	6%
Day 141	**pH**	8.66	7.33	7.19	7.99	0.6470	8%
	dO (mg/L)	8.2	4.8	5	6.9	1.5329	22%
	Total NA	13.8	12.0	11.9	11.950	1.069	9%

TABLE A.6: Chemical characteristics of active aerobic microcosms

Aerobic Microcosms		**Positive Control A**	**Positive Control B**	**Positive Control C**	***Positive Control Average***	***Standard Deviation***	***Relative Standard Deviation***
Day 1	**pH**	----------	----------	----------	----------	----------	----------
	Total NA	23.6	31.9	23.2	26.233	4.912	19%
Day 9	**pH**	----------	----------	----------	----------	----------	----------
	Total NA	18.2	18.5	15.6	17.433	1.595	9%
Day 14	**pH**						
	Total NA	27.3	30.3	24.7	27.433	2.802	10%
Day 44	**pH**	7.353333333	7.36	7.36	7.36	0.0038	0%
	dO (mg/L)	6.7		6.3	6.5	0.2828	4%
	Total NA	21.7	16.1	16.0	17.947	3.251	18%
Day 58	**pH**	8.393333333	7.53	8.21	8.04	0.4549	6%
	dO (mg/L)	8.15	6.37	7.73	7.9	0.2970	4%
	Total NA	16.3	16.1	18.4	16.933	1.274	8%
Day 84	**pH**	8.48	8.39	8.43	8.43	0.0451	1%
	dO (mg/L)	7.45	7.66	7.58	7.5	0.0919	1%
	Total NA	14.3	13.2	14.2	13.900	0.608	4%
Day 141	**pH**	7.14	7.21	7.26	8.43	0.0451	1%
	dO (mg/L)	4.2	4.6	4.9	7.5	0.0919	1%
	Total NA	11.5	11.1	10.3	10.967	0.611	6%

Table A.7: Chemical characteristics of positive control aerobic microcosms

A.9 Detailed Naphthenic Acid Graphs for Microcosms

The distribution of carbon numbers and Z families of naphthenic acids in the complex mixtures extracted and derivatized from microcosms. The bars represent the percentage (by number of ions) of NAs in the mixture that can account for a given carbon number of a given Z family (a specific m/z value). The sum of all bars equals 100% (Holowenko et al., 2002).

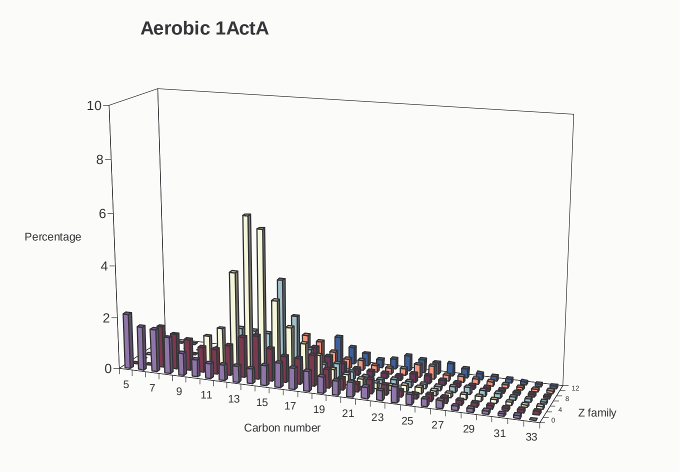


FIGURE A.1: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 1ActA".

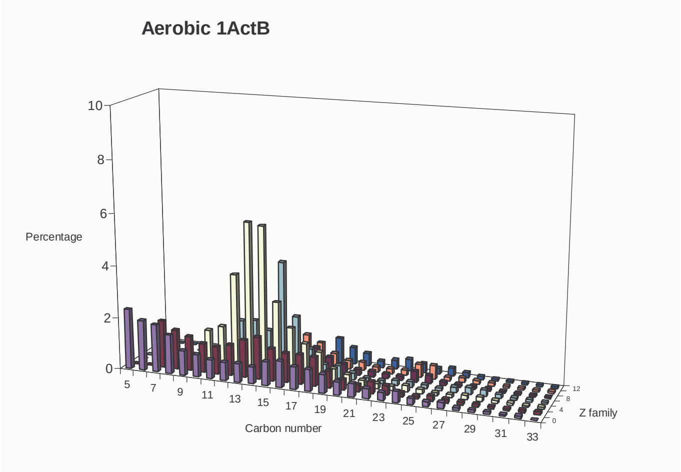


Figure A.2: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 1ActB”

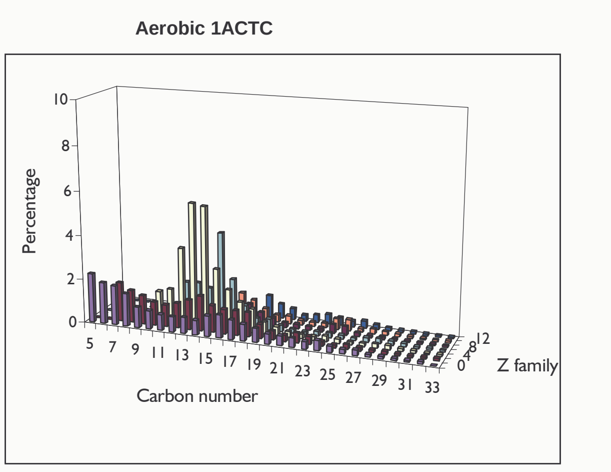


Figure A.3: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 1ActC”

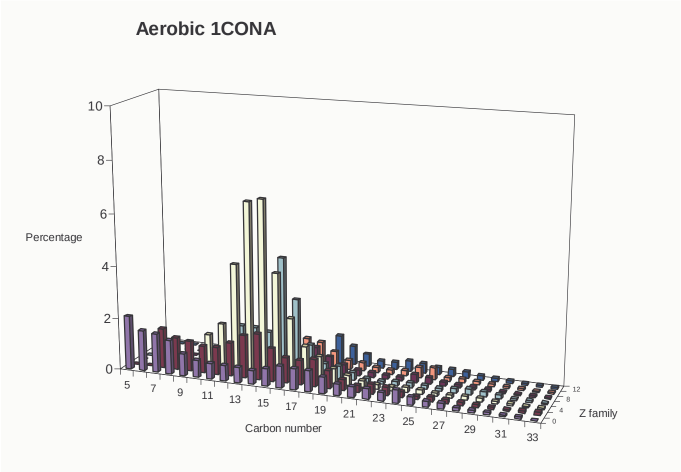


Figure A.4: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 1ConA".

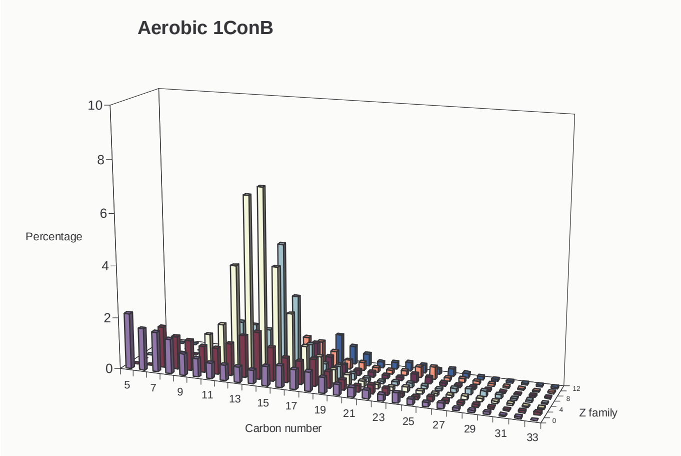


Figure A.5: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 1ConB".

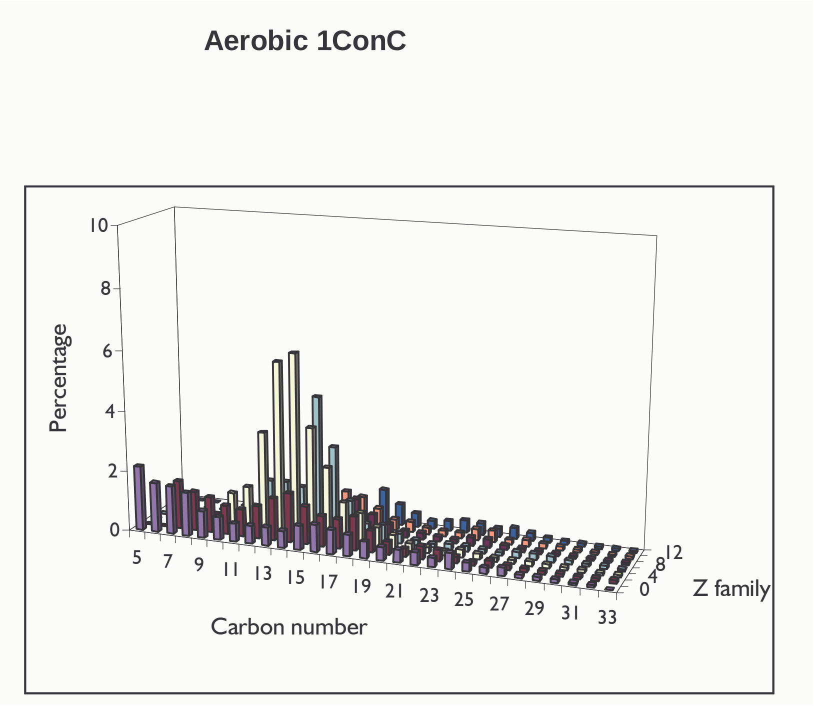


FIGURE A.6: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 1ConC".

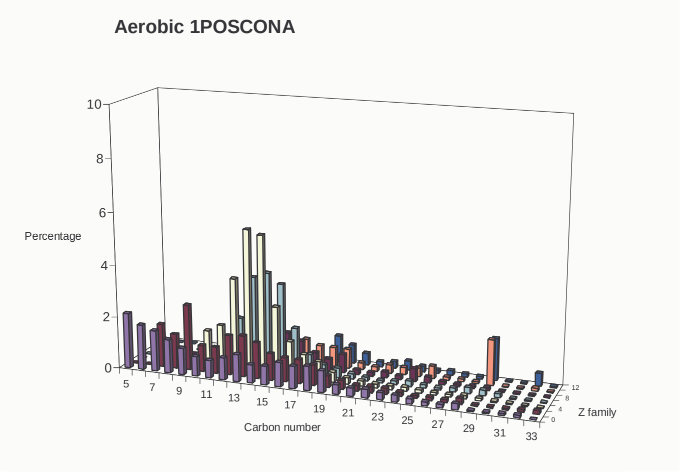


FIGURE A.7: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic PosConA".

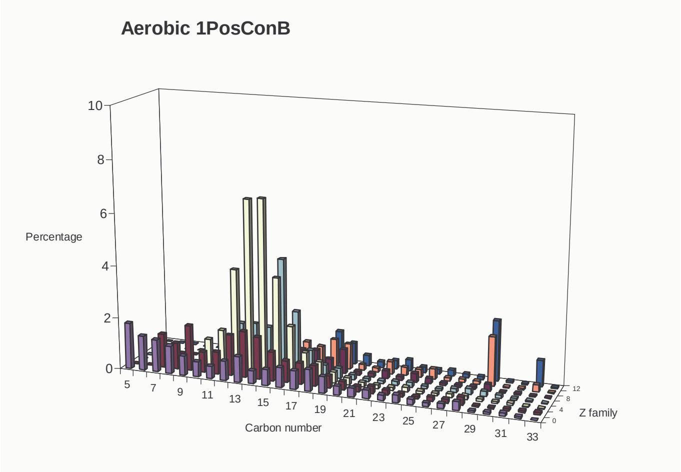


Figure A.8: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 1PosConB”.

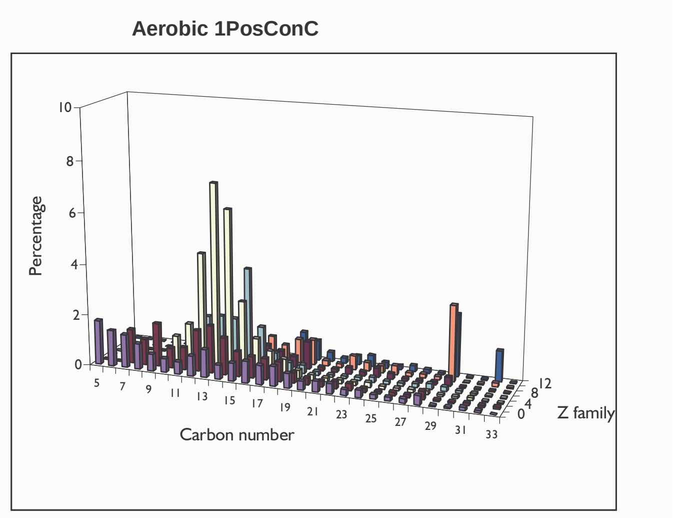


Figure A.9: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 1PosConC”.

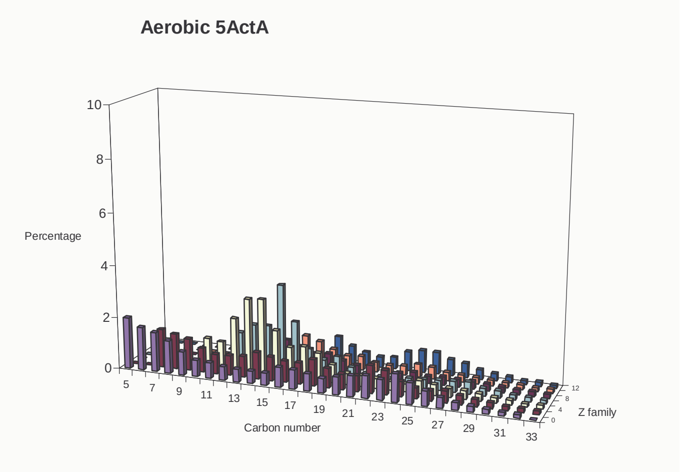


Figure A.10: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 5ActA”.

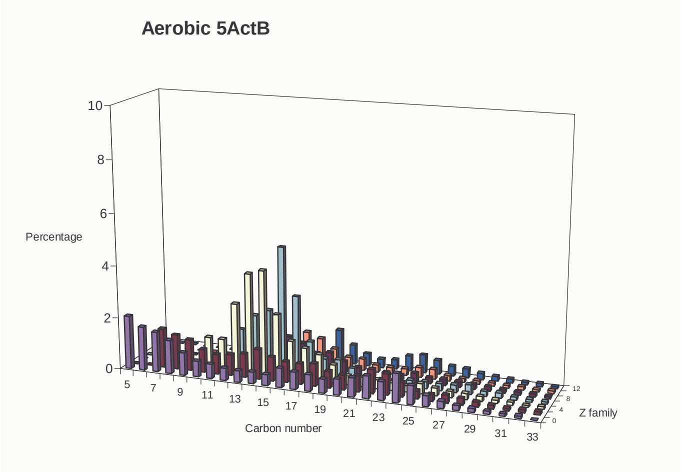


FIGURE A.11: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 5ActB".

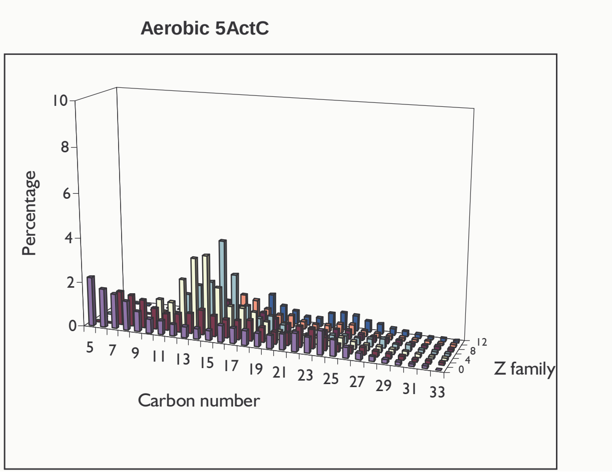


FIGURE A.12: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 5ActC".

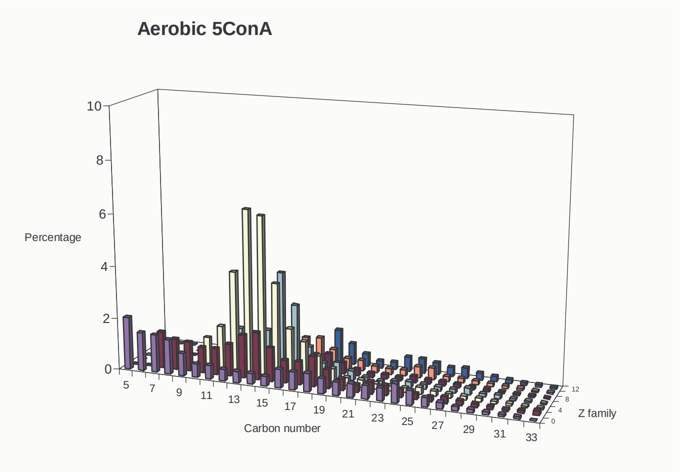


Figure A.13: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 5ConA".

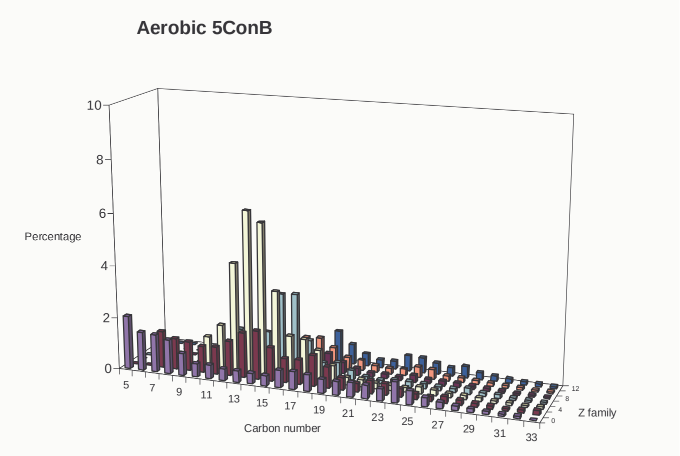


Figure A.14: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 5ConB".

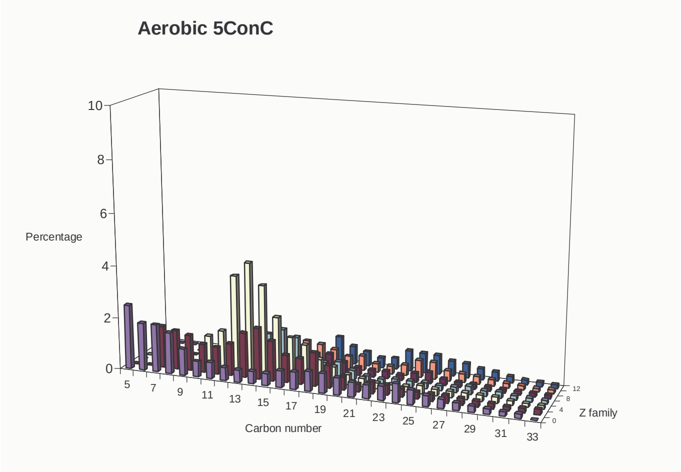


FIGURE A.15: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 5ConC".

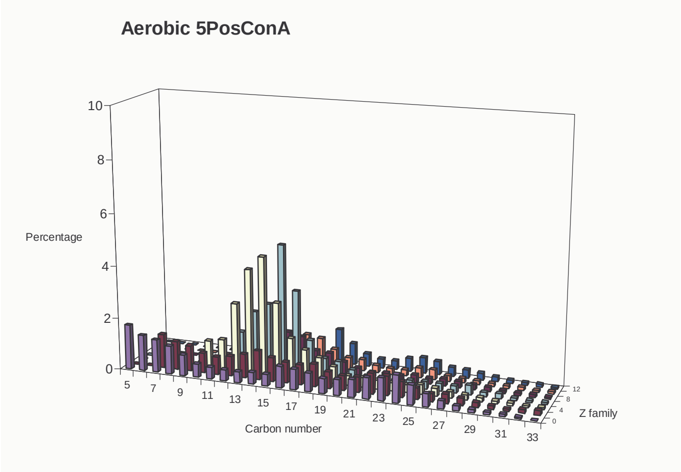


FIGURE A.16: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 5PosConA".

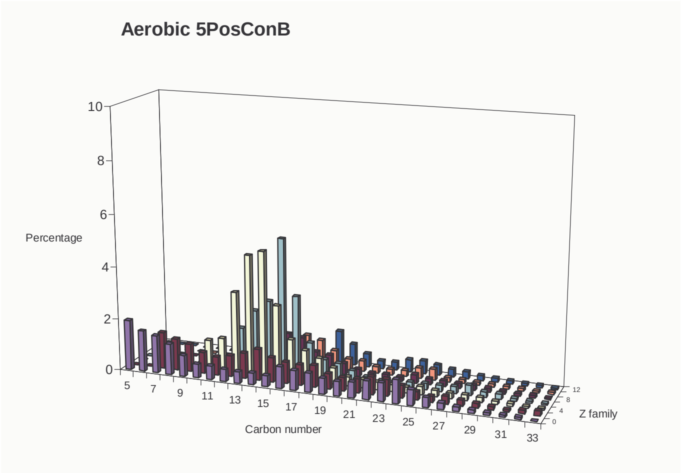


Figure A.17: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 5PosConB”.

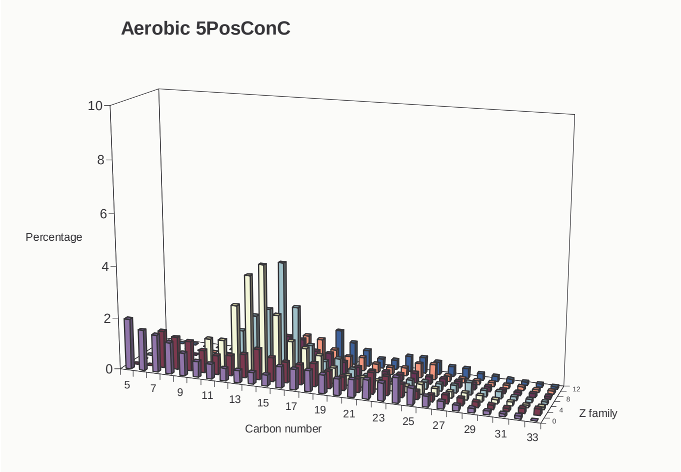


Figure A.18: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 5PosConC”.

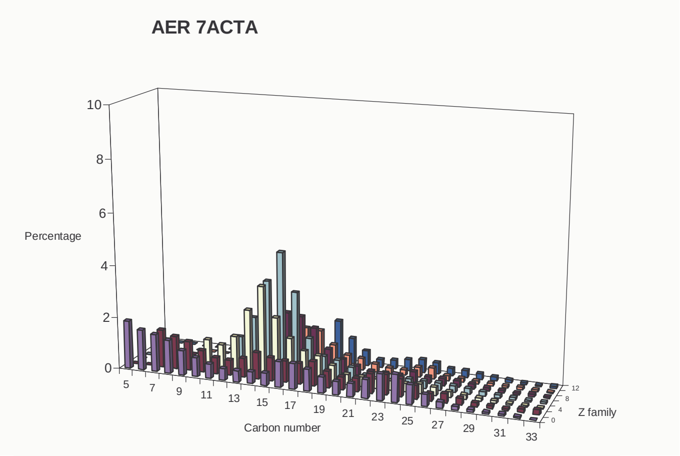


FIGURE A.19: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 7ActA".

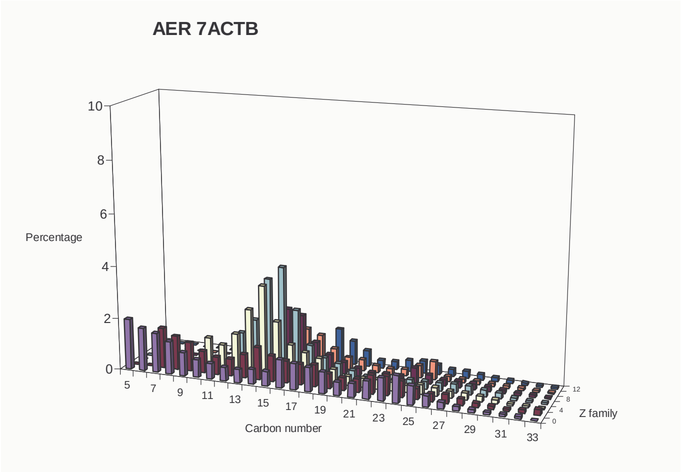


Figure A.20: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 7ActB".

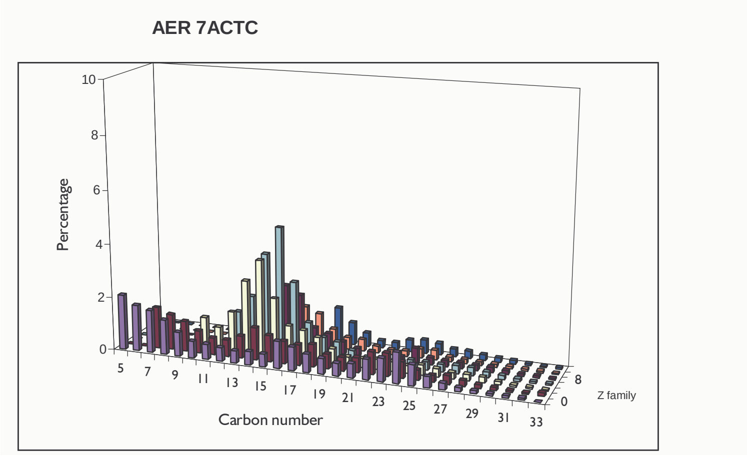


Figure A.21: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 7ActC".

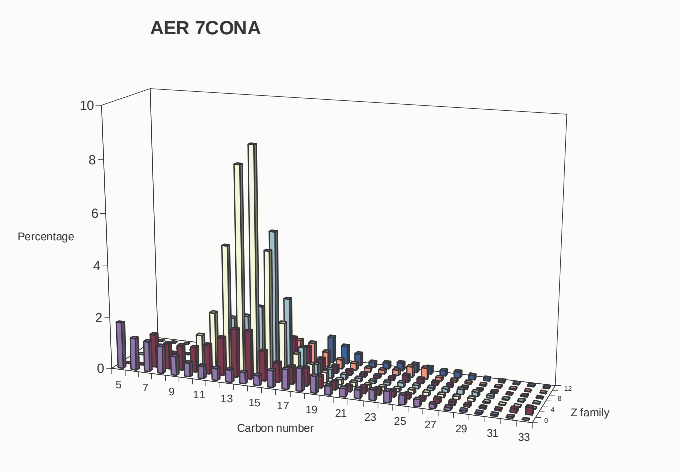


FIGURE A.22: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 7ConA".

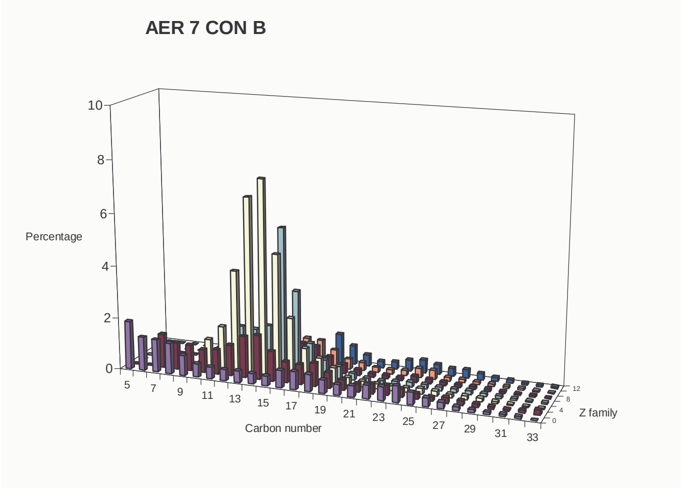


FIGURE A.23: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Aerobic 7ConB".

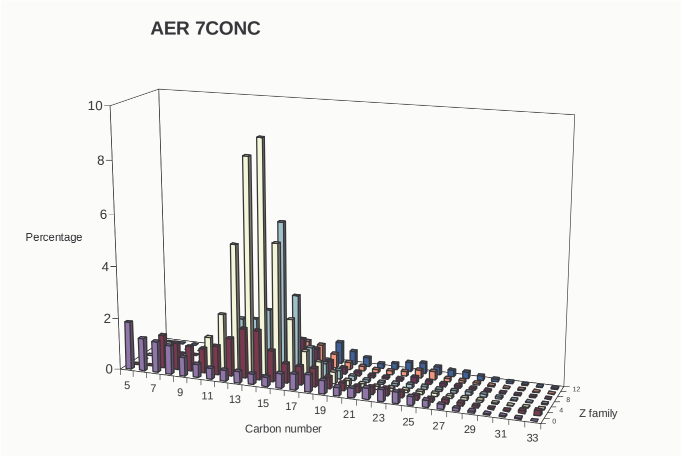


Figure A.24: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 7ConC”.

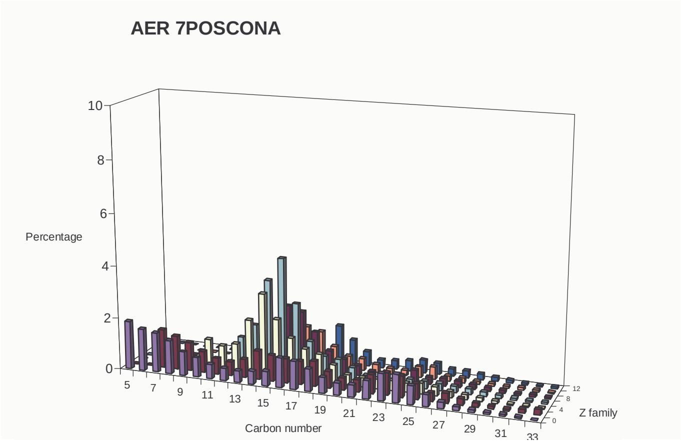


Figure A.25: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 7PosConA”.

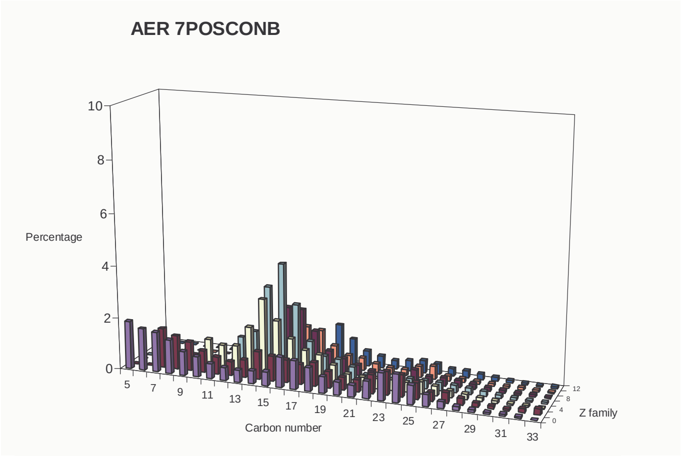


Figure A.26: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 7PosConB”.

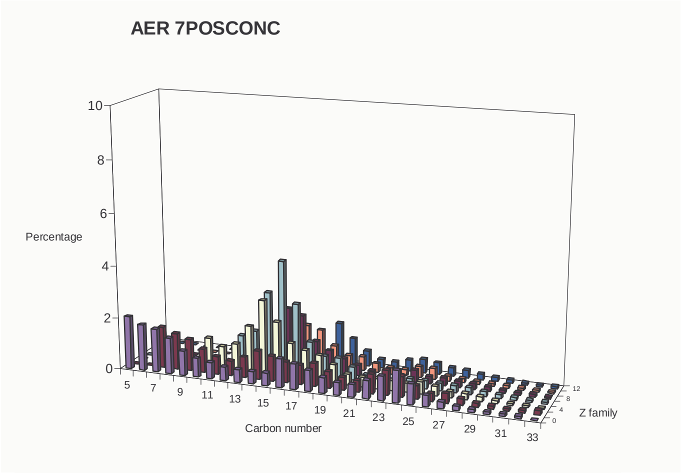


Figure A.27: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Aerobic 7PosConC”.

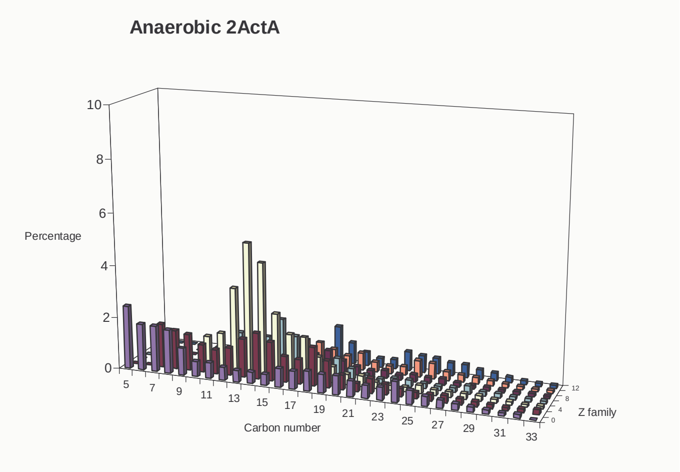


FIGURE A.28: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 2ActA".

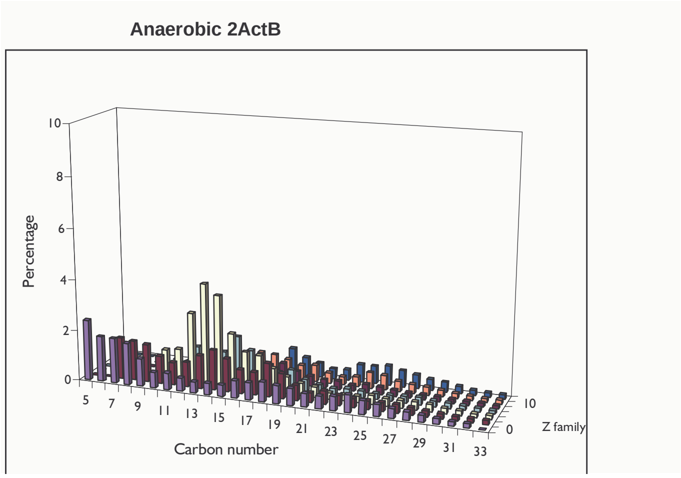


FIGURE A.29: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 2ActB".

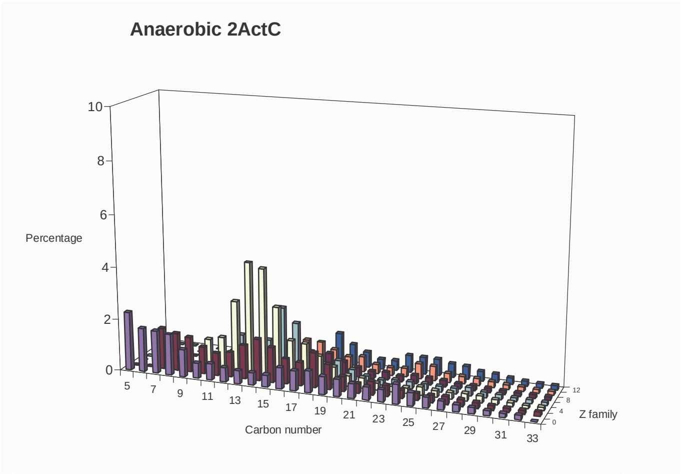


FIGURE A.30: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 2ActC".

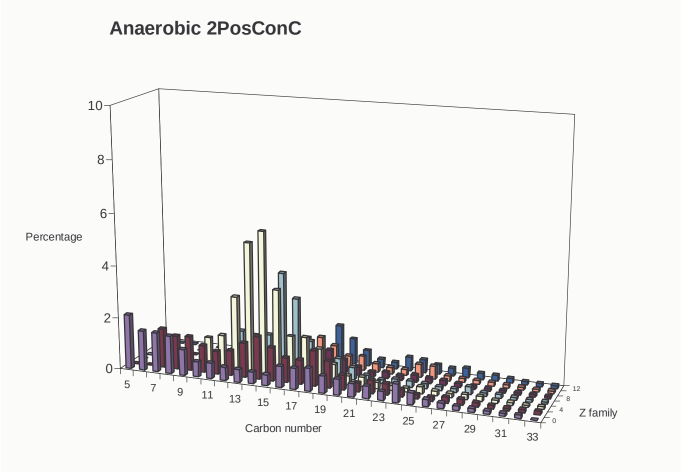


FIGURE A.31: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 2PosConC".

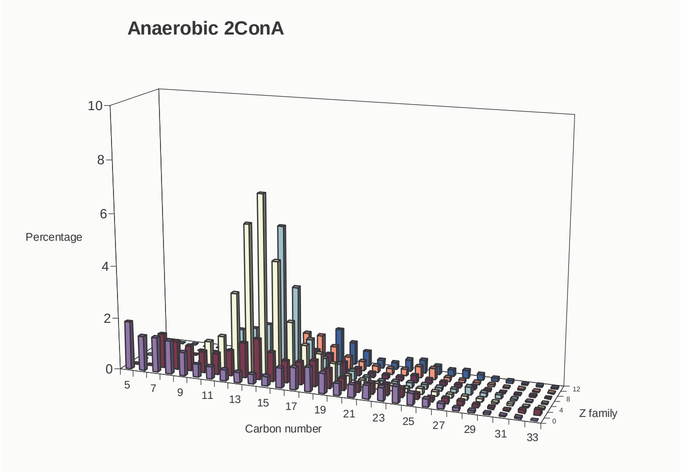


FIGURE A.32: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 2ConA".

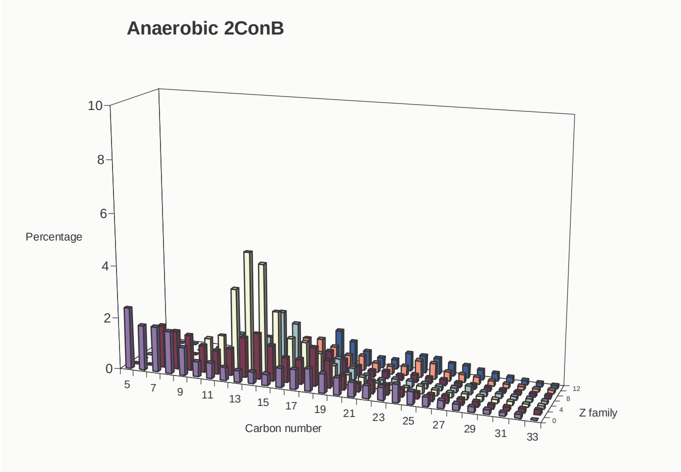


FIGURE A.33: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 2ConB".

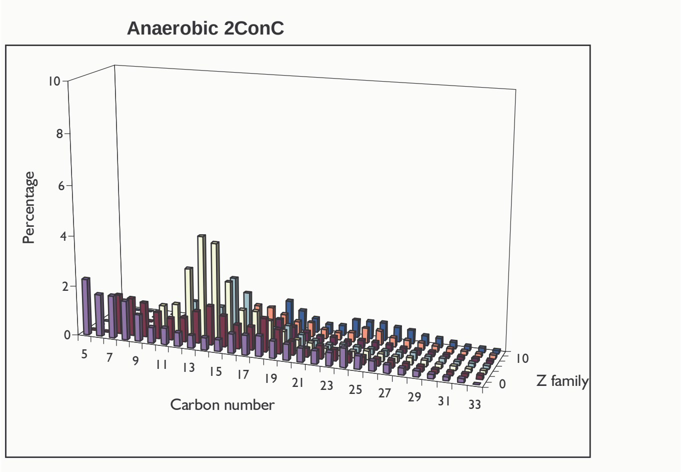


FIGURE A.34: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 2ConC".

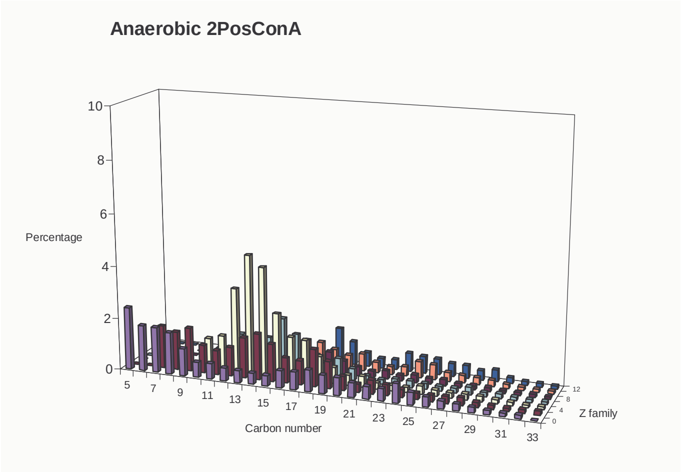


FIGURE A.35: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Anerobic 2PosConA”.

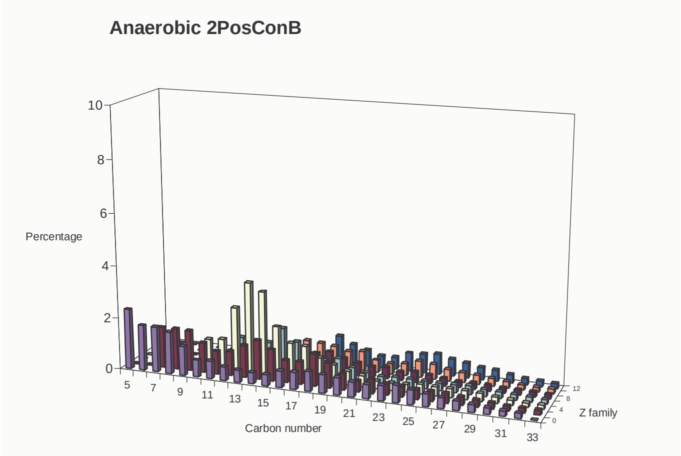


FIGURE A.36: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Anerobic 2PosConB”.

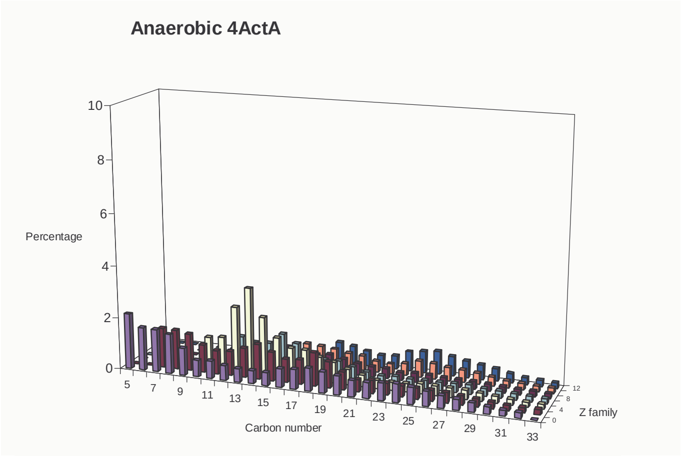


FIGURE A.37: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Anerobic 4ActA”.

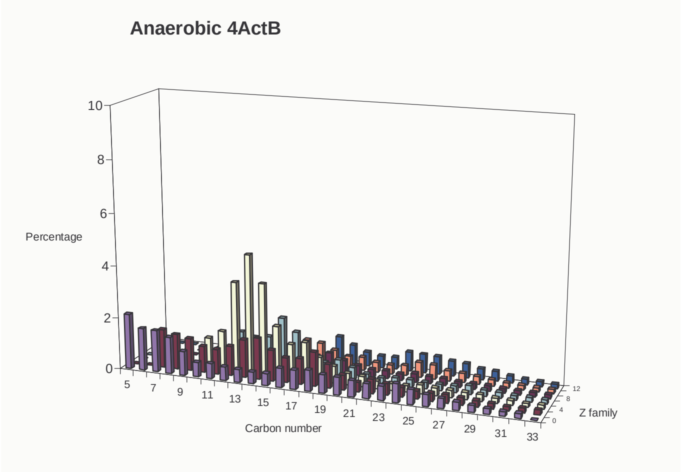


Figure A.38: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 4ActB".

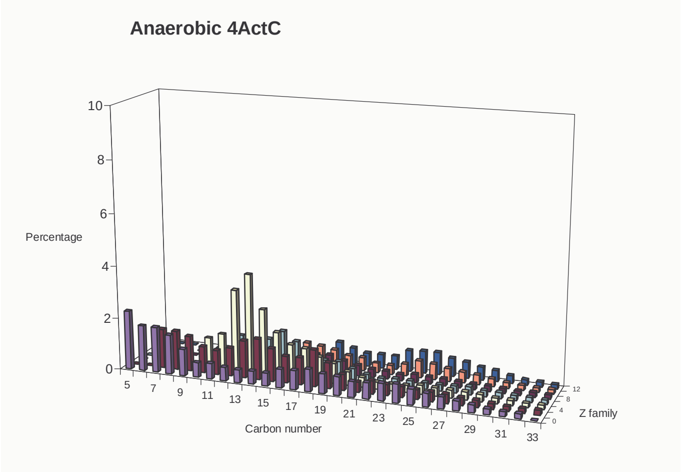


Figure A.39: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 4ActC".

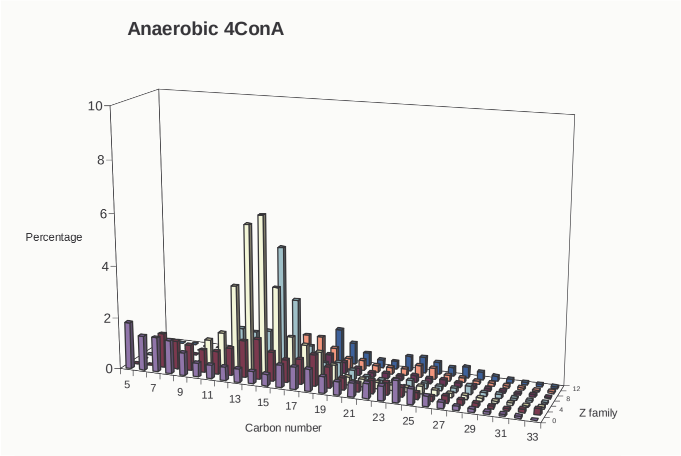


Figure A.40: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 4ConA".

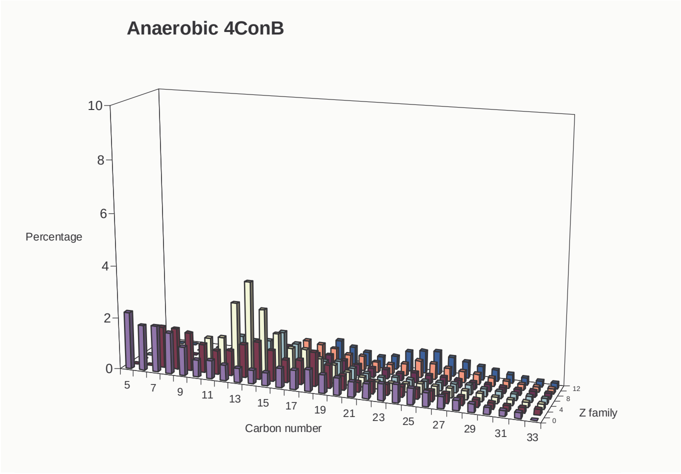


Figure A.41: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 4ConB".

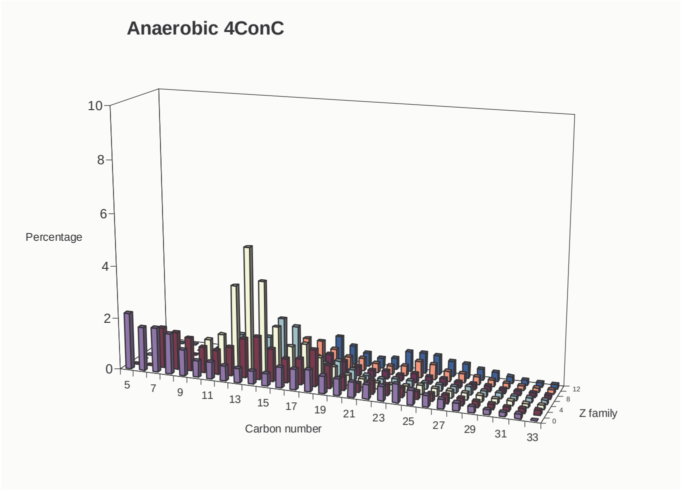


FIGURE A.42: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 4ConC".

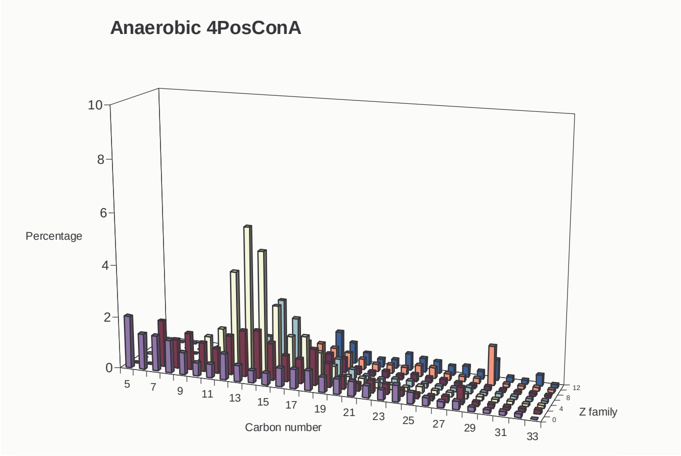


FIGURE A.43: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anerobic 4PosConA".

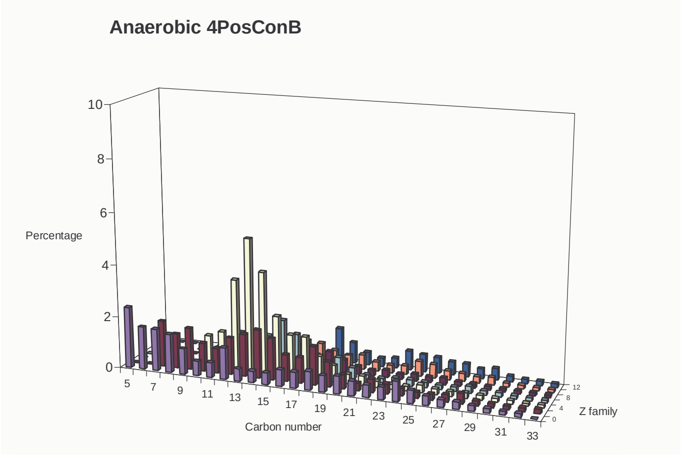


Figure A.44: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Anerobic 4PosConB”.

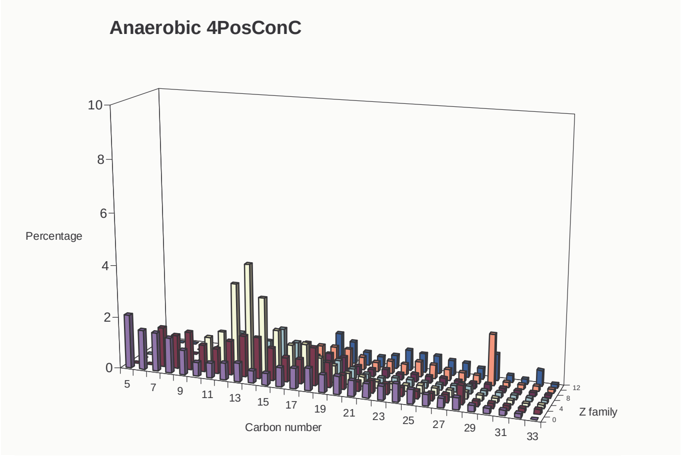


Figure A.45: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Anerobic 4PosConC”.

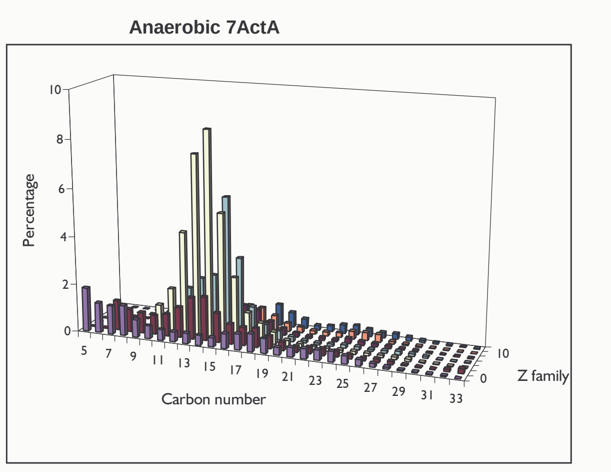


Figure A.46: The distribution of carbon numbers and Z families extracted and derivatized from microcosm “Anaerobic 7ActA”.

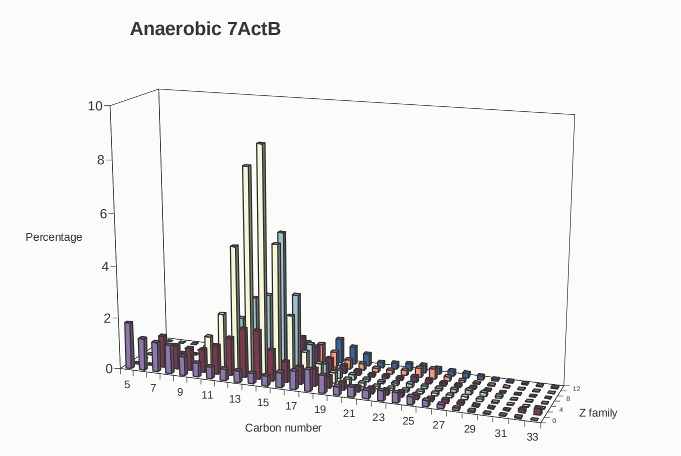


FIGURE A.47: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anaerobic 7ActB".

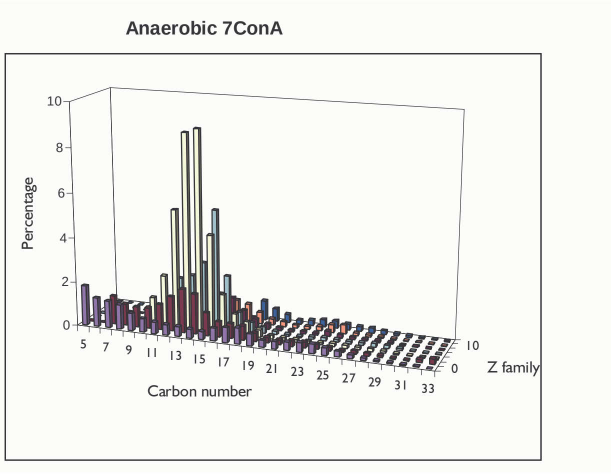


FIGURE A.48: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anaerobic 7ConA".

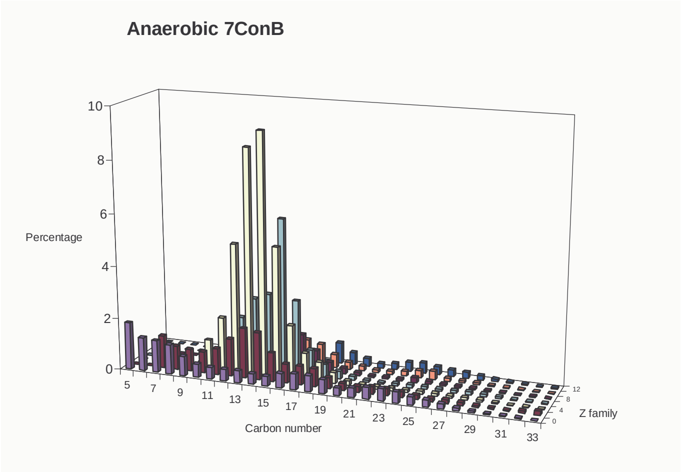


Figure A.49: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anaerobic 7ConB".

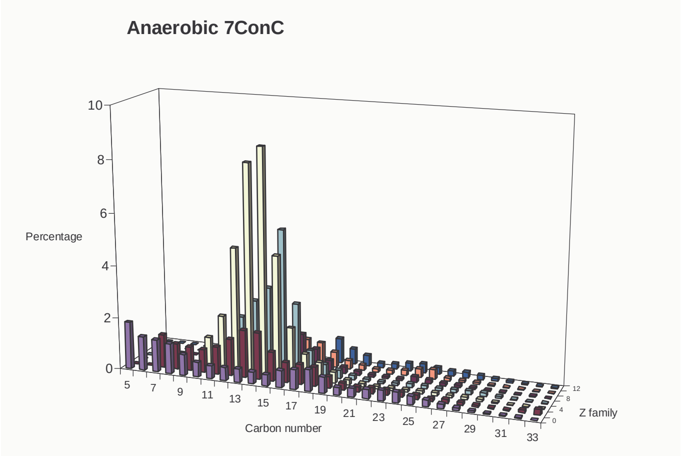


Figure A.50: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anaerobic 7ConC".

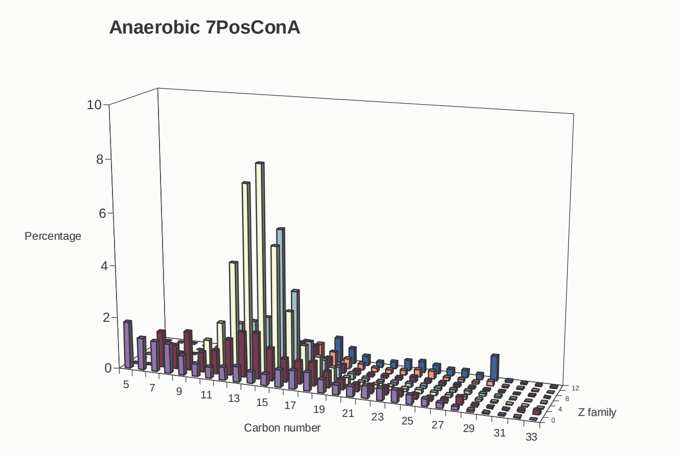


FIGURE A.51: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anaerobic 7PosConA".

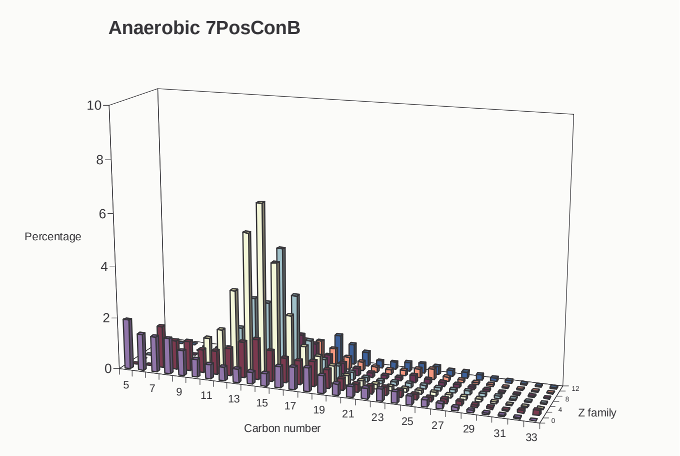


FIGURE A.52: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anaerobic 7PosConB".

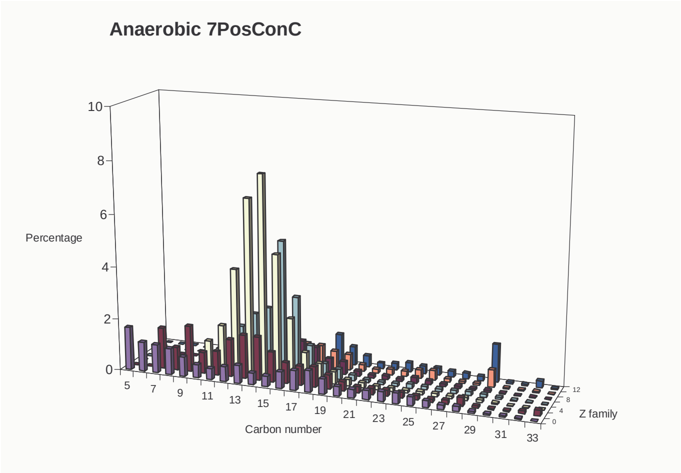


Figure A.53: The distribution of carbon numbers and Z families extracted and derivatized from microcosm "Anaerobic 7PosConC".

Appendix B

Sorption of stock naphthenic acids

for Françoise Gervais

Set Up- Nov 13, 2003- Sample Nov 17, 2003

(by Marianne VanderGriendt)

B.1 Design:

1. Control -Water Only plus Naphthenic Acid (NA)(10, 30 and 100 mg/L) 3 conc. * 3 triplicate= 9
2. Active - Soil/Water plus Naphthenic Acid (10, 30, and 100 mg/L) 3 conc. * 3 triplicate= 9
3. Desorption- Soil/ water, 3 only (largest volume bottles – 1 L)

Total 21 bottles (plus 1 extra of 10 and 30 mg/L Actives)

Analysis - Total NA (FTIR) and Detailed NA (GC-MS) on some bottles

Analytical requirement of 1.5 mg/ml of NA in methylene chloride for Total NA analysis ie. 100ml of water at 15mg/L = 1.5 mg/ml

Analytical requirement of 1.5 – 2.0 mg/ml of NA in methylene chloride for Detailed NA analysis ie. 200ml of water @ 15mg/L = 3.0mg/ml (extra for extraction efficiency)

Soil Requirements:

Kd design – normal ratio = 30ml/50g of soil in a 60ml vial (no headspace) – this design does not afford enough volume for the analytical analysis.

1. Type 1 water = 10mg/L – Require at least 450 ml @ 10 mg/L for analytical analysis (150ml water for total NA, 300 ml water for detailed NA)

Bottle size = 1L, 834g of soil * 6 (3 active, 3 control-desorption)= 5 kg

2. Type 2 water = 30mg/L – Require at least 150ml @30mg/L for analytical analysis (50ml water for total NA, 100 ml water for detailed NA)

Bottle size = 500ml, 417g of soil * 3 (3 active) = 1.251 kg

3. Type 3 water = 100mg/L – Require at least 45ml @100mg/L for analytical analysis (15ml for total NA, 30ml for detailed NA)

Bottle size = 100ml, 84g of soil * 3 (3 active) = 0.25 kg

Total Soil required = approximately 7 Kg

Soil was air dried and sieved through a 2.00 mm sieve

Soil was obtained from white pails (2) (no location provided on pail)

Water Requirements (Ions, NA addition):

Water Composition (from F. Gervais – based on site ion concentrations)

Artificial Groundwater would then consist of:

NaHCO3 1315 mg/L

CaCl2 82.5 mg/L

MgSO4 30 mg/L

NaSO4 135 mg/L

Nacl 148 mg/L

Ph to 7.0 and hope that nothing precipitates out.

B.2 Method

B.2.1 Type 1 water

(10mg/L NA) Active(719ml) * 3 = 2157ml + 3 Control (1040) *3 = 3120ml = 7 L required

Ions to add to 7L quantity of water:

NaHCO3	9.205g
CaCl2	0.5775g
MgSO4	0.21g
NaSO4	0.945g
Nacl	1.036g

Addition of basic NA stock UW 456 (concentration approximately 617mg/L) –

V1C1=V2C2

7L*(10mg/L NA)=x(617mg/L)

x=113.45ml – Add 113.45 ml of NA stock to 6.88655 L of deionized water. Initial pH was 8.56 - pH to 7.0 and stir overnight. Ph to 7.0 again before experimental set up. Used concentrated Hcl to pH

B.2.2 Type 2 water

(30mg/L NA) Active(400ml) * 3= 1200ml + 3 Control (500ml) *3 = 1500ml = 4 L (extra water prepared for trial microcosm soil extractions –)

Ions to add to 4L quantity of water:

NaHCO3	5.26g
CaCl2	0.33g
MgSO4	0.12g
NaSO4	0.54g
Nacl	0.592g

Addition of basic NA stock UW 456 (concentration approximately 617mg/L) –

V1C1=V2C2

4L*(30mg/L NA)=x(617mg/L)

x=194.49ml – Add 194.49 ml of NA stock to 3.80551 L of deionized water. Initial pH was 8.96 - pH to 7.0 and stir overnight. Ph to 7.0 again before experimental set up. Used concentrated Hcl to pH

B.2.3 Type 3 water

(100mg/L NA) active(70ml) *3 = 210ml + 3 Control (100ml) *3 = 300ml = 1L

Ions to add to 1L quantity of water:

NaHCO3	1.315g
CaCl2	0.0825g
MgSO4	0.030g
NaSO4	0.0135g
Nacl	0.148g

Addition of basic NA stock UW 456 (concentration approximately 617mg/L) –

V1C1=V2C2

1L*(100mg/L)=x(617mg/L)

x=162.07ml – Add 162.07 ml of NA stock to 0.838 L of deionized water. Initial pH was 9.44 - pH to 7.0 and stir overnight. Ph to 7.0 again before experimental set up. Used concentrated Hcl to pH

B.2.4 Type 4 water

(water only) Desorption(719ml) *3 = 2157 (make extra) = 4L

Ions to add to 4L quantity of water:

NaHCO3	5.26g
CaCl2	0.33g
MgSO4	0.12g
NaSO4	0.54g
Nacl	0.592g

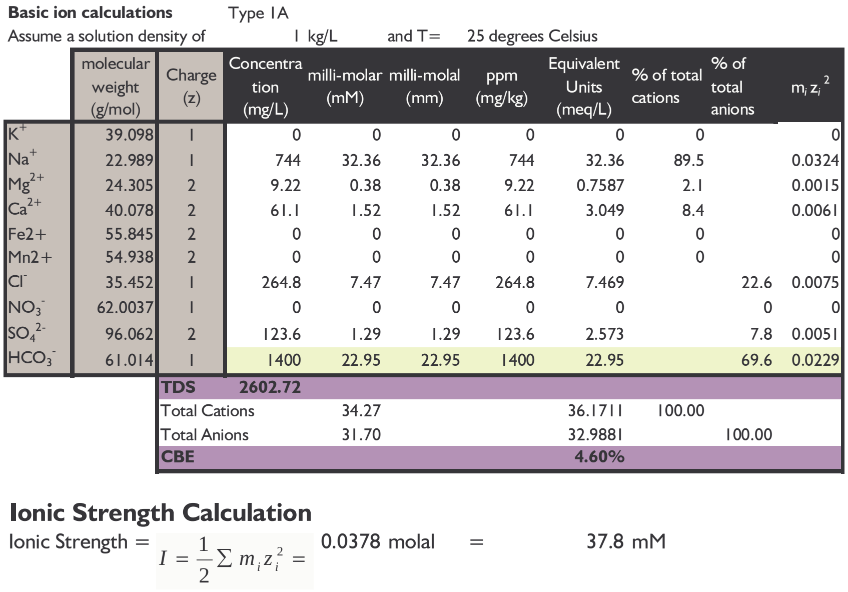
Initial pH was 7.90 - pH to 7.0 and stir overnight. Ph to 7.0 again before experimental set up. Used concentrated Hcl to pH

No NA addition was made to this water.

After the experimental set up, larger 1L and 500ml bottles were placed on there sides on a shaker at 50 rpm. Smaller 100ml bottles were placed on a rotating wheel.

B.3 Sampling

After 84 (3.5days) hours of incubation, bottles were opened and appropriate volumes of water were removed with a 60ml ground glass syringe (fitted with a wide bore Teflon tip). Care was taken not to disturb the settled sediment. Fines would not settle, so samples were centrifuged at 2000 rpm for 45 min. (Greg Friday's centrifuge). This supernatant was allocated for Total and dissolved NA analysis (also pH and some cation/anion, conductivity, total dissolved solids (with a probe) analysis etc.).



Basic ion calculations Type 1A

Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	744	32.36	32.36	744	32.36	89.5		0.0324
Mg^{2+}	24.305	2	9.22	0.38	0.38	9.22	0.7587	2.1		0.0015
Ca^{2+}	40.078	2	61.1	1.52	1.52	61.1	3.049	8.4		0.0061
Fe2+	55.845	2	0	0	0	0	0	0		0
Mn2+	54.938	2	0	0	0	0	0	0		0
Cl^-	35.452	1	264.8	7.47	7.47	264.8	7.469		22.6	0.0075
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	123.6	1.29	1.29	123.6	2.573		7.8	0.0051
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		69.6	0.0229
		TDS	**2602.72**							
		Total Cations		34.27			36.1711	100.00		
		Total Anions		31.70			32.9881		100.00	
		CBE					**4.60%**			

Ionic Strength Calculation

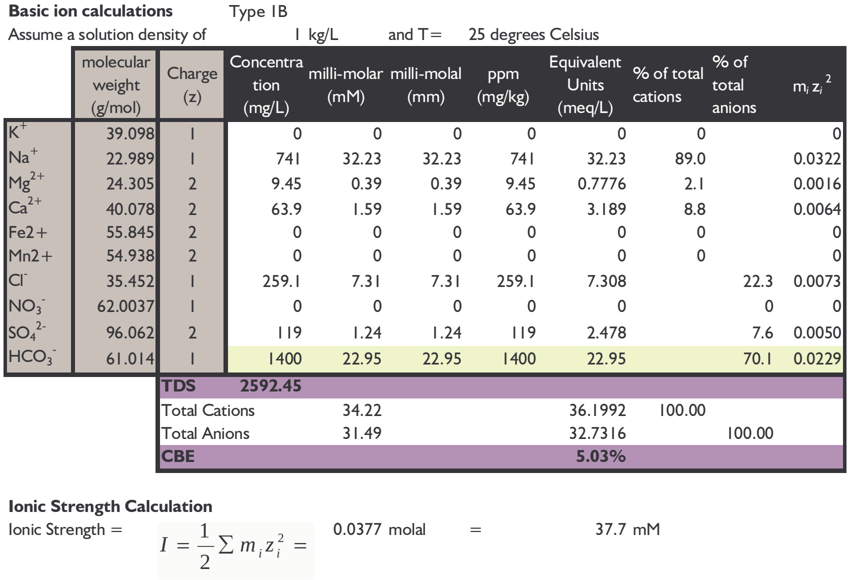
Ionic Strength = $I = \frac{1}{2} \sum m_i z_i^2 =$ 0.0378 molal = 37.8 mM

Table B.1: Basic ion calculations for the surrogate NA batch reactor Type 1A.

B.4 Water Chemistry of Batch Equilibriation Reactors

B.4.1 Reactors using naphthenic acids surrogates

The concentrations for bicarbonate were estimated by assuming a charge balance of zero (yellow cells). The values for potassium, ferrous iron, manganese and nitrate are below detection limit, 10, 0.075, 0.014 and 1.09 mg/L respectively.

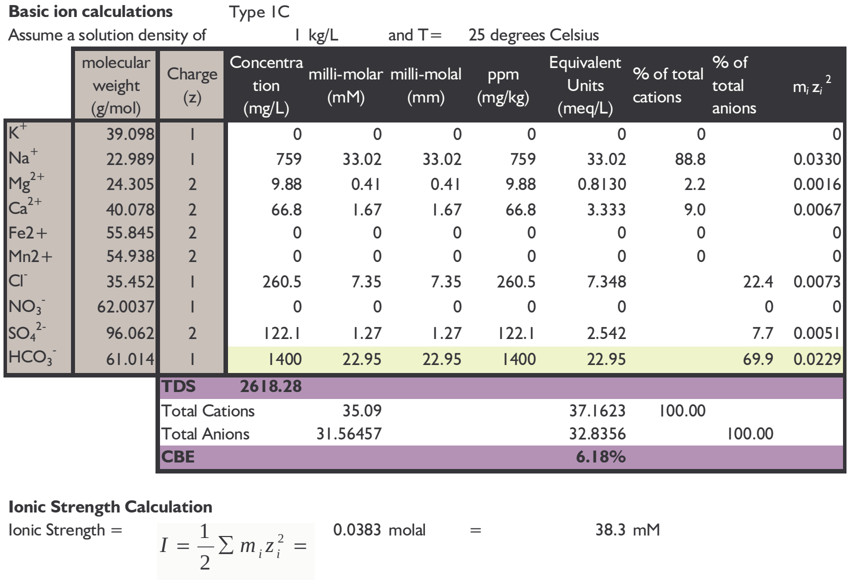


Basic ion calculations Type 1B
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	741	32.23	32.23	741	32.23	89.0		0.0322
Mg^{2+}	24.305	2	9.45	0.39	0.39	9.45	0.7776	2.1		0.0016
Ca^{2+}	40.078	2	63.9	1.59	1.59	63.9	3.189	8.8		0.0064
Fe2+	55.845	2	0	0	0	0	0	0		0
Mn2+	54.938	2	0	0	0	0	0	0		0
Cl^-	35.452	1	259.1	7.31	7.31	259.1	7.308		22.3	0.0073
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	119	1.24	1.24	119	2.478		7.6	0.0050
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.1	0.0229
		TDS	**2592.45**							
		Total Cations		34.22			36.1992	100.00		
		Total Anions		31.49			32.7316		100.00	
		CBE					**5.03%**			

Ionic Strength Calculation
Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0377 molal = 37.7 mM

Table B.2: Basic ion calculations for the surrogate NA batch reactor Type 1B .

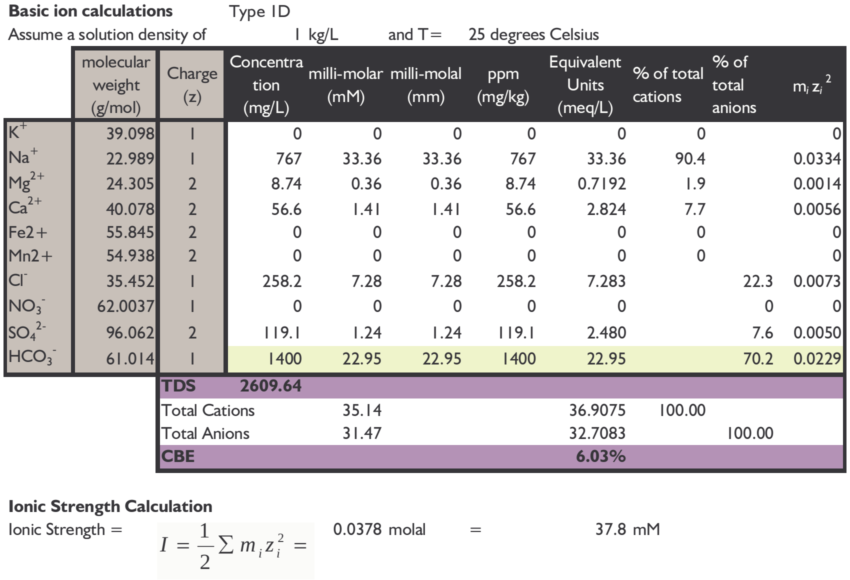


Basic ion calculations Type 1C
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	759	33.02	33.02	759	33.02	88.8		0.0330
Mg^{2+}	24.305	2	9.88	0.41	0.41	9.88	0.8130	2.2		0.0016
Ca^{2+}	40.078	2	66.8	1.67	1.67	66.8	3.333	9.0		0.0067
Fe2+	55.845	2	0	0	0	0	0	0		0
Mn2+	54.938	2	0	0	0	0	0	0		0
Cl^-	35.452	1	260.5	7.35	7.35	260.5	7.348		22.4	0.0073
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	122.1	1.27	1.27	122.1	2.542		7.7	0.0051
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		69.9	0.0229
		TDS	**2618.28**							
		Total Cations		35.09			37.1623	100.00		
		Total Anions		31.56457			32.8356		100.00	
		CBE					**6.18%**			

Ionic Strength Calculation
Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0383 molal = 38.3 mM

Table B.3: Basic ion calculations for the surrogate NA batch reactor Type 1C.



Basic ion calculations Type 1D

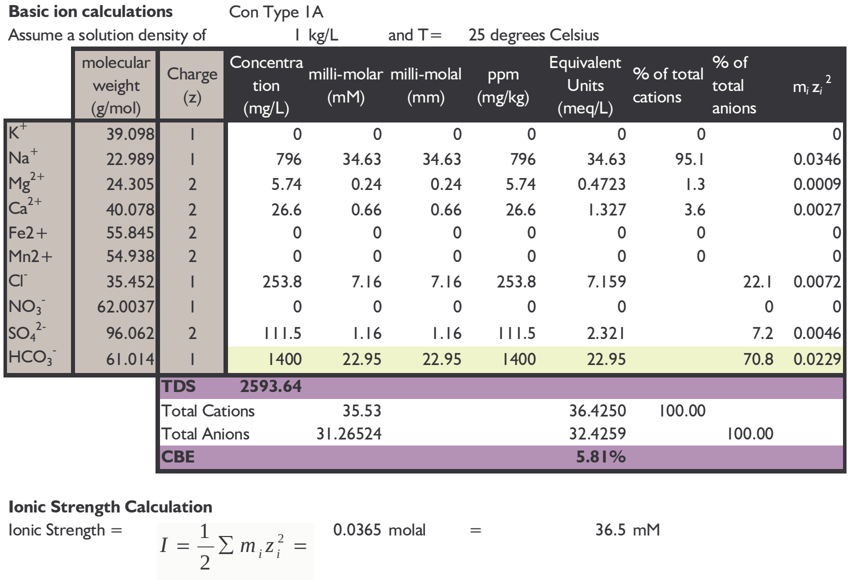
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	767	33.36	33.36	767	33.36	90.4		0.0334
Mg^{2+}	24.305	2	8.74	0.36	0.36	8.74	0.7192	1.9		0.0014
Ca^{2+}	40.078	2	56.6	1.41	1.41	56.6	2.824	7.7		0.0056
Fe2+	55.845	2	0	0	0	0	0	0		0
Mn2+	54.938	2	0	0	0	0	0	0		0
Cl^-	35.452	1	258.2	7.28	7.28	258.2	7.283		22.3	0.0073
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	119.1	1.24	1.24	119.1	2.480		7.6	0.0050
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.2	0.0229
		TDS	**2609.64**							
		Total Cations		35.14			36.9075	100.00		
		Total Anions		31.47			32.7083		100.00	
		CBE					**6.03%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0378 molal = 37.8 mM

Table B.4: Basic ion calculations for the surrogate NA batch reactor Type 1D.



Basic ion calculations Con Type 1A

Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	796	34.63	34.63	796	34.63	95.1		0.0346
Mg^{2+}	24.305	2	5.74	0.24	0.24	5.74	0.4723	1.3		0.0009
Ca^{2+}	40.078	2	26.6	0.66	0.66	26.6	1.327	3.6		0.0027
Fe2+	55.845	2	0	0	0	0	0	0		0
Mn2+	54.938	2	0	0	0	0	0	0		0
Cl^-	35.452	1	253.8	7.16	7.16	253.8	7.159		22.1	0.0072
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	111.5	1.16	1.16	111.5	2.321		7.2	0.0046
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.8	0.0229
		TDS	**2593.64**							
		Total Cations		35.53			36.4250	100.00		
		Total Anions		31.26524			32.4259		100.00	
		CBE					**5.81%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0365 molal = 36.5 mM

Table B.5: Basic ion calculations for the surrogate NA batch reactor Type 1A Control.

Basic ion calculations Con Type1 B
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	804.0	34.97	34.97	804	34.97	94.9		0.0350
Mg^{2+}	24.305	2	5.90	0.24	0.24	5.9	0.4855	1.3		0.0010
Ca^{2+}	40.078	2	27.7	0.69	0.69	27.7	1.382	3.8		0.0028
Fe2+	55.845	2	0	0	0	0	0	0		0
Mn2+	54.938	2	0	0	0	0	0	0		0
Cl^-	35.452	1	256.9	7.25	7.25	256.9	7.246		22.3	0.0072
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	112.4	1.17	1.17	112.4	2.340		7.2	0.0047
HCO_3^-	61.014	1	1400.0	22.95	22.95	1400	22.95		70.5	0.0229
		TDS	**2601**							
		Total Cations		35.91			36.84	100.00		
		Total Anions		31.36			32.53		100.00	
		CBE					**6.21%**			

Ionic Strength Calculation
Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0368 molal = 36.8 mM

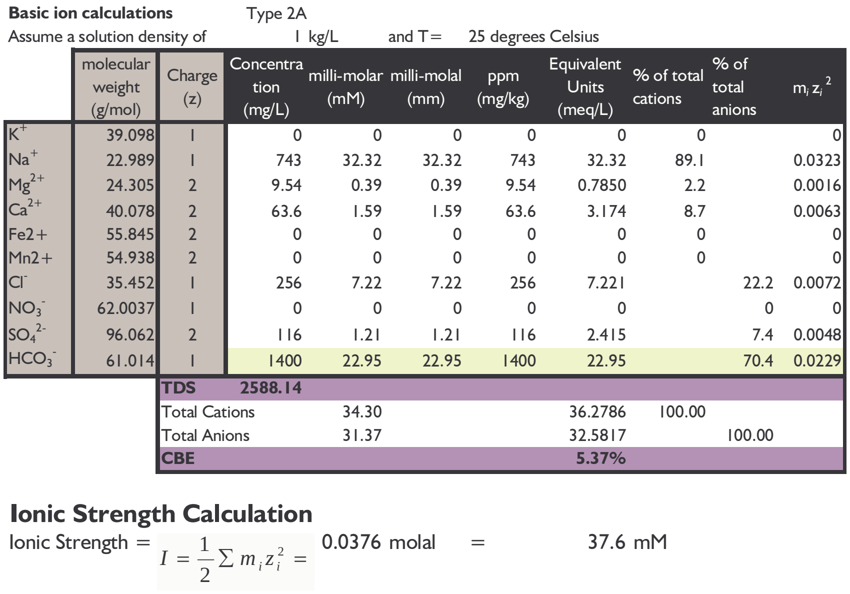
TABLE B.6: Basic ion calculations for the surrogate NA batch reactor Type 1B Control.

Basic ion calculations Con Type1 C
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	808	35.15	35.15	808	35.15	95.1		0.0351
Mg^{2+}	24.305	2	5.78	0.24	0.24	5.78	0.4756	1.3		0.0010
Ca^{2+}	40.078	2	26.6	0.66	0.66	26.6	1.327	3.6		0.0027
Fe2+	55.845	2	0	0	0	0	0	0		0
Mn2+	54.938	2	0	0	0	0	0	0		0
Cl^-	35.452	1	255	7.19	7.19	255	7.193		22.1	0.0072
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	112.7	1.17	1.17	112.7	2.346		7.2	0.0047
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.6	0.0229
		TDS	**2608.08**							
		Total Cations		36.05			36.9503	100.00		
		Total Anions		31.31158			32.4848		100.00	
		CBE					**6.43%**			

Ionic Strength Calculation
Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0368 molal = 36.8 mM

TABLE B.7: Basic ion calculations for the surrogate NA batch reactor Type 1C Control.



Basic ion calculations Type 2A

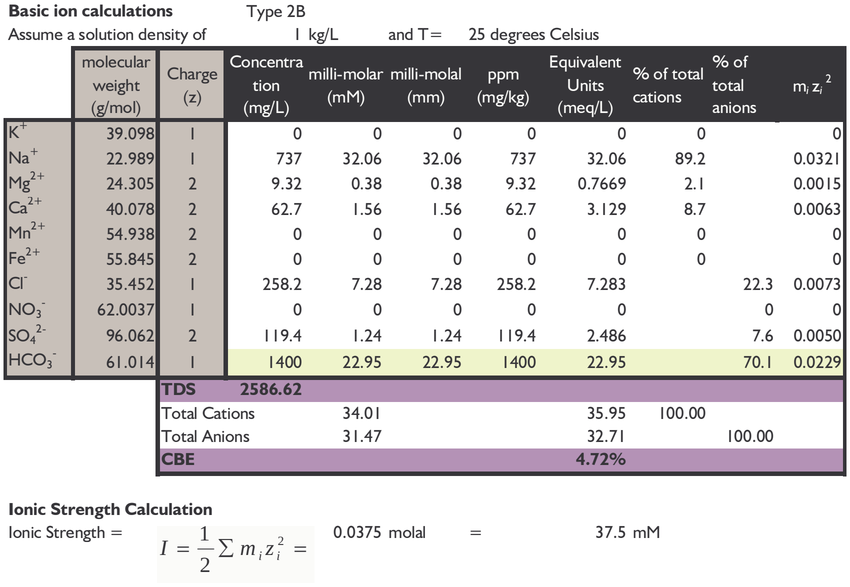
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	743	32.32	32.32	743	32.32	89.1		0.0323
Mg^{2+}	24.305	2	9.54	0.39	0.39	9.54	0.7850	2.2		0.0016
Ca^{2+}	40.078	2	63.6	1.59	1.59	63.6	3.174	8.7		0.0063
Fe2+	55.845	2	0	0	0	0	0	0		0
Mn2+	54.938	2	0	0	0	0	0	0		0
Cl^-	35.452	1	256	7.22	7.22	256	7.221		22.2	0.0072
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	116	1.21	1.21	116	2.415		7.4	0.0048
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.4	0.0229
		TDS	**2588.14**							
		Total Cations		34.30			36.2786	100.00		
		Total Anions		31.37			32.5817		100.00	
		CBE					**5.37%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0376 molal = 37.6 mM

Table B.8: Basic ion calculations for the surrogate NA batch reactor Type 2A.



Basic ion calculations Type 2B

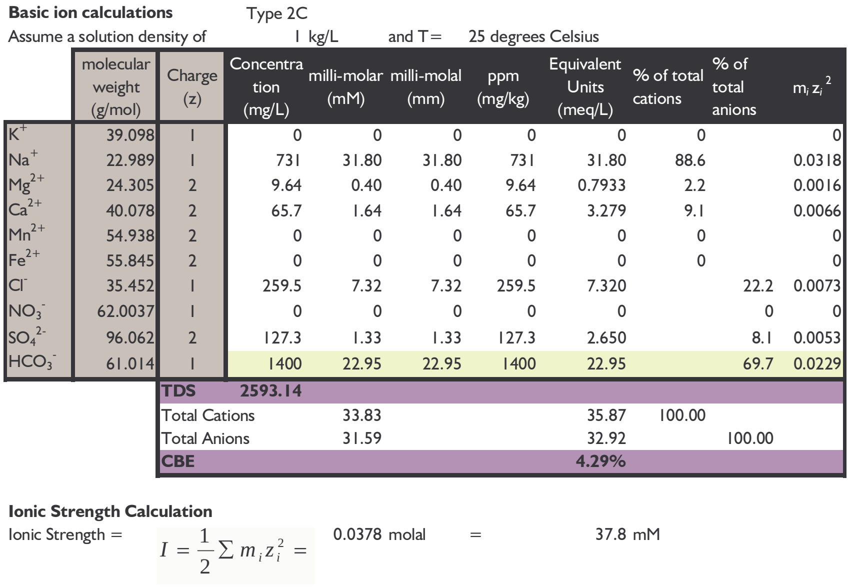
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	737	32.06	32.06	737	32.06	89.2		0.0321
Mg^{2+}	24.305	2	9.32	0.38	0.38	9.32	0.7669	2.1		0.0015
Ca^{2+}	40.078	2	62.7	1.56	1.56	62.7	3.129	8.7		0.0063
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	258.2	7.28	7.28	258.2	7.283		22.3	0.0073
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	119.4	1.24	1.24	119.4	2.486		7.6	0.0050
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.1	0.0229
		TDS	**2586.62**							
		Total Cations		34.01			35.95	100.00		
		Total Anions		31.47			32.71		100.00	
		CBE					**4.72%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0375 molal = 37.5 mM

Table B.9: Basic ion calculations for the surrogate NA batch reactor Type 2B.



Basic ion calculations Type 2C

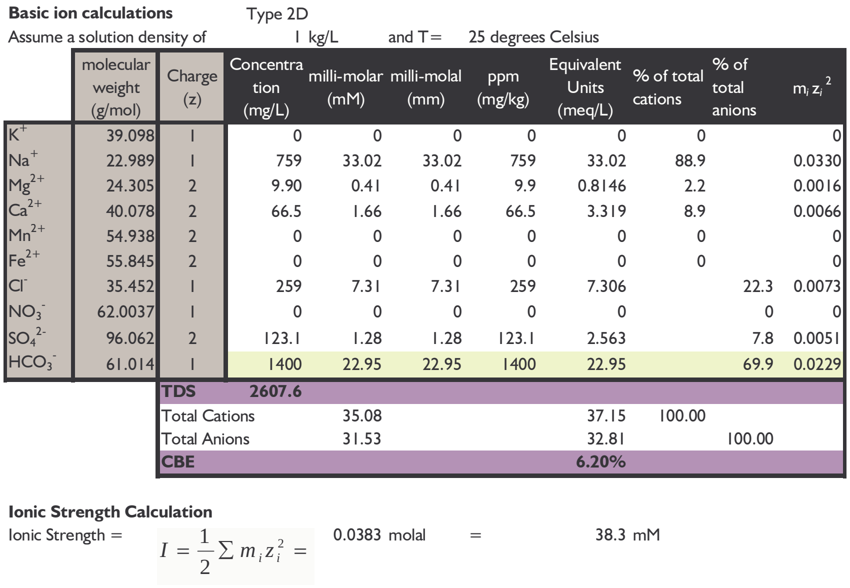
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	731	31.80	31.80	731	31.80	88.6		0.0318
Mg^{2+}	24.305	2	9.64	0.40	0.40	9.64	0.7933	2.2		0.0016
Ca^{2+}	40.078	2	65.7	1.64	1.64	65.7	3.279	9.1		0.0066
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	259.5	7.32	7.32	259.5	7.320		22.2	0.0073
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	127.3	1.33	1.33	127.3	2.650		8.1	0.0053
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		69.7	0.0229
		TDS	**2593.14**							
		Total Cations		33.83			35.87	100.00		
		Total Anions		31.59			32.92		100.00	
		CBE					**4.29%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0378 molal = 37.8 mM

TABLE B.10: Basic ion calculations for the surrogate NA batch reactor Type 2C.



Basic ion calculations Type 2D

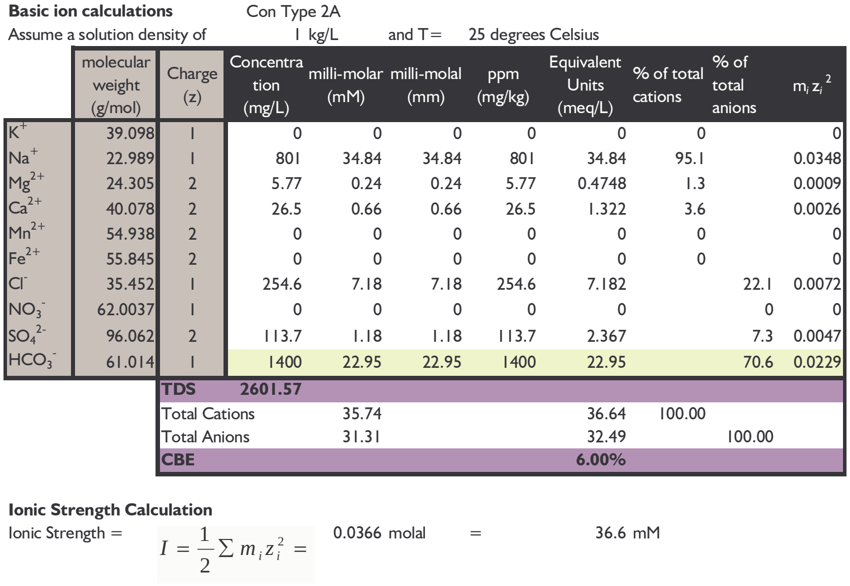
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	759	33.02	33.02	759	33.02	88.9		0.0330
Mg^{2+}	24.305	2	9.90	0.41	0.41	9.9	0.8146	2.2		0.0016
Ca^{2+}	40.078	2	66.5	1.66	1.66	66.5	3.319	8.9		0.0066
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	259	7.31	7.31	259	7.306		22.3	0.0073
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	123.1	1.28	1.28	123.1	2.563		7.8	0.0051
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		69.9	0.0229
		TDS	**2607.6**							
		Total Cations		35.08			37.15	100.00		
		Total Anions		31.53			32.81		100.00	
		CBE					**6.20%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0383 molal = 38.3 mM

TABLE B.11: Basic ion calculations for the surrogate NA batch reactor Type 2D.



Basic ion calculations Con Type 2A

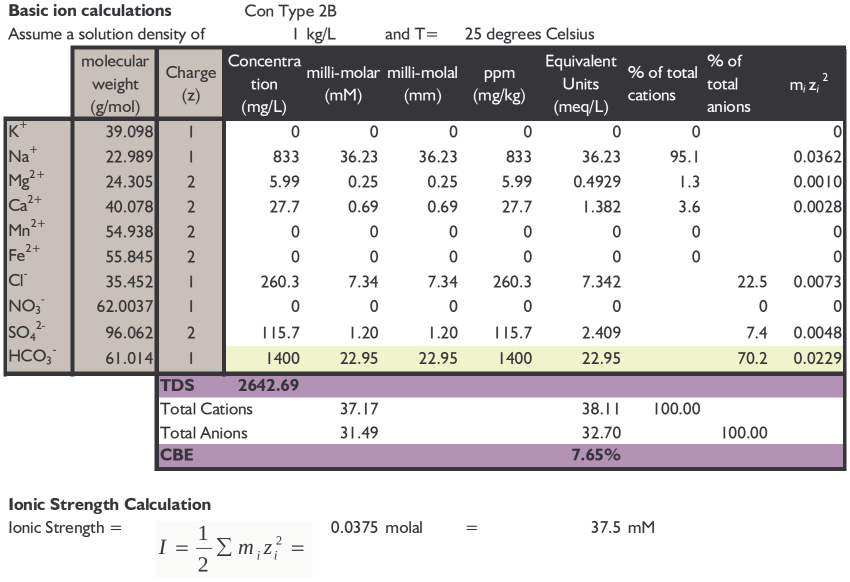
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	801	34.84	34.84	801	34.84	95.1		0.0348
Mg^{2+}	24.305	2	5.77	0.24	0.24	5.77	0.4748	1.3		0.0009
Ca^{2+}	40.078	2	26.5	0.66	0.66	26.5	1.322	3.6		0.0026
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	254.6	7.18	7.18	254.6	7.182		22.1	0.0072
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	113.7	1.18	1.18	113.7	2.367		7.3	0.0047
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.6	0.0229
		TDS	**2601.57**							
		Total Cations		35.74			36.64	100.00		
		Total Anions		31.31			32.49		100.00	
		CBE					**6.00%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0366 molal = 36.6 mM

Table B.12: Basic ion calculations for the surrogate NA batch reactor Type 2A Control.



Basic ion calculations Con Type 2B

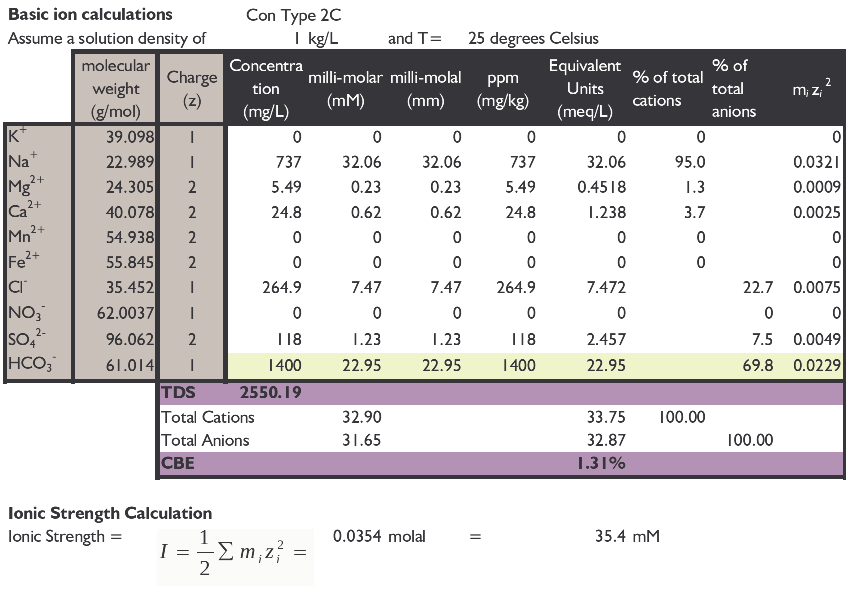
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	833	36.23	36.23	833	36.23	95.1		0.0362
Mg^{2+}	24.305	2	5.99	0.25	0.25	5.99	0.4929	1.3		0.0010
Ca^{2+}	40.078	2	27.7	0.69	0.69	27.7	1.382	3.6		0.0028
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	260.3	7.34	7.34	260.3	7.342		22.5	0.0073
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	115.7	1.20	1.20	115.7	2.409		7.4	0.0048
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.2	0.0229
		TDS	**2642.69**							
		Total Cations		37.17			38.11	100.00		
		Total Anions		31.49			32.70		100.00	
		CBE					**7.65%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0375 molal = 37.5 mM

Table B.13: Basic ion calculations for the surrogate NA batch reactor Type 2B Control.



Basic ion calculations Con Type 2C

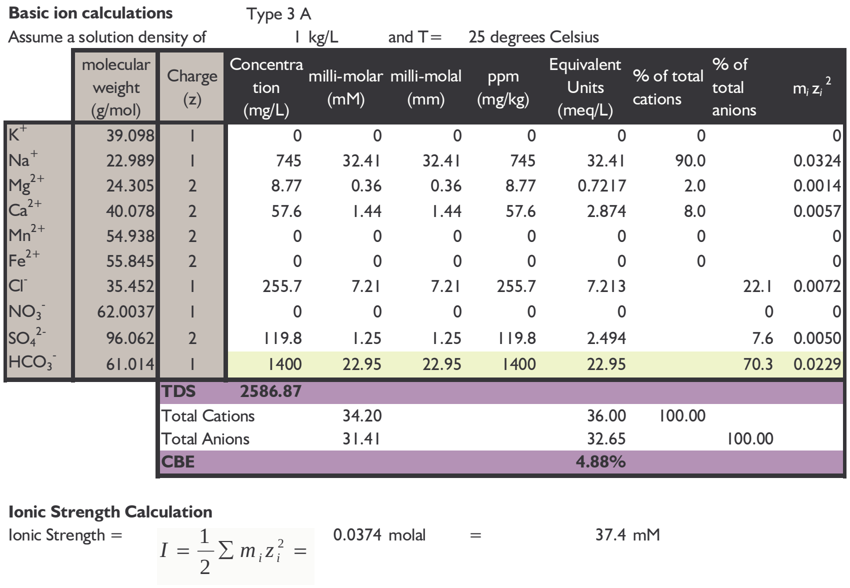
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	737	32.06	32.06	737	32.06	95.0		0.0321
Mg^{2+}	24.305	2	5.49	0.23	0.23	5.49	0.4518	1.3		0.0009
Ca^{2+}	40.078	2	24.8	0.62	0.62	24.8	1.238	3.7		0.0025
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	264.9	7.47	7.47	264.9	7.472		22.7	0.0075
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	118	1.23	1.23	118	2.457		7.5	0.0049
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		69.8	0.0229
		TDS	**2550.19**							
		Total Cations		32.90			33.75	100.00		
		Total Anions		31.65			32.87		100.00	
		CBE					**1.31%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0354 molal = 35.4 mM

TABLE B.14: Basic ion calculations for the surrogate NA batch reactor Type 2C Control.



Basic ion calculations Type 3 A

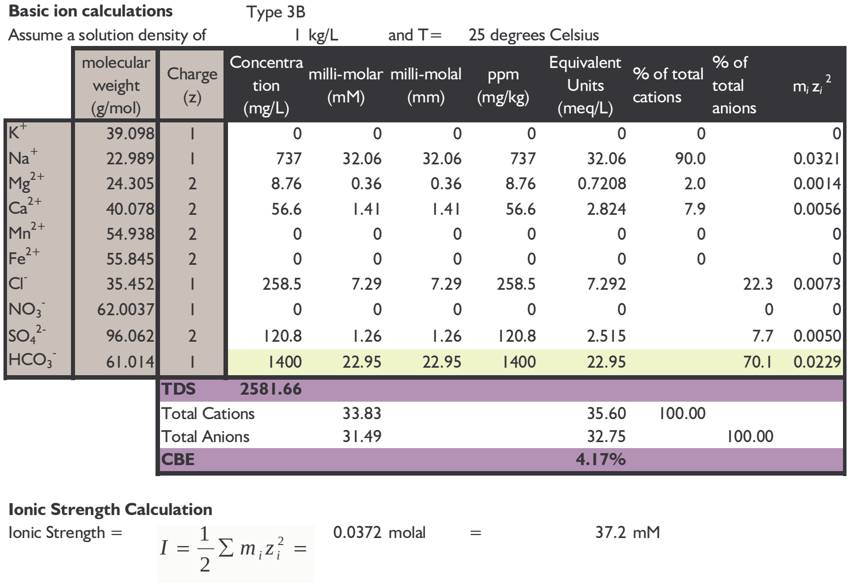
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	745	32.41	32.41	745	32.41	90.0		0.0324
Mg^{2+}	24.305	2	8.77	0.36	0.36	8.77	0.7217	2.0		0.0014
Ca^{2+}	40.078	2	57.6	1.44	1.44	57.6	2.874	8.0		0.0057
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	255.7	7.21	7.21	255.7	7.213		22.1	0.0072
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	119.8	1.25	1.25	119.8	2.494		7.6	0.0050
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.3	0.0229
		TDS	**2586.87**							
		Total Cations		34.20			36.00	100.00		
		Total Anions		31.41			32.65		100.00	
		CBE					**4.88%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0374 molal = 37.4 mM

TABLE B.15: Basic ion calculations for the surrogate NA batch reactor Type 3A.

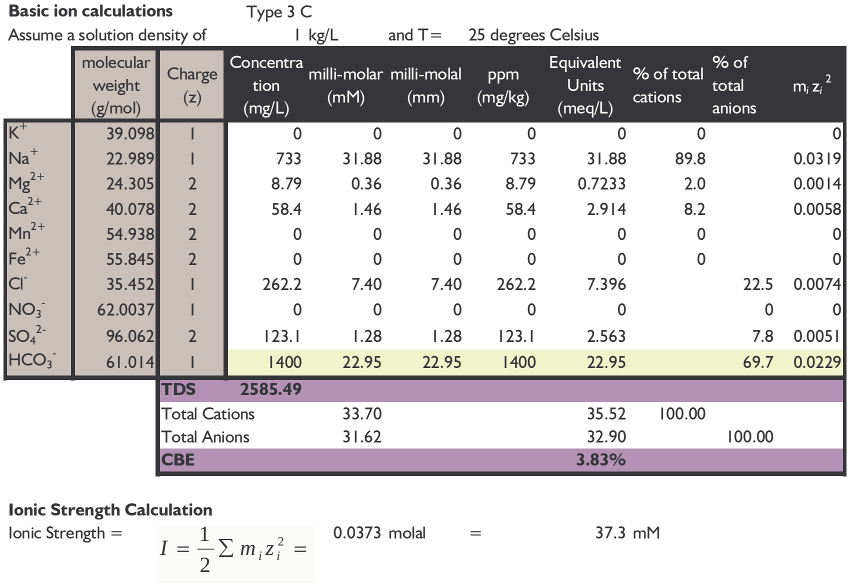


Basic ion calculations Type 3B
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	737	32.06	32.06	737	32.06	90.0		0.0321
Mg^{2+}	24.305	2	8.76	0.36	0.36	8.76	0.7208	2.0		0.0014
Ca^{2+}	40.078	2	56.6	1.41	1.41	56.6	2.824	7.9		0.0056
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	258.5	7.29	7.29	258.5	7.292		22.3	0.0073
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	120.8	1.26	1.26	120.8	2.515		7.7	0.0050
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.1	0.0229
		TDS	**2581.66**							
		Total Cations		33.83			35.60	100.00		
		Total Anions		31.49			32.75		100.00	
		CBE					**4.17%**			

Ionic Strength Calculation
Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0372 molal = 37.2 mM

TABLE B.16: Basic ion calculations for the surrogate NA batch reactor Type 3B.

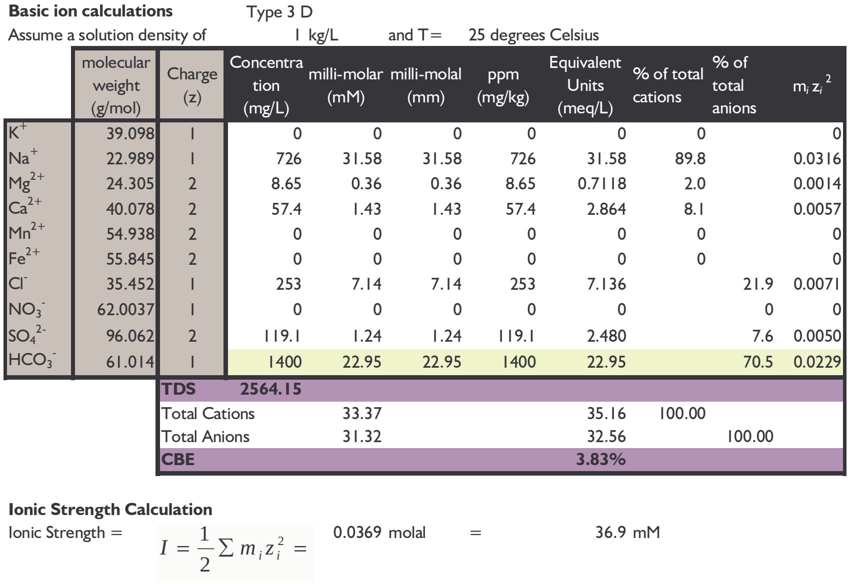


Basic ion calculations Type 3 C
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	733	31.88	31.88	733	31.88	89.8		0.0319
Mg^{2+}	24.305	2	8.79	0.36	0.36	8.79	0.7233	2.0		0.0014
Ca^{2+}	40.078	2	58.4	1.46	1.46	58.4	2.914	8.2		0.0058
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	262.2	7.40	7.40	262.2	7.396		22.5	0.0074
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	123.1	1.28	1.28	123.1	2.563		7.8	0.0051
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		69.7	0.0229
		TDS	**2585.49**							
		Total Cations		33.70			35.52	100.00		
		Total Anions		31.62			32.90		100.00	
		CBE					**3.83%**			

Ionic Strength Calculation
Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0373 molal = 37.3 mM

TABLE B.17: Basic ion calculations for the surrogate NA batch reactor Type 3C.



Basic ion calculations Type 3 D

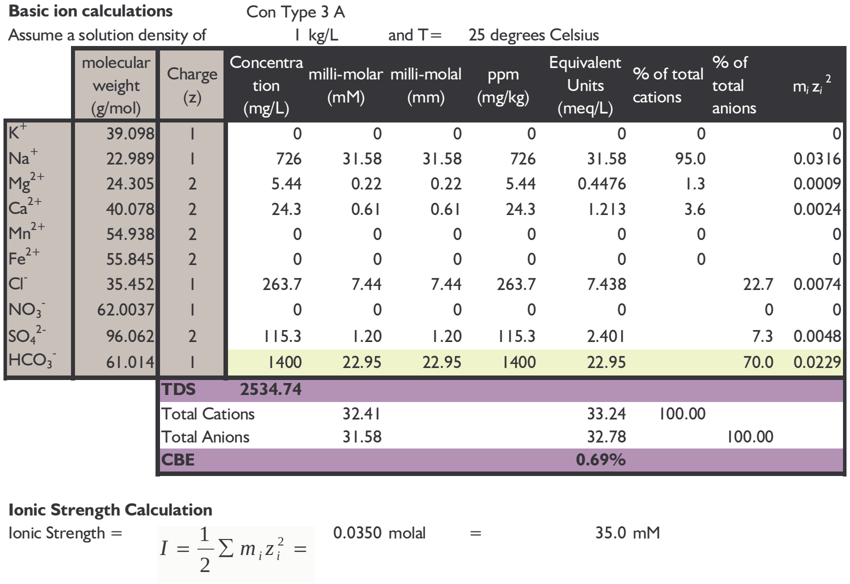
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	726	31.58	31.58	726	31.58	89.8		0.0316
Mg^{2+}	24.305	2	8.65	0.36	0.36	8.65	0.7118	2.0		0.0014
Ca^{2+}	40.078	2	57.4	1.43	1.43	57.4	2.864	8.1		0.0057
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	253	7.14	7.14	253	7.136		21.9	0.0071
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	119.1	1.24	1.24	119.1	2.480		7.6	0.0050
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.5	0.0229
		TDS	**2564.15**							
		Total Cations		33.37			35.16	100.00		
		Total Anions		31.32			32.56		100.00	
		CBE					**3.83%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0369 molal = 36.9 mM

Table B.18: Basic ion calculations for the surrogate NA batch reactor Type 3D.



Basic ion calculations Con Type 3 A

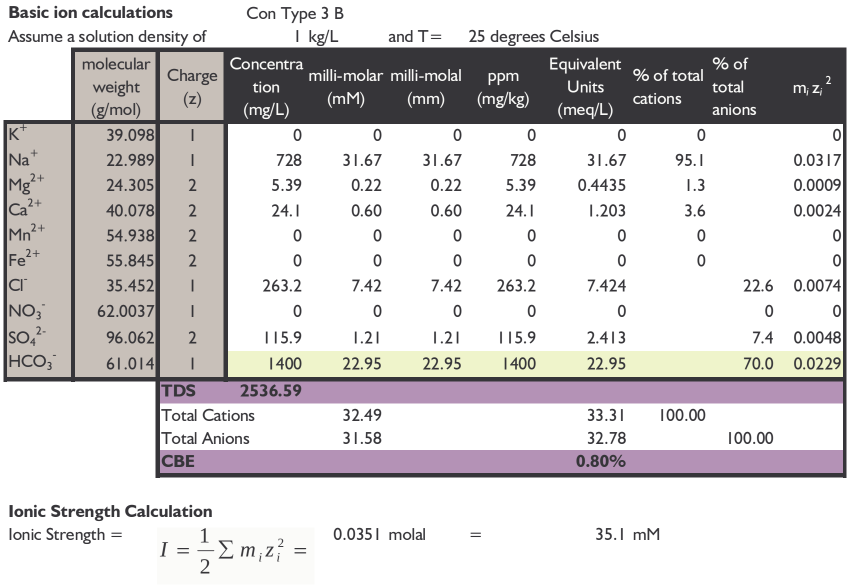
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	726	31.58	31.58	726	31.58	95.0		0.0316
Mg^{2+}	24.305	2	5.44	0.22	0.22	5.44	0.4476	1.3		0.0009
Ca^{2+}	40.078	2	24.3	0.61	0.61	24.3	1.213	3.6		0.0024
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	263.7	7.44	7.44	263.7	7.438		22.7	0.0074
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	115.3	1.20	1.20	115.3	2.401		7.3	0.0048
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.0	0.0229
		TDS	**2534.74**							
		Total Cations		32.41			33.24	100.00		
		Total Anions		31.58			32.78		100.00	
		CBE					**0.69%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0350 molal = 35.0 mM

Table B.19: Basic ion calculations for the surrogate NA batch reactor Type 3A Control.



Basic ion calculations Con Type 3 B

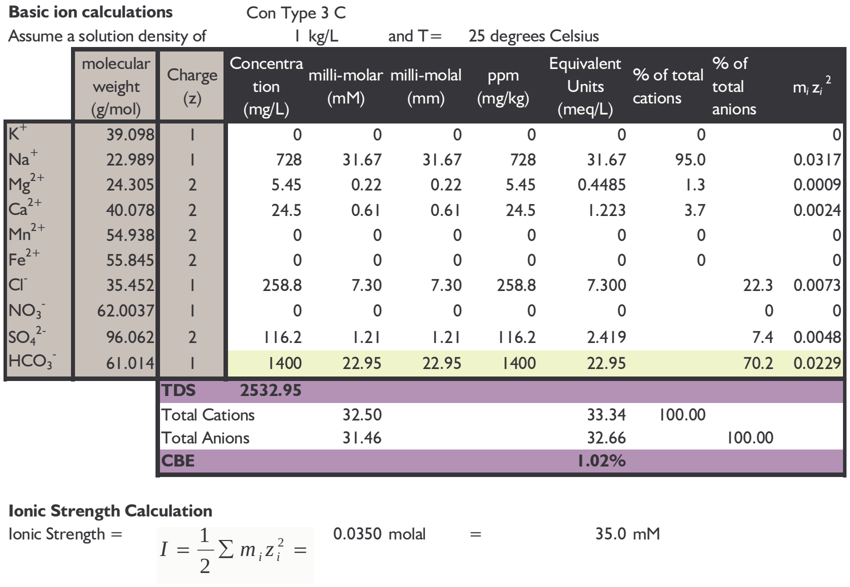
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	728	31.67	31.67	728	31.67	95.1		0.0317
Mg^{2+}	24.305	2	5.39	0.22	0.22	5.39	0.4435	1.3		0.0009
Ca^{2+}	40.078	2	24.1	0.60	0.60	24.1	1.203	3.6		0.0024
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	263.2	7.42	7.42	263.2	7.424		22.6	0.0074
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	115.9	1.21	1.21	115.9	2.413		7.4	0.0048
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.0	0.0229
		TDS	**2536.59**							
		Total Cations		32.49			33.31	100.00		
		Total Anions		31.58			32.78		100.00	
		CBE					**0.80%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0351 molal = 35.1 mM

TABLE B.20: Basic ion calculations for the surrogate NA batch reactor Type 3B Control.



Basic ion calculations Con Type 3 C

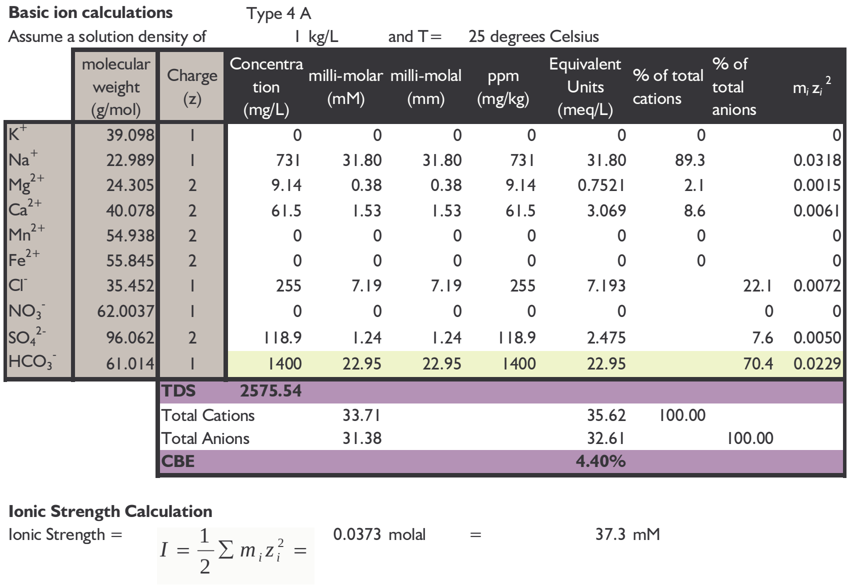
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	728	31.67	31.67	728	31.67	95.0		0.0317
Mg^{2+}	24.305	2	5.45	0.22	0.22	5.45	0.4485	1.3		0.0009
Ca^{2+}	40.078	2	24.5	0.61	0.61	24.5	1.223	3.7		0.0024
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	258.8	7.30	7.30	258.8	7.300		22.3	0.0073
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	116.2	1.21	1.21	116.2	2.419		7.4	0.0048
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.2	0.0229
		TDS	**2532.95**							
		Total Cations		32.50			33.34	100.00		
		Total Anions		31.46			32.66		100.00	
		CBE					**1.02%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0350 molal = 35.0 mM

TABLE B.21: Basic ion calculations for the surrogate NA batch reactor Type 3C Control.



Basic ion calculations Type 4 A

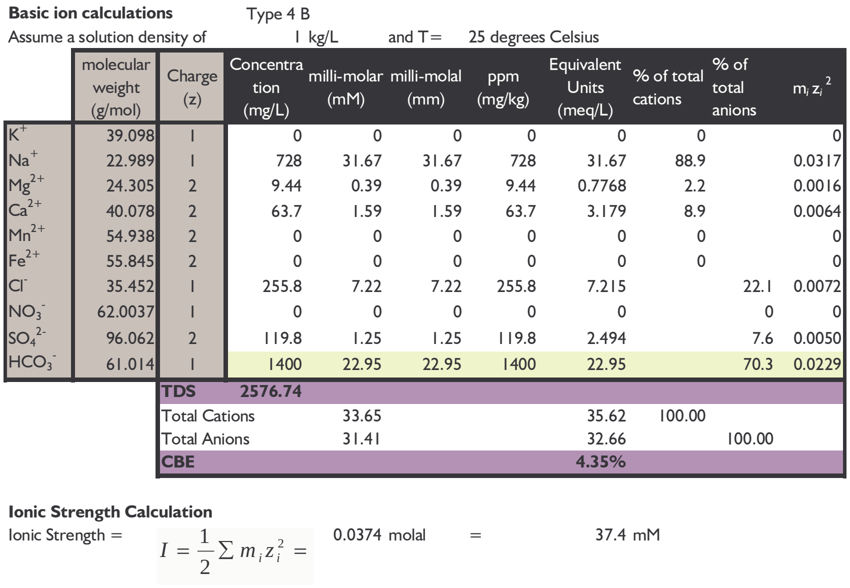
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	731	31.80	31.80	731	31.80	89.3		0.0318
Mg^{2+}	24.305	2	9.14	0.38	0.38	9.14	0.7521	2.1		0.0015
Ca^{2+}	40.078	2	61.5	1.53	1.53	61.5	3.069	8.6		0.0061
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	255	7.19	7.19	255	7.193		22.1	0.0072
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	118.9	1.24	1.24	118.9	2.475		7.6	0.0050
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.4	0.0229
		TDS	**2575.54**							
		Total Cations		33.71			35.62	100.00		
		Total Anions		31.38			32.61		100.00	
		CBE					**4.40%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0373 molal = 37.3 mM

TABLE B.22: Basic ion calculations for the surrogate NA batch reactor Type 4A.



Basic ion calculations Type 4 B

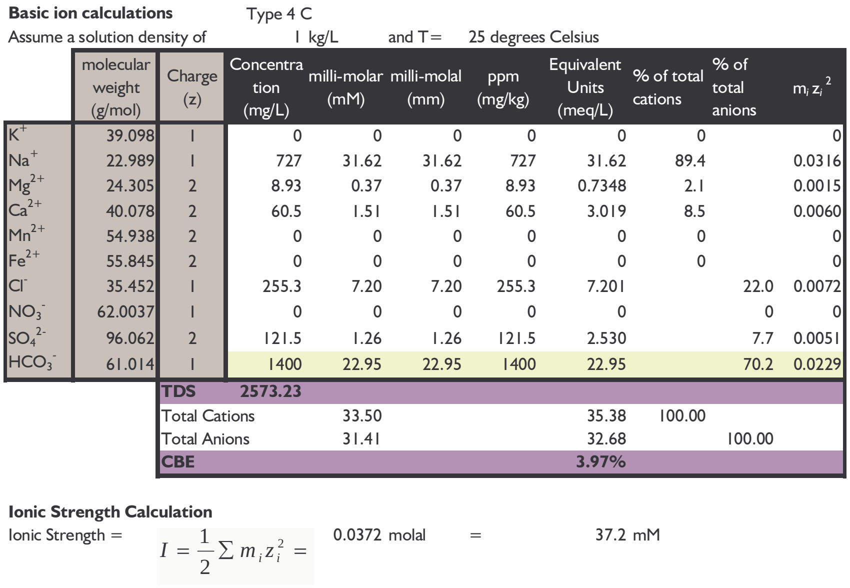
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	728	31.67	31.67	728	31.67	88.9		0.0317
Mg^{2+}	24.305	2	9.44	0.39	0.39	9.44	0.7768	2.2		0.0016
Ca^{2+}	40.078	2	63.7	1.59	1.59	63.7	3.179	8.9		0.0064
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	255.8	7.22	7.22	255.8	7.215		22.1	0.0072
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	119.8	1.25	1.25	119.8	2.494		7.6	0.0050
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.3	0.0229
		TDS	**2576.74**							
		Total Cations		33.65			35.62	100.00		
		Total Anions		31.41			32.66		100.00	
		CBE					**4.35%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.0374 molal = 37.4 mM

TABLE B.23: Basic ion calculations for the surrogate NA batch reactor Type 4B.



Basic ion calculations Type 4 C

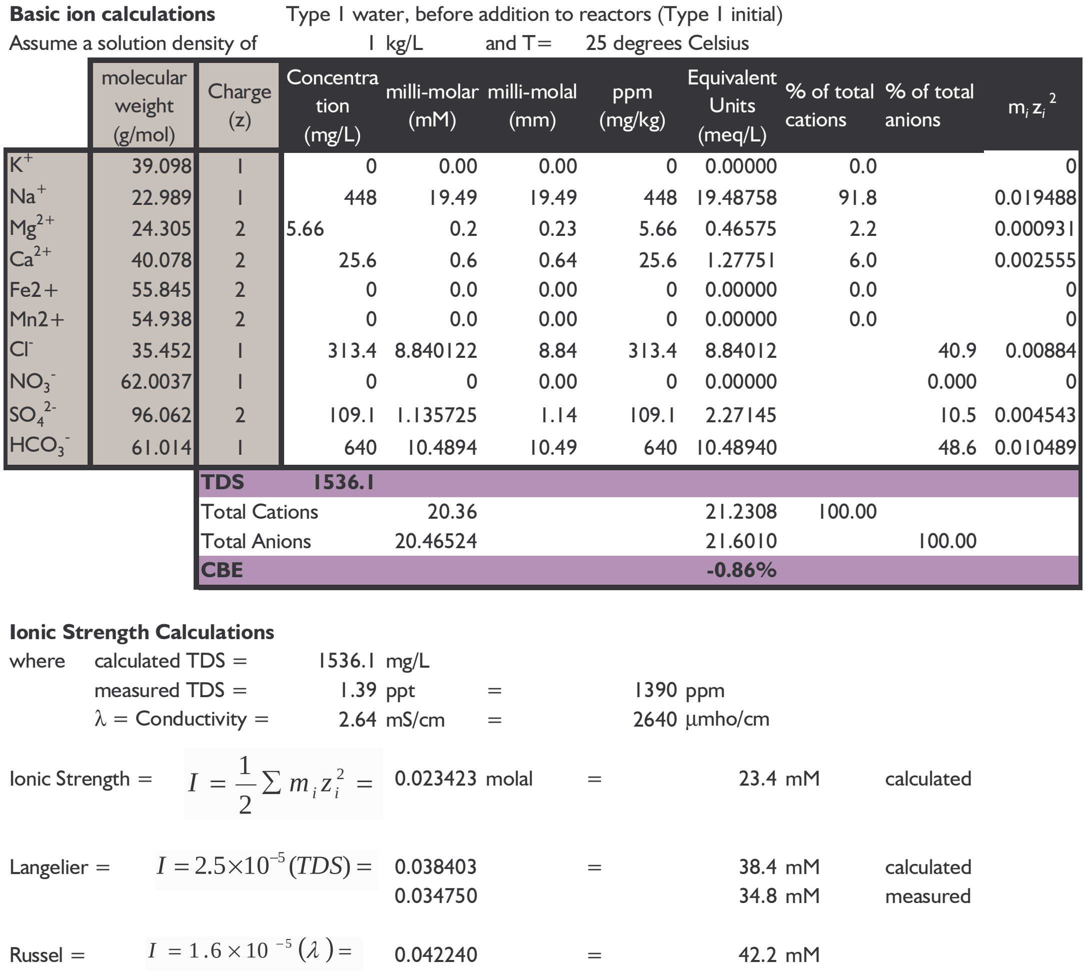
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0	0	0	0	0		0
Na^+	22.989	1	727	31.62	31.62	727	31.62	89.4		0.0316
Mg^{2+}	24.305	2	8.93	0.37	0.37	8.93	0.7348	2.1		0.0015
Ca^{2+}	40.078	2	60.5	1.51	1.51	60.5	3.019	8.5		0.0060
Mn^{2+}	54.938	2	0	0	0	0	0	0		0
Fe^{2+}	55.845	2	0	0	0	0	0	0		0
Cl^-	35.452	1	255.3	7.20	7.20	255.3	7.201		22.0	0.0072
NO_3^-	62.0037	1	0	0	0	0	0		0	0
SO_4^{2-}	96.062	2	121.5	1.26	1.26	121.5	2.530		7.7	0.0051
HCO_3^-	61.014	1	1400	22.95	22.95	1400	22.95		70.2	0.0229
		TDS	**2573.23**							
		Total Cations		33.50			35.38	100.00		
		Total Anions		31.41			32.68		100.00	
		CBE					**3.97%**			

Ionic Strength Calculation

Ionic Strength = $I = \frac{1}{2} \Sigma m_i z_i^2 =$ 0.0372 molal = 37.2 mM

Table B.24: Basic ion calculations for the surrogate NA batch reactor Type 4C.



Basic ion calculations Type 1 water, before addition to reactors (Type 1 initial)

Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0.00	0.00	0	0.00000	0.0		0
Na^+	22.989	1	448	19.49	19.49	448	19.48758	91.8		0.019488
Mg^{2+}	24.305	2	5.66	0.2	0.23	5.66	0.46575	2.2		0.000931
Ca^{2+}	40.078	2	25.6	0.6	0.64	25.6	1.27751	6.0		0.002555
Fe2+	55.845	2	0	0.0	0.00	0	0.00000	0.0		0
Mn2+	54.938	2	0	0.0	0.00	0	0.00000	0.0		0
Cl^-	35.452	1	313.4	8.840122	8.84	313.4	8.84012		40.9	0.00884
NO_3^-	62.0037	1	0	0	0.00	0	0.00000		0.000	0
SO_4^{2-}	96.062	2	109.1	1.135725	1.14	109.1	2.27145		10.5	0.004543
HCO_3^-	61.014	1	640	10.4894	10.49	640	10.48940		48.6	0.010489
		TDS	**1536.1**							
		Total Cations		20.36			21.2308	100.00		
		Total Anions		20.46524			21.6010		100.00	
		CBE					**-0.86%**			

Ionic Strength Calculations

where calculated TDS = 1536.1 mg/L

measured TDS = 1.39 ppt = 1390 ppm

λ = Conductivity = 2.64 mS/cm = 2640 µmho/cm

Ionic Strength = $I = \frac{1}{2} \sum m_i z_i^2 =$ 0.023423 molal = 23.4 mM calculated

Langelier = $I = 2.5 \times 10^{-5} (TDS) =$ 0.038403 = 38.4 mM calculated

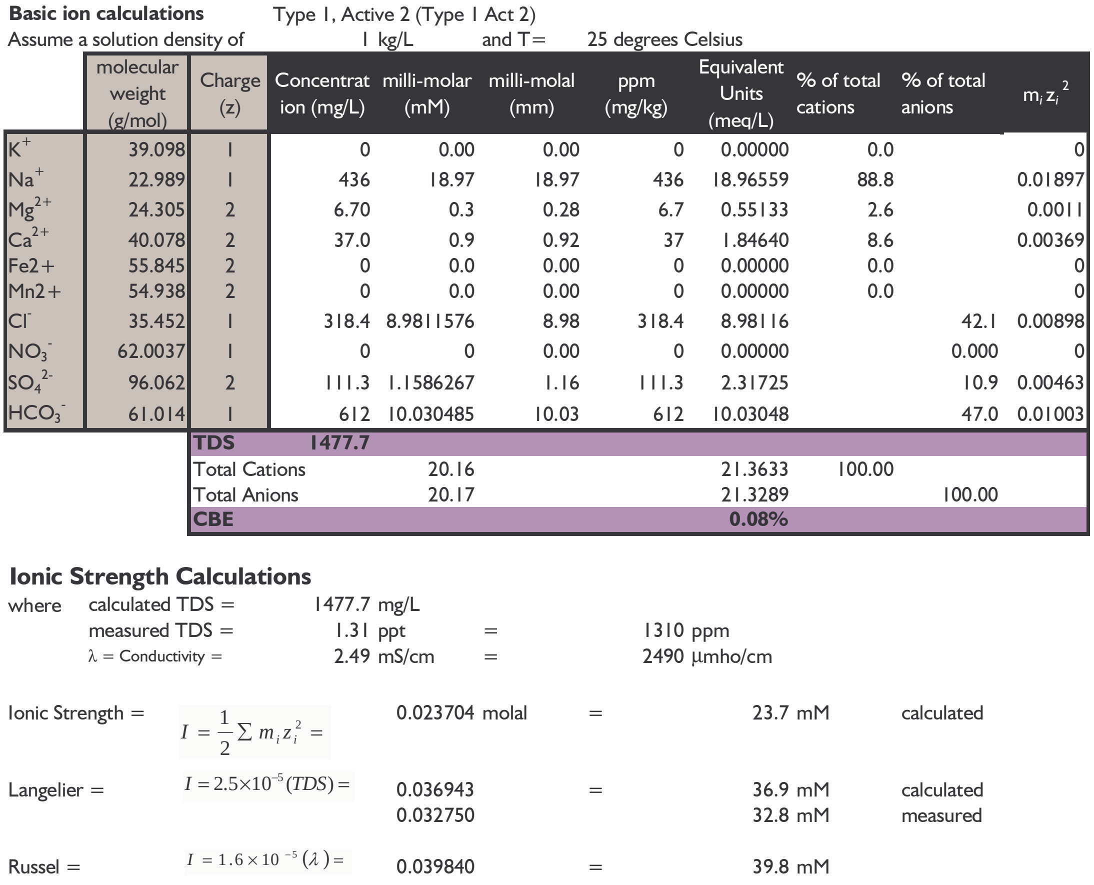
0.034750 34.8 mM measured

Russel = $I = 1.6 \times 10^{-5} (\lambda) =$ 0.042240 = 42.2 mM

Table B.25: Basic ion calculations for the batch reactor Type 1, Initial Water using stock naphthenic acid.

B.4.2 Reactors using stock naphthenic acids

The values for potassium, ferrous iron, manganese and nitrate are below detection limit, 6.00-12.0, 0.100-0.200, 0.006-0.012 and 1.08 mg/L respectively.



Basic ion calculations Type 1, Active 2 (Type 1 Act 2)

Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0.00	0.00	0	0.00000	0.0		0
Na^+	22.989	1	436	18.97	18.97	436	18.96559	88.8		0.01897
Mg^{2+}	24.305	2	6.70	0.3	0.28	6.7	0.55133	2.6		0.0011
Ca^{2+}	40.078	2	37.0	0.9	0.92	37	1.84640	8.6		0.00369
Fe2+	55.845	2	0	0.0	0.00	0	0.00000	0.0		0
Mn2+	54.938	2	0	0.0	0.00	0	0.00000	0.0		0
Cl^-	35.452	1	318.4	8.9811576	8.98	318.4	8.98116		42.1	0.00898
NO_3^-	62.0037	1	0	0	0.00	0	0.00000		0.000	0
SO_4^{2-}	96.062	2	111.3	1.1586267	1.16	111.3	2.31725		10.9	0.00463
HCO_3^-	61.014	1	612	10.030485	10.03	612	10.03048		47.0	0.01003
		TDS	**1477.7**							
		Total Cations		20.16			21.3633	100.00		
		Total Anions		20.17			21.3289		100.00	
		CBE					**0.08%**			

Ionic Strength Calculations

where calculated TDS = 1477.7 mg/L

measured TDS = 1.31 ppt = 1310 ppm

λ = Conductivity = 2.49 mS/cm = 2490 μmho/cm

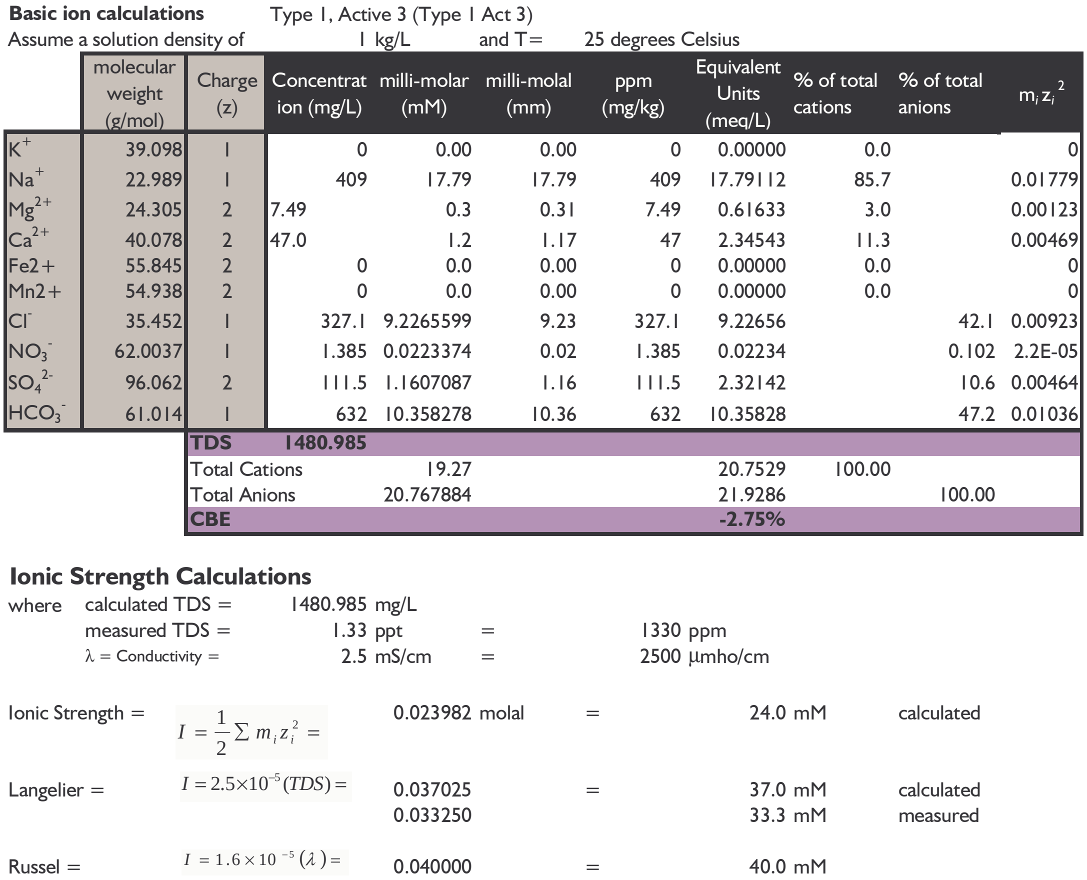
Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.023704 molal = 23.7 mM calculated

Langelier = $I = 2.5\times10^{-5}(TDS) =$ 0.036943 = 36.9 mM calculated

0.032750 32.8 mM measured

Russel = $I = 1.6\times10^{-5}(\lambda) =$ 0.039840 = 39.8 mM

TABLE B.26: Basic ion calculations for the batch reactor Type 1, Act 2 using stock naphthenic acid.



Basic ion calculations Type 1, Active 3 (Type 1 Act 3)

Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0.00	0.00	0	0.00000	0.0		0
Na^+	22.989	1	409	17.79	17.79	409	17.79112	85.7		0.01779
Mg^{2+}	24.305	2	7.49	0.3	0.31	7.49	0.61633	3.0		0.00123
Ca^{2+}	40.078	2	47.0	1.2	1.17	47	2.34543	11.3		0.00469
Fe2+	55.845	2	0	0.0	0.00	0	0.00000	0.0		0
Mn2+	54.938	2	0	0.0	0.00	0	0.00000	0.0		0
Cl^-	35.452	1	327.1	9.2265599	9.23	327.1	9.22656		42.1	0.00923
NO_3^-	62.0037	1	1.385	0.0223374	0.02	1.385	0.02234		0.102	2.2E-05
SO_4^{2-}	96.062	2	111.5	1.1607087	1.16	111.5	2.32142		10.6	0.00464
HCO_3^-	61.014	1	632	10.358278	10.36	632	10.35828		47.2	0.01036
		TDS	**1480.985**							
		Total Cations		19.27			20.7529	100.00		
		Total Anions		20.767884			21.9286		100.00	
		CBE					**-2.75%**			

Ionic Strength Calculations

where calculated TDS = 1480.985 mg/L

measured TDS = 1.33 ppt = 1330 ppm

λ = Conductivity = 2.5 mS/cm = 2500 µmho/cm

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.023982 molal = 24.0 mM calculated

Langelier = $I = 2.5\times10^{-5}(TDS) =$ 0.037025 = 37.0 mM calculated

0.033250 33.3 mM measured

Russel = $I = 1.6\times10^{-5}(\lambda) =$ 0.040000 = 40.0 mM

Table B.27: Basic ion calculations for the batch reactor Type 1, Act 3 using stock naphthenic acid.

Basic ion calculations Type 2 water, before addition to reactors (Type 2 initial)
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0.00	0.00	0	0.00000	0.0		0
Na^+	22.989	1	514	22.36	22.36	514	22.35852	92.8		0.022359
Mg^{2+}	24.305	2	5.77	0.2	0.24	5.77	0.47480	2.0		0.00095
Ca^{2+}	40.078	2	25.4	0.6	0.63	25.4	1.26753	5.3		0.002535
Fe2+	55.845	2	0	0.0	0.00	0	0.00000	0.0		0
Mn2+	54.938	2	0	0.0	0.00	0	0.00000	0.0		0
Cl^-	35.452	1	344.8	9.7258265	9.73	344.8	9.72583		39.0	0.009726
NO_3^-	62.0037	1	0	0	0.00	0	0.00000		0.000	0
SO_4^{2-}	96.062	2	110.1	1.1461348	1.15	110.1	2.29227		9.2	0.004585
HCO_3^-	61.014	1	790	12.947848	12.95	790	12.94785		51.9	0.012948
		TDS	**1784.3**							
		Total Cations		23.23			24.1008	100.00		
		Total Anions		23.82			24.9659		100.00	
		CBE					**-1.76%**			

Ionic Strength Calculations

where calculated TDS = 1784.3 mg/L
measured TDS = 1.54 ppt = 1540 ppm
λ = Conductivity = 2.93 mS/cm = 2930 µmho/cm

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.026551 molal = 26.6 mM calculated

Langelier = $I = 2.5\times10^{-5}(TDS) =$ 0.044608 = 44.6 mM calculated
0.038500 38.5 mM measured

Russel = $I = 1.6\times10^{-5}(\lambda) =$ 0.046880 = 46.9 mM

TABLE B.28: Basic ion calculations for the batch reactor Type 2, Initial Water using stock naphthenic acid.

Basic ion calculations Type 2, Active #4 (Type 2 Act 4)

Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0.00	0.00	0	0.00000	0.0		0
Na^+	22.989	1	486	21.14	21.14	486	21.14055	88.8		0.02114
Mg^{2+}	24.305	2	7.05	0.3	0.29	7.05	0.58013	2.4		0.00116
Ca^{2+}	40.078	2	41.9	1.0	1.05	41.9	2.09092	8.8		0.00418
Fe2+	55.845	2	0	0.0	0.00	0	0.00000	0.0		0
Mn2+	54.938	2	0	0.0	0.00	0	0.00000	0.0		0
Cl^-	35.452	1	335.1	9.4522171	9.45	335.1	9.45222		38.4	0.00945
NO_3^-	62.0037	1	0	0	0.00	0	0.00000		0.000	0
SO_4^{2-}	96.062	2	109.3	1.1378068	1.14	109.3	2.27561		9.2	0.00455
HCO_3^-	61.014	1	788	12.915069	12.92	788	12.91507		52.4	0.01292
		TDS	**1760.3**							
		Total Cations		22.48			23.8116	100.00		
		Total Anions		23.505093			24.6429		100.00	
		CBE					**-1.72%**			

Ionic Strength Calculations

where calculated TDS = 1760.3 mg/L

measured TDS = 1.28 ppt = 1280 ppm

λ = Conductivity = 2.78 mS/cm = 2780 µmho/cm

Ionic Strength = $I = \frac{1}{2} \sum m_i z_i^2 =$ 0.026701 molal = 26.7 mM calculated

Langelier = $I = 2.5 \times 10^{-5} (TDS) =$ 0.044008 = 44.0 mM calculated

0.032000 32.0 mM measured

Russel = $I = 1.6 \times 10^{-5} (\lambda) =$ 0.044480 = 44.5 mM

Table B.29: Basic ion calculations for the batch reactor Type 2, Active 4 using stock naphthenic acid.

Basic ion calculations Type 3 water, before addition to reactors (Type 3 initial)
Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0.0	0.0	0.00	0	0.0	0.0		0.0000
Na^+	22.989	1	734.0	31.9	31.93	734	31.9	94.8		0.0319
Mg^{2+}	24.305	2	5.68	0.2	0.23	5.68	0.5	1.4		0.0009
Ca^{2+}	40.078	2	25.7	0.6	0.64	25.7	1.3	3.8		0.0026
Fe2+	55.845	2	0.0	0.0	0.00	0	0.0	0.0		0.0000
Mn2+	54.938	2	0.0	0.0	0.00	0	0.0	0.0		0.0000
Cl^-	35.452	1	702.3	19.8	19.81	702.3	19.8		50.6	0.0198
NO_3^-	62.0037	1	0.0	0	0.00	0	0.0		0.000	0.0000
SO_4^{2-}	96.062	2	109.1	1.1	1.14	109.1	2.3		5.8	0.0045
HCO_3^-	61.014	1	1040.0	17.0	17.05	1040	17.0		43.6	0.0170
		TDS	**2611.1**							
		Total Cations		32.80			33.68	100.00		
		Total Anions		37.99			39.13		100.00	
		CBE					**-7.48%**			

Ionic Strength Calculations

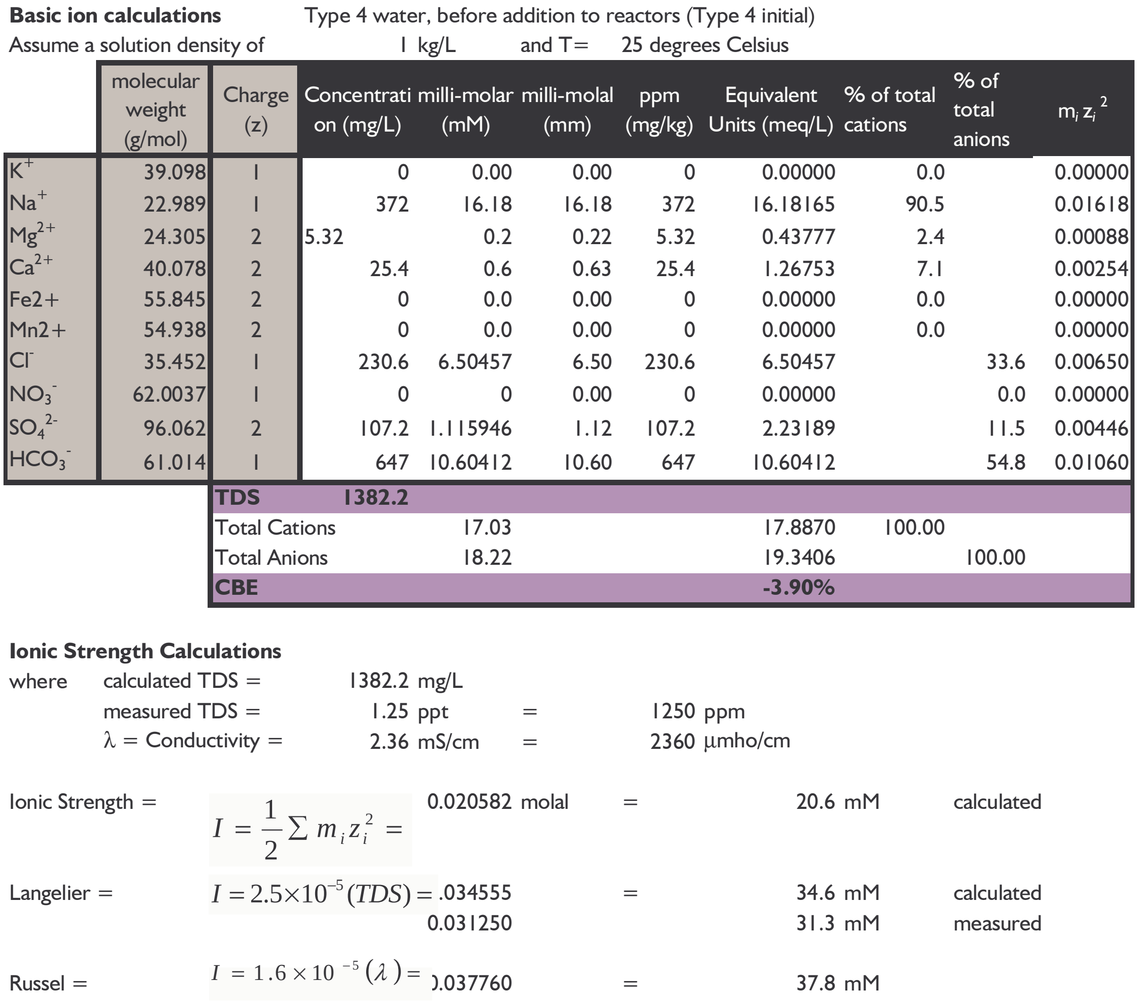
where calculated TDS = 2611.1 mg/L
measured TDS = 2.25 ppt = 2250 ppm
λ = Conductivity = 4.23 mS/cm = 4230 µmho/cm

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.038413 molal = 38.4 mM calculated

Langelier = $I = 2.5\times10^{-5}(TDS) =$ 0.065278 = 65.3 mM calculated
0.056250 56.3 mM measured

Russel = $I = 1.6\times10^{-5}(\lambda) =$ 0.067680 = 67.7 mM

TABLE B.30: Basic ion calculations for the batch reactor Type 3, Initial Water using stock naphthenic acid.



Basic ion calculations Type 4 water, before addition to reactors (Type 4 initial)

Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0.00	0.00	0	0.00000	0.0		0.00000
Na^+	22.989	1	372	16.18	16.18	372	16.18165	90.5		0.01618
Mg^{2+}	24.305	2	5.32	0.2	0.22	5.32	0.43777	2.4		0.00088
Ca^{2+}	40.078	2	25.4	0.6	0.63	25.4	1.26753	7.1		0.00254
Fe2+	55.845	2	0	0.0	0.00	0	0.00000	0.0		0.00000
Mn2+	54.938	2	0	0.0	0.00	0	0.00000	0.0		0.00000
Cl^-	35.452	1	230.6	6.50457	6.50	230.6	6.50457		33.6	0.00650
NO_3^-	62.0037	1	0	0	0.00	0	0.00000		0.0	0.00000
SO_4^{2-}	96.062	2	107.2	1.115946	1.12	107.2	2.23189		11.5	0.00446
HCO_3^-	61.014	1	647	10.60412	10.60	647	10.60412		54.8	0.01060
		TDS	**1382.2**							
		Total Cations		17.03			17.8870	100.00		
		Total Anions		18.22			19.3406		100.00	
		CBE					**-3.90%**			

Ionic Strength Calculations

where calculated TDS = 1382.2 mg/L

measured TDS = 1.25 ppt = 1250 ppm

λ = Conductivity = 2.36 mS/cm = 2360 µmho/cm

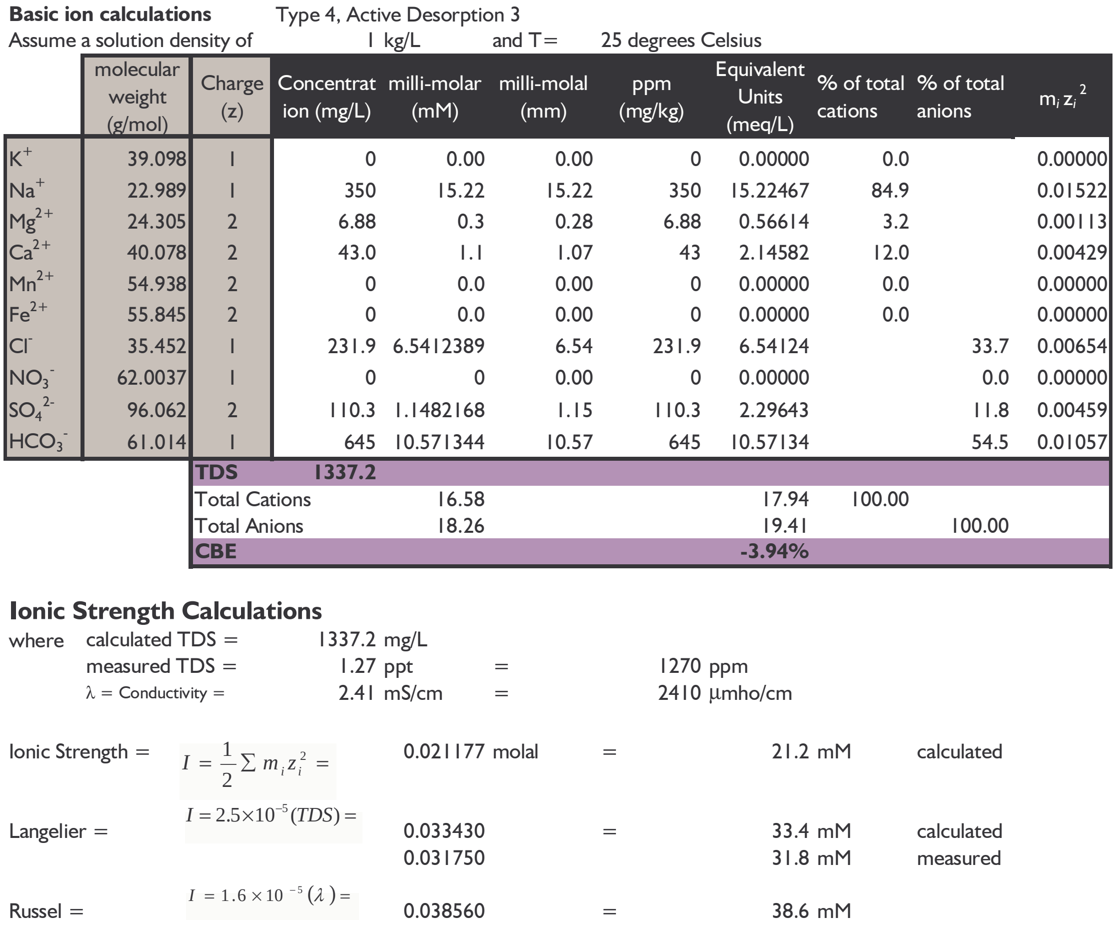
Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.020582 molal = 20.6 mM calculated

Langelier = $I = 2.5\times10^{-5}(TDS) =$ .034555 = 34.6 mM calculated

0.031250 31.3 mM measured

Russel = $I = 1.6\times10^{-5}(\lambda) =$ .037760 = 37.8 mM

TABLE B.31: Basic ion calculations for the batch reactor Type 4, Initial Water using stock naphthenic acid.



Basic ion calculations Type 4, Active Desorption 3

Assume a solution density of 1 kg/L and T= 25 degrees Celsius

	molecular weight (g/mol)	Charge (z)	Concentration (mg/L)	milli-molar (mM)	milli-molal (mm)	ppm (mg/kg)	Equivalent Units (meq/L)	% of total cations	% of total anions	$m_i z_i^2$
K^+	39.098	1	0	0.00	0.00	0	0.00000	0.0		0.00000
Na^+	22.989	1	350	15.22	15.22	350	15.22467	84.9		0.01522
Mg^{2+}	24.305	2	6.88	0.3	0.28	6.88	0.56614	3.2		0.00113
Ca^{2+}	40.078	2	43.0	1.1	1.07	43	2.14582	12.0		0.00429
Mn^{2+}	54.938	2	0	0.0	0.00	0	0.00000	0.0		0.00000
Fe^{2+}	55.845	2	0	0.0	0.00	0	0.00000	0.0		0.00000
Cl^-	35.452	1	231.9	6.5412389	6.54	231.9	6.54124		33.7	0.00654
NO_3^-	62.0037	1	0	0	0.00	0	0.00000		0.0	0.00000
SO_4^{2-}	96.062	2	110.3	1.1482168	1.15	110.3	2.29643		11.8	0.00459
HCO_3^-	61.014	1	645	10.571344	10.57	645	10.57134		54.5	0.01057
		TDS	**1337.2**							
		Total Cations		16.58			17.94	100.00		
		Total Anions		18.26			19.41		100.00	
		CBE					**-3.94%**			

Ionic Strength Calculations

where calculated TDS = 1337.2 mg/L

measured TDS = 1.27 ppt = 1270 ppm

λ = Conductivity = 2.41 mS/cm = 2410 µmho/cm

Ionic Strength = $I = \frac{1}{2}\sum m_i z_i^2 =$ 0.021177 molal = 21.2 mM calculated

Langelier = $I = 2.5\times10^{-5}(TDS) =$ 0.033430 = 33.4 mM calculated

0.031750 = 31.8 mM measured

Russel = $I = 1.6\times10^{-5}(\lambda) =$ 0.038560 = 38.6 mM

TABLE B.32: Basic ion calculations for the batch reactor Type 4, Active Desorption 3 using stock naphthenic acid.

Appendix C

Development of an Analytical Method to Measure Naphthenic Acid Surrogates

There is no standard analytical method available for the analysis of the carboxylated alkanes and cycloalkanes that were chosen for a batch sorption isotherm (Table C.1). Method development by M. Vandergriendt (Organic Geochemistry Lab, University of Waterloo) was based on Fedorak's tert-butyldimethylsilyl derivatization (ref???), itself an adaptation (St. John ???), and using a gas chromatograph (GC) coupled with either a flame ionization detector (FID) or mass spectrometer (MS).

In order to facilitate discussion, the different surrogates will sometimes be referred to as a number defined in table C.2.

C.1 Method Development

In order to produce reliable data for the sorption isotherms, the goal was RSD (relative standard deviation) and %Error for the analytical method in the range of 1 to 20% (ideally 10%) and R-square values approaching 1 (ie 0.99) for each of the NA's. A simple linear regresion is a best-fit line based on the positions of the data points. The ”goodness of fit” of the line is described by the r-squared term such that an r-squared of 1.0 is a perfect fit to the data and an r-squared of 0.0 means there is no relationship

Name	CAS	Molecular Formula	Mol. Weight	Z #
Heptanoic acid	111-14-8	$C_7H_{14}O_2$	130.18	0
Octadecanoic acid or stearic acid	57-11-4	$C_{18}H_{36}O_2$	284.48	0
16-Methyl heptadecanoic acid or isostearic acid	2724-58-5	$C_{18}H_{36}O_2$	284.48	0
4-Methylcyclohexaneacetic acid, cis/trans mix	6603-71-0	$C_9H_{16}O_2$	156.2	-2
1-Methyl-1-cyclohexanecarboxylic acid	1123-25-7	$C_8H_{14}O_2$	142.2	-2
Cycloheptanecarboxylic acid	1460-16-8	$C_8H_{14}O_2$	142.2	-2
4-Pentylbicyclo [2.2.2]octane-1-carboxylic acid	73152-70-2	$C_{14}H_{24}O_2$	224.34	-4
3-Methyl-octahydro-pentalene-1-carboxylic acid	87-30-9	$C_{10}H_{16}O_2$	168.23	-4
3-Methyl-adamantane-1-carboxylic acid	33649-73-9	$C_{12}H18O_2$	194.27	-6
Cholanic Acid or 5-β-cholanic acid	546-18-9	$C_{24}H40O_2$	360.57	-8

Table C.1: List of ten naphthenic acid surrogates initially chosen for the batch sorption experiment.

	Name
1	Heptanoic acid
2	Octadecanoic acid or stearic acid
3	16-Methyl heptadecanoic acid or isostearic acid
4	4-Methylcyclohexaneacetic acid, cis/trans mix
5	1-Methyl-1-cyclohexanecarboxylic acid
6	Cycloheptanecarboxylic acid
7	4-Pentylbicyclo [2.2.2]octane-1-carboxylic acid
8	3-Methyl-octahydro-pentalene-1-carboxylic acid
9	3-Methyl-adamantane-1-carboxylic acid
10	Cholanic Acid or 5-β-cholanic acid

Table C.2: Legend for the ten naphthenic acid surrogates.

between x and y. Another way to think of this is that an r-squared of 0.95 means that x explains 95% of the variability in y.

C.1.1 Determination of Retention Times

Individual standards were prepared for each of the 10 compounds for use in constructing the initial calibration curves and in determining retention time of the individual naphthenic acids on the GC. The NA surrogates were derivatized individually using the full method developed by Fedorak's lab. The temperature program was 35°C for 0.5 min, 15°C/min to 300°C and hold 12 min. The column was DB-5 with a 30 m lenth.

After derivatization and analysis, no peaks were detected for heptanoic acid, 1-methyl-1-cyclohexanecarboxylic acid, cycloheptanecarboxylic acid and 4-methylcyclohexaneacetic acid. The elution order for the other derivatized compounds on the GC was:

1. 3-Methyl-octahydro-pentalene-1-carboxylic acid
2. 3-Methyl-adamantane-1-carboxylic acid
3. 4-Pentylbicyclo [2.2.2]octane-1-carboxylic acid
4. 16-Methyl heptadecanoic acid
5. Octadecanoic acid (Stearic acid)
6. Cholanic acid

Following these results, the 10 compounds were run on the GC in the underivatized form using the same temperature program and column. All peaks were detected and retention times were detected. Peak shape for the underivatized compounds was not Gaussian under these conditions. The surrogate 4-methylcyclohexaneacetic acid saw some peak separation due to the different properties of the *cis-* and *trans-* isomers. Each isotherm will be analyzed twice, once underivatized for C7 to C12 and once derivatized for C14 to C24.

Chemical name	High Std 10 g/L	Low Std 4 g/L	Limited Mass Std
Heptanoic acid	X	X	
Octadecanoic acid	X	X	
16-Methyl heptadecanoic acid			X (6 g/L)
4-Methylcyclohexaneacetic acid	X	X	
1-Methyl-1-cyclohexanecarboxylic acid	X	X	
Cycloheptanecarboxylic acid	X	X	
4-Pentylbicyclo [2.2.2]octane-1-CA	X	X	
3-Methyl-octahydro-pentalene-1-CA	X	X	
3-Methyl-adamantane-1-carboxylic acid			X (12 g/L)
Cholanic Acid or 5-β-cholanic acid	X	X	

TABLE C.3: Naphthenic acid surrogates used in the creation of standards H-17, H-5, H-56, H-16.5 and L-5, L-2, L-16.5, L-6.5.

C.2 Standard Curves for Analytical Method

C.2.1 Stock Standard Preparation

Three stock standards were mixed in methylene chloride (Table C.3). A 10 000 mg/L solution of 8 of the chemicals was created with approximately 9 900-10 350 mg/L of each chemical. A second set of standards was created by dissolving the surrogates in concentrations of approximately 3 500 to 4 500 mg/L. Finally, a third standard was mixed for the two expensive chemicals which were available in very low amounts. These stocks were used for standard curve preparation and for the solubility test throughout the method development .

C.2.2 Standard Preparation

The next step was to perform water extraction calibrations to to determine the reproducibility and accuracy of the 2 methods (%error, %relative standard deviation).Water standards were prepared (16 mL) and spiked with appropriate amounts of stock standard to prepare a standard curve of approximately 10, 3, 1.2 and 0.5 mg/L. Microextraction was used to extract the naphthenic acids from the water. One millilitre of methylene chloride was added to the 16 mL of water standard, capped and shaken for 20 min (standard procedure). After shaking, 0.6 ml of the methylene chloride was recovered and 200 μL of this was derivatized and run on the GC-FID, while the remaining sample was injected, underivatized onto the GC-FID. Again recoveries for the derivatized samples were poor for C7 to C10 peaks # 1,5, 6,4,8 but the heavier back end peaks C12 to C26 looked more promising (#9,7,3,2.10). The underivatized samples yielded better results for the lighter peaks C7-C10 #1,5,6,4,8, and poor results for the rest. Underivatized peak shape was poor (not Gaussian) so it was determined that we would move to a more polar Nukol column designed for organic acids (same as FFAP column).

C.2.3 Derivatized Analysis

The same derivatization method was used three times, modified to progress toward appropriate accuracy and precision. As well as minimizing RSD and %error, the goal was to improve the least squares regression line.

C.2.3.1 First Standard Curve Attempts (Feb 12)

The derivatization procedure had previously been modified by adding an acetic acid step after the derivatization, to remove the derivatizing agent in order to extend column life. When a previous analysis had successfully derivatized and recovered the #5 peak, this step was not being used. It was felt that removal of this step may help recovery of the C7 to C10 peaks. Additionally, the microextraction portion of the procedure was removed to see if water in the solvent might be affecting the derivatization procedure. Instead of adding the stock standard to 16 ml of water and extracting with 1 ml of methylene chloride, the stock standard was added directly to the 1 ml of methylene chloride. Methylene chloride samples were again split into two aliquots for derivatized and underivatized analysis. Derivatized recoveries for the C7 to C10 compounds were much improved, but still too variable for use. It was unclear if improvement was due to the removal of the acetic acid procedure or because the samples were in methylene chloride only (no water extraction). Underivatized NA's were run on the Nukol column and only the first 2 peaks, #1 and #5, were regressed for an r-square of 0.99, a good fit (temperature program not developed yet –isocratic run at 130°C).

C.2.3.2 Second Standard Curve Attempts (Feb 16 and 19, 2004)

A water extraction was again performed. The volumes used were scaled up to 53 ml of water and 3.3 mls of methylene chloride while maintaining the same ratio as the previous 16 ml water/1 ml methylene chloride. This was done to provide more methylene chloride for the 2 different methods in the future batch isotherms and for duplicate analyses.The acetic acid procedure was again omitted and 2 modifications were suggested by Shirley. First, 0.6 g of sodium sulfate was added to the methylene chloride to remove any water that may have gotten into the methylene chloride during the water extraction (since the previous calibration attempt in methylene chloride, gave us better recovery). Second, Shirley added 250 μL of derivatizing agent instead of 200 μL, just in case the derivatizing agent was limited. Derivatized results were again poor for the C7 to C10 peaks, but C12 to C26 (#9,7,3,2, and 10) had %errors within approximately 1 to 20% while R-square values were 0.99. The method seems usable for these last 5 NA's. For the underivatized samples, Nukol column injections using a better temperature program (intial temperature 100°C, hold for 2 min, rate 6°Cper min to 180°C and hold for 15 min) yielded usable R-squared values between .98 to .99 and better % errors for lighter peaks #1,5,6,4,9,7 (Tables C.4 and C.5).

C.3 Solubility Test and Standard Curve Construction (March 2, 2004)

Using a combination of derivatized and underivatized methods, an analytical technique with calibrations that are somewhat acceptable for analysis of all of the 10 NA's has been developed. For the purposes of the batch sorption experiment, it was not necessary to determing saturated solubility. No solubility testing was done on these compounds other than to attempt to dissolve 10 mg/L of each surrogate in methylene chloride and injecting into room-temperature water. The methylene chloride made up less than 0.105% of the resulting solution, and so is not considered to be a cosolvent.

The water was supplemented with inorganic ions to an ionic strength of 20 mM and pH of 7.12. Hypovials (triplicate) containing 155 ml of salt water were spiked with known concentrations of stock standard. Hypovials were placed on a rotating wheel for ninety hours. After this time, undissolved chemical was visible in the water so the vials were placed on a shaker at 37°C for another 24 hours in an attempt to

Chemical name	**Fedorak**	**No Acetic Acid Addition**		
		Feb 12	**Feb 16**	**Mar 2**
Octadecanoic acid	.99	.99	.9997	.99
16-Methyl heptadecanoic acid	n/a	n/a	.9989	.99
4-Pentylbicyclo [2.2.2]octane-1-carboxylic acid	.9969	.99	.999	.998
3-Methyl-octahydro-pentalene-1-carboxylic acid	.92	.99	.95	*
3-Methyl-adamantane-1-carboxylic acid	n/a	n/a	.99	.99
5-β-cholanic acid	.99	.99	.999	.95699
Samples which will be run underivatized				
Heptanoic acid	.83	.84	*	*
4-Methylcyclohexaneacetic acid	.84	.99	.86/.90	*
1-Methyl-1-cyclohexane-carboxylic acid	n/a	.81	*	*
Cycloheptanecarboxylic acid	.78	.97	.80	*
*chromatography too poor for linear regression				

Table C.4: Summary of r2 value for the linear regression of derivatized analysis.

Chemical name	**Underivatized**	**Nukol Column**		
		Feb 12	**Feb 19**	**Mar 2**
Octadecanoic acid	n/a	n/a	.99	.9933
16-Methyl heptadecanoic acid	n/a	n/a	*	*
4-Pentylbicyclo [2.2.2]octane-1-carboxylic acid	.96	n/a	.98	.9958
3-Methyl-octahydro-pentalene-1-carboxylic acid	.986	n/a	.98699	.99
3-Methyl-adamantane-1-carboxylic acid	n/a	n/a	.996	.9995
5-β-cholanic acid	n/a	n/a	*	*
Samples which will be run underivatized				
Heptanoic acid	.955	.99	.98	.988
4-Methylcyclohexaneacetic acid	.9562	n/a	.988	.99
1-Methyl-1-cyclohexanecarboxylic acid	.99	.99	.979	.99
Cycloheptanecarboxylic acid	.98	n/a	.96	.99
*chromatography too poor for linear regression				

Table C.5: Summary of r-squared value for the linear regression of underivatized analysis.

encourage NA dissolution. After this incubation, the vials were allowed to settle for 6 hours and return to room temperature. Undissolved chemicals were still visible and care was taken during sampling to avoid them. Two aliquots were removed from each bottle. One sample was filtered with a 0.45 micron *HVLP (Duropore – Polyvinylidene fluoride –millipore chart indicated that these filters were resistant to organic acids)* and the other sample was not. Calibration curves for both derivatized and underivatized methods were prepared as previous (Feb 16/19, 2004). Each sample was analyzed, along with the calibration curve standards, using both the derivatized and underivatized methods and the March 2 calibrations. Calibrations were again almost acceptable and can probably be improved by doing duplicate derivatizations for the derivatized method, and duplicate manual GC injections for the underivatized method. Problems were encountered with the first filtered sample. The filter unit was not functioning properly and the sample had to be filtered twice and the sample was abused.

The three compounds that were calculated to be sparingly soluble had molar solubilities on the order of 10^{-7}; theory and measurement correspond well in this instance. All other compounds were added at concentrations well below their theoretical solubility and the percent error between the concentrations added and measured in the filtered sample was generally good. Four aliquots had %error above 21%: heptanoic acid (43%), 1-methyl-1-cyclohexance carboxylic acid (32%) and cycloheptanecarboxylic acid (34%). There were only two samples for these calculations since the first sample was filtered twice and these are the compounds most likely to volatilize. The unfiltered samples all had %error $\leq$15%.

C.4 Recommendations for isotherm

1. Exclude isostearic acid and stearic acid. Solubility is so low that measurement noise is probably equivalent to sorption changes, since the calibration curve is not very good for this low concentration. In spite of these problems, cholanic acid will be kept since it offers the potential for unique data. Standards concentration will be lowered to extend the calibration curve down to solubility.

2. Use 8 other compounds, starting with full-strength stock and serially diluting it by 1/2 and 1/4.

Chemical name	Calculated Solubility (mol/L)	Measured Solubility $\pm$ RSD (mg/L)	Measured Solubility (mol/L)
Heptanoic acid	≥ 1	$\geq 7.8 \pm 7\%$	$6.0E-05$
Octadecanoic acid or stearic acid	≤ 0.01	$0.08 \pm 18\%$	$2.8E-07$
16-Methylheptadecanoic acid or isostearic acid	≤ 0.01	$0.04 \pm 15\%$	$1.2E-07$
cis?-4-Methylcyclohexaneacetic acid	$1 > S > 0.1$	$\geq 6.41 \pm 7\%$	$3.5E-05$
trans?-4-Methylcyclohexaneacetic acid	$1 > S > 0.1$	$\geq 5.63 \pm 3\%$	$3.4E-05$
1-Methyl-1-cyclohexanecarboxylic acid	$1 > S > 0.1$	$\geq 12.53 \pm 8\%$	$6.6E-05$
Cycloheptanecarboxylic acid	$1 > S > 0.1$	$\geq 13.40 \pm 9\%$	$7.7E-05$
4-Pentylbicyclo [2.2.2]octane-1-carboxylic acid	≤ 0.01	$\geq 10.67 \pm 9\%$	$4.9E-05$
		$\geq 11.10 \pm 7\%$	$4.5E-05$
3-Methyl-octahydro-pentalene-1-carboxylic acid	$1 > S > 0.1$	$\geq 12.40 \pm 5\%$	$6.3E-05$
3-Methyl-adamantane-1-carboxylic acid	$0.1 > S$	$\geq 12.72 \pm 8\%$	$6.5E-05$
	$S > 0.01$	$\geq 13.54 \pm 0.05\%$	$6.5E-05$
5-β-cholanic acid	≤ 0.01	$0.30 \pm 18\%$	$8.2E-07$

Table C.6: Result of solubility test of ten naphthenic acid surrogates used in the batch sorption experiment. The calculated solubility refers to the number of moles of a compound that dissolve in pure water at 25 degrees Celsius to produce a liter of saturated solution. RSD is the relative standard deviation which is a percentage of the value.

3. Use artificial groundwater as before, where I=20 mM.
4. pH = ˜7.
5. Incubated at room temperature.
6. 4-Methylcyclohexaneacetic acid will be added at the same concentrations as the other surrogates since the resulting concentration of *cis* and *trans* isomers will still be within the range of the calibration curve.

Appendix D

Lab Report, K_d Experiment Using Eight Surrogate Naphthenic Acid Compounds

Francois Gervais – Set-up April 16, 2004 – Sampled April 19, 2004 –(brief outline of what was done)

written by Marianne VanderGriendt, Organic Geochemistry Lab, University of Waterloo

8 Surrogate Naphthenic Acid Compounds:

1	Heptanoic acid
5	1-Methyl-1-cyclohexanecarboxylic acid
6	Cycloheptanecarboxylic acid
4	4-Methylcyclohexaneacetic acid
4	4-Methylcyclohexaneacetic acid
8	3-Methyl-octahydro-pentalene-1-carboxylic acid
9	3-Methyl-adamantane-1-carboxylic acid
7	4-Pentylbicyclo [2.2.2]octane-1-carboxylic acid
3	16-Methyl heptadecanoic acid
2	Octadecanoic acid (Stearic acid)
10	CHOLANIC ACID

NaHCO3	1.315g
CaCl2	0.0825g
MgSO4	0.030g
NaSO4	.0135g
Nacl	0.148g

D.1 Design:

Used 210g of soil in a 250ml scew cap bottles with Teflon lined scew cap tops – Approximately 175 ml of water added . . . Able to recover approximately 120 ml of water for analytical analysis, pH and ion analysis

1. Controls – Water/Azide/8 Naphthenic Acids at 3 concentrations (10, 5 and 1.5 mg/L) * 3 (triplicate)= 9 bottles
2. Active – Soil/Water/Azide/8 Naphthenic Acids at 3 concentrations (10, 5, and 1.5 mg/L) *4 quadruple = 12 bottles
3. Desorption Controls– Soil/ Water/Azide, 3 bottles

Four types of water were required for the experiment:

Francois made 20L of ion doped water (nanopure water) using the following recipe:

Ions to add to 1L quantity of water:

Sodium Azide (18g per 18 L = 0.1%) was added to the ion doped water and then the water was pH with Hcl to 7.0

Type 1 water- using the ion doped/azide water above, was prepared in a 2.65L bottle and received the addition of 2.65 ml of a 10,000 mg/L stock solution (containing 8 surrogate naphthenic acid compounds -prepared in methylene chloride) for a final concentration of 10 mg/L.

Type 2 water using the ion doped/azide water, was prepared in a 2.65L bottle and received the addition of 1.325 ml of a 10,000 mg/L stock solution (containing 8 surrogate naphthenic acid compounds -prepared in methylene chloride) for a final concentration of 5 mg/L.

Type 3 water using the ion doped/azide water, was prepared in a 2.54L bottle and received the addition of 0.381 ml of a 10,000 mg/L stock solution (containing 8 surrogate naphthenic acid compounds -prepared in methylene chloride) for a final concentration of 1.5 mg/L.

When adding water to the soil bottles, care was taken to avoid any headspace within the bottle (bottles were filled $\frac{1}{2}$ full of water –swirled to remove trapped air and then topped up).

The bottles were incubated at room temperature on a rotary shaker at 75 rpm for 55 hours. They were then removed from the shaker and left to settle for 15 hours. Analysis occurred after 70 hours of incubation.

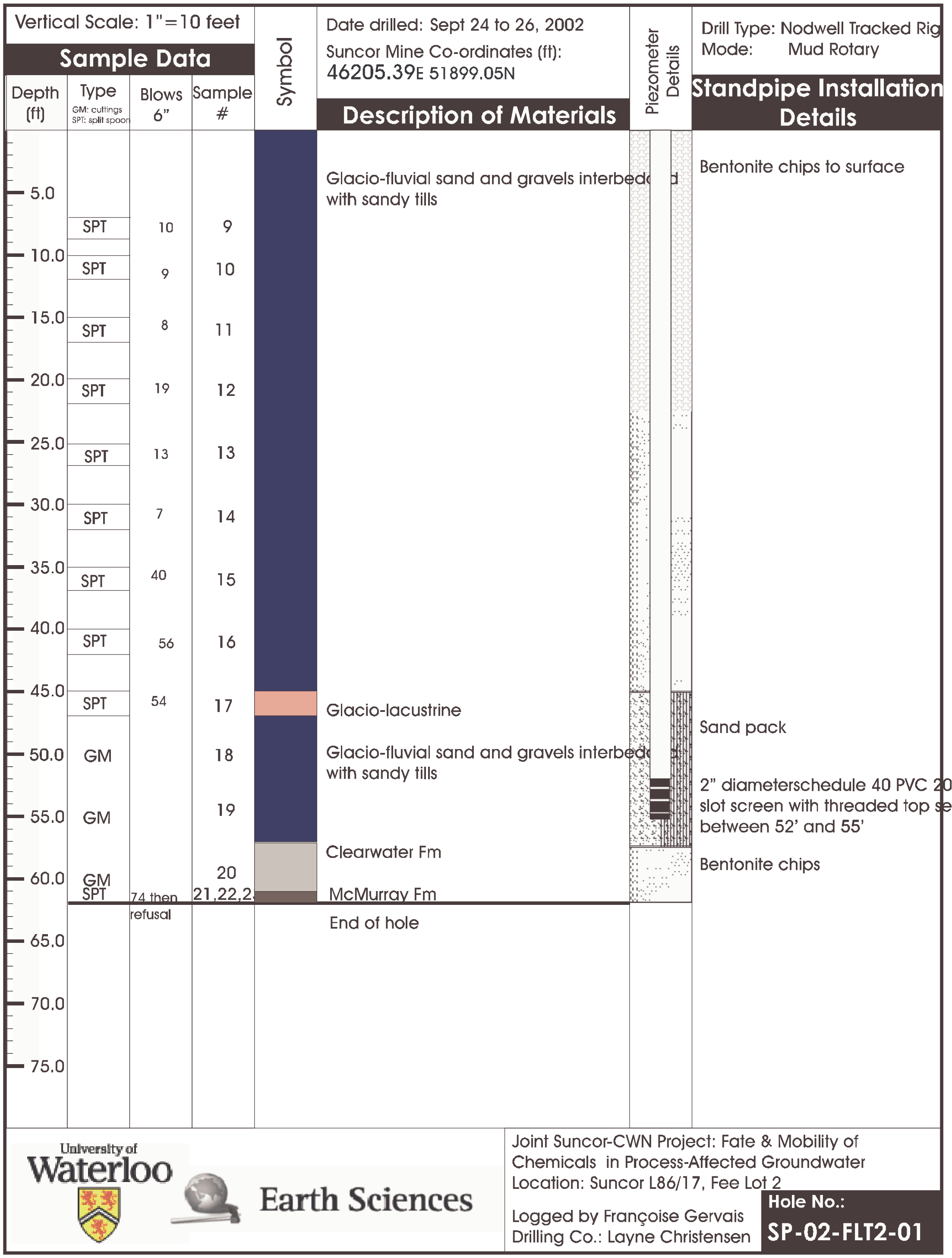
D.2 Analysis

All water used for analysis was filtered with 0.45 micron HVLP Durapore (Polyvinylidene fluoride) filters (Millipore®). Fifty three ml of water from each sample was placed it in a 60 ml hypovial. Hypovials received the addition 0.66ml of 1:1 H_2SO_4 to bring the pH <2, followed by the addition of 3.3 ml of methylene chloride. Hypovials were sealed with a Teflon®aluminum crimp top seal and shaken for 20 minutes at 350 rpm. After shaking, the methylene chloride was removed from the hypovials and placed in 2 ml screw cap vials with 0.6 g of sodium sulfate (as a drying agent to remove water from the methylene chloride). 200 ìl of the methylene chloride was used for the derivatization procedure (Shirley), while 1ì was injected onto the Nukol column for analysis.

Other samples were taken for pH, cations and anions.

Appendix E

Borehole Logs for New Piezometers



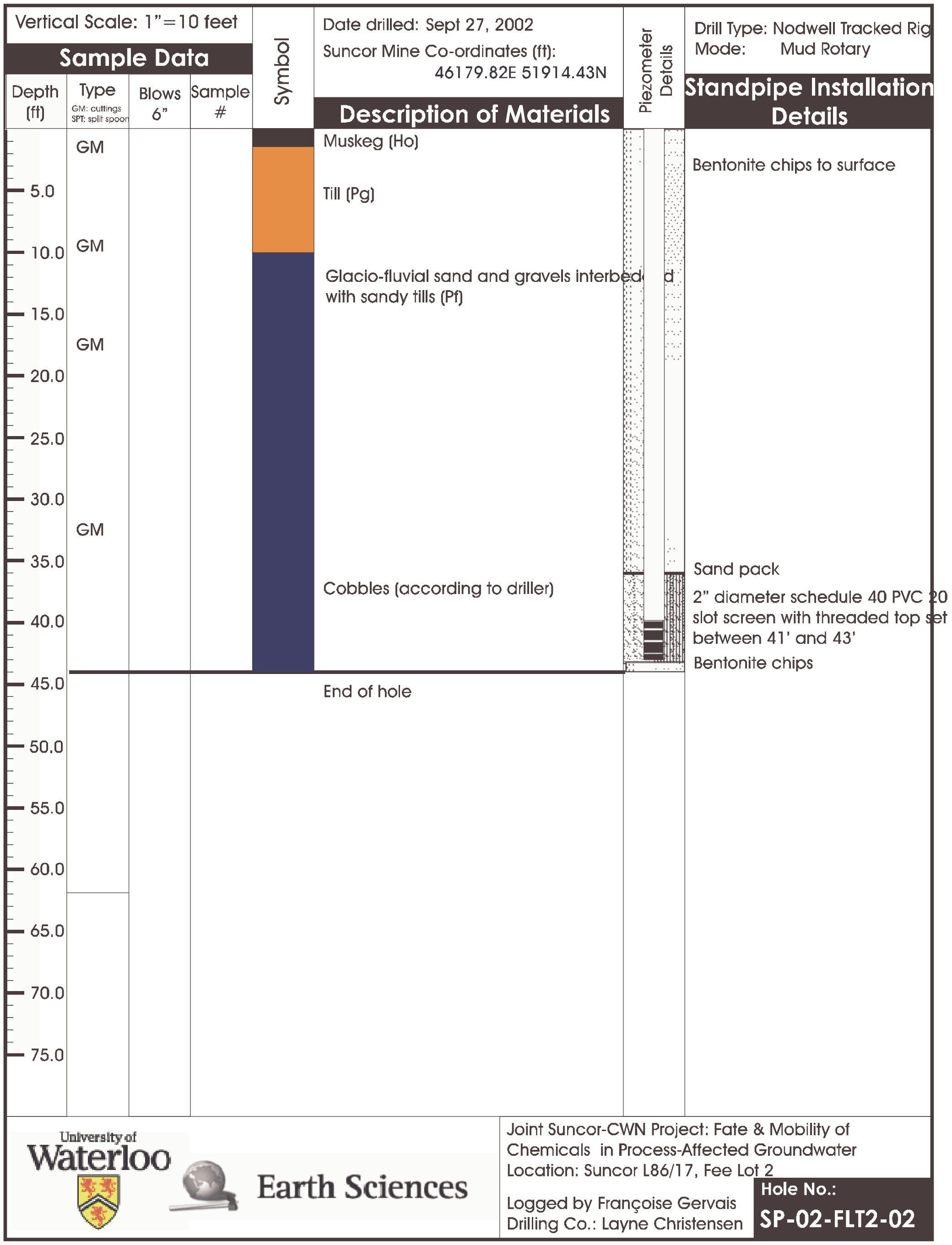
Date drilled: Sept 24 to 26, 2002
Suncor Mine Co-ordinates (ft):
46205.39E 51899.05N

Drill Type: Nodwell Tracked Rig
Mode: Mud Rotary

Type (GM: cuttings, SPT: split spoon)	Blows 6"	Sample #
SPT	10	9
SPT	9	10
SPT	8	11
SPT	19	12
SPT	13	13
SPT	7	14
SPT	40	15
SPT	56	16
SPT	54	17
GM		18
GM		19
GM		20
SPT	74 then refusal	21,22,2

Joint Suncor-CWN Project: Fate & Mobility of Chemicals in Process-Affected Groundwater
Location: Suncor L86/17, Fee Lot 2
Logged by Françoise Gervais
Drilling Co.: Layne Christensen
Hole No.: SP-02-FLT2-01

Figure E.1: Borehole log for SP-02-FLT2-01



Vertical Scale: 1"=10 feet

Sample Data

Depth (ft)	Type GM: cuttings SPT: split spoon	Blows 6"	Sample #
	GM		
5.0			
10.0	GM		
15.0			
	GM		
20.0			
25.0			
30.0			
	GM		
35.0			
40.0			
45.0			
50.0			
55.0			
60.0			
65.0			
70.0			
75.0			

Symbol

Date drilled: Sept 27, 2002
Suncor Mine Co-ordinates (ft):
46179.82E 51914.43N

Description of Materials

Muskeg (Ho)

Till (Pg)

Glacio-fluvial sand and gravels interbed d
with sandy tills (Pf)

Cobbles (according to driller)

End of hole

Piezometer Details

Drill Type: Nodwell Tracked Rig
Mode: Mud Rotary

Standpipe Installation Details

Bentonite chips to surface

Sand pack

2" diameter schedule 40 PVC 20 slot screen with threaded top set between 41' and 43'

Bentonite chips

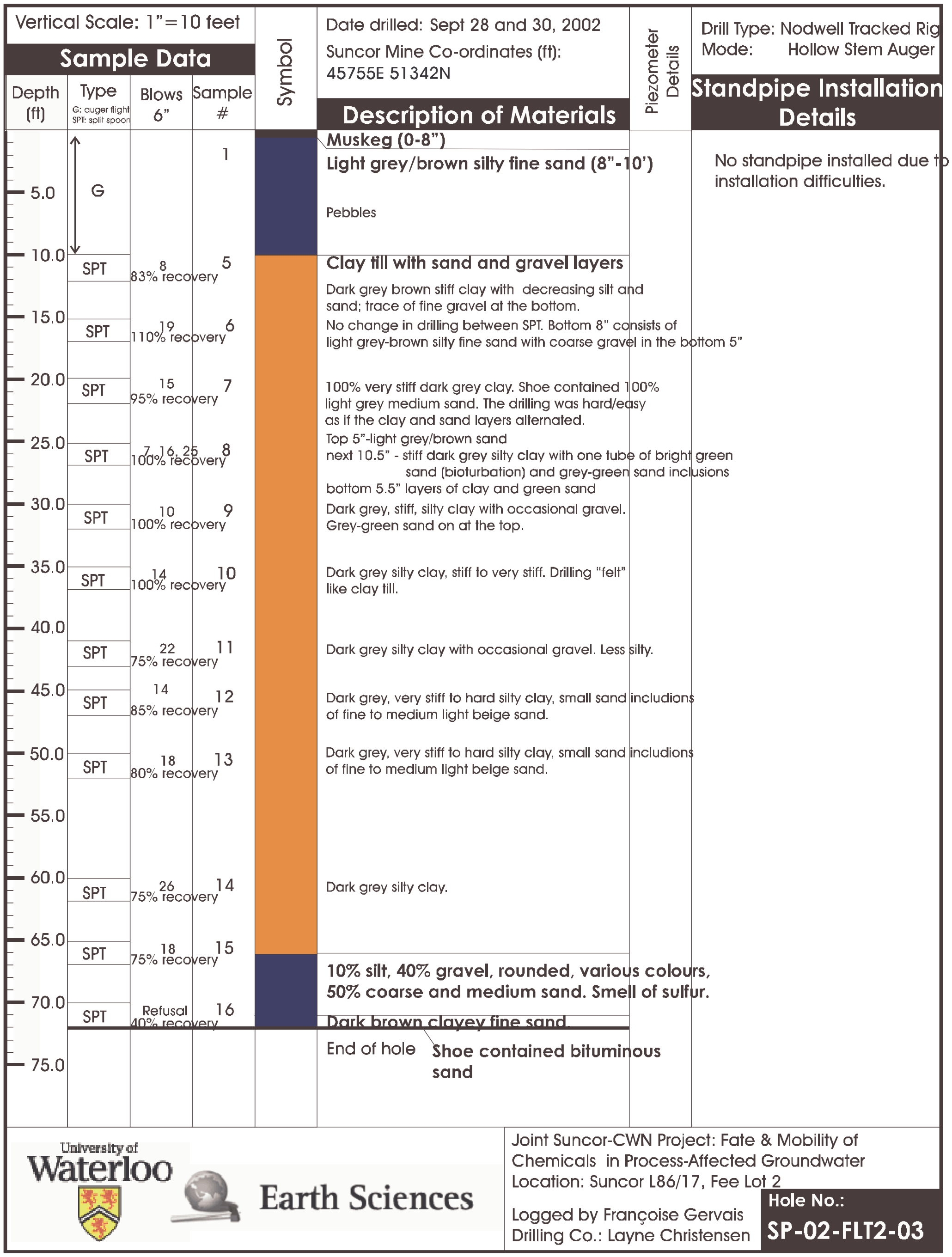
University of Waterloo Earth Sciences

Joint Suncor-CWN Project: Fate & Mobility of Chemicals in Process-Affected Groundwater
Location: Suncor L86/17, Fee Lot 2

Logged by Françoise Gervais
Drilling Co.: Layne Christensen

Hole No.:
SP-02-FLT2-02

Figure E.2: Borehole log for SP-02-FLT2-02



Vertical Scale: 1"=10 feet

Sample Data

Date drilled: Sept 28 and 30, 2002
Suncor Mine Co-ordinates (ft): 45755E 51342N

Drill Type: Nodwell Tracked Rig
Mode: Hollow Stem Auger

Depth (ft)	Type (G: auger flight, SPT: split spoon)	Blows 6"	Sample #	Description of Materials
0–10.0	G		1	**Muskeg (0-8")** **Light grey/brown silty fine sand (8"-10')** Pebbles
10.0	SPT	8 83% recovery	5	**Clay till with sand and gravel layers** Dark grey brown stiff clay with decreasing silt and sand; trace of fine gravel at the bottom.
15.0	SPT	19 110% recovery	6	No change in drilling between SPT. Bottom 8" consists of light grey-brown silty fine sand with coarse gravel in the bottom 5"
20.0	SPT	15 95% recovery	7	100% very stiff dark grey clay. Shoe contained 100% light grey medium sand. The drilling was hard/easy as if the clay and sand layers alternated.
25.0	SPT	7, 16, 25 100% recovery	8	Top 5"-light grey/brown sand next 10.5" - stiff dark grey silty clay with one tube of bright green sand (bioturbation) and grey-green sand inclusions bottom 5.5" layers of clay and green sand
30.0	SPT	10 100% recovery	9	Dark grey, stiff, silty clay with occasional gravel. Grey-green sand on at the top.
35.0	SPT	14 100% recovery	10	Dark grey silty clay, stiff to very stiff. Drilling "felt" like clay till.
40.0	SPT	22 75% recovery	11	Dark grey silty clay with occasional gravel. Less silty.
45.0	SPT	14 85% recovery	12	Dark grey, very stiff to hard silty clay, small sand includions of fine to medium light beige sand.
50.0	SPT	18 80% recovery	13	Dark grey, very stiff to hard silty clay, small sand includions of fine to medium light beige sand.
55.0				
60.0	SPT	26 75% recovery	14	Dark grey silty clay.
65.0	SPT	18 75% recovery	15	**10% silt, 40% gravel, rounded, various colours, 50% coarse and medium sand. Smell of sulfur.**
70.0	SPT	Refusal 40% recovery	16	**Dark brown clayey fine sand**
75.0				End of hole **Shoe contained bituminous sand**

Piezometer Details

Standpipe Installation Details

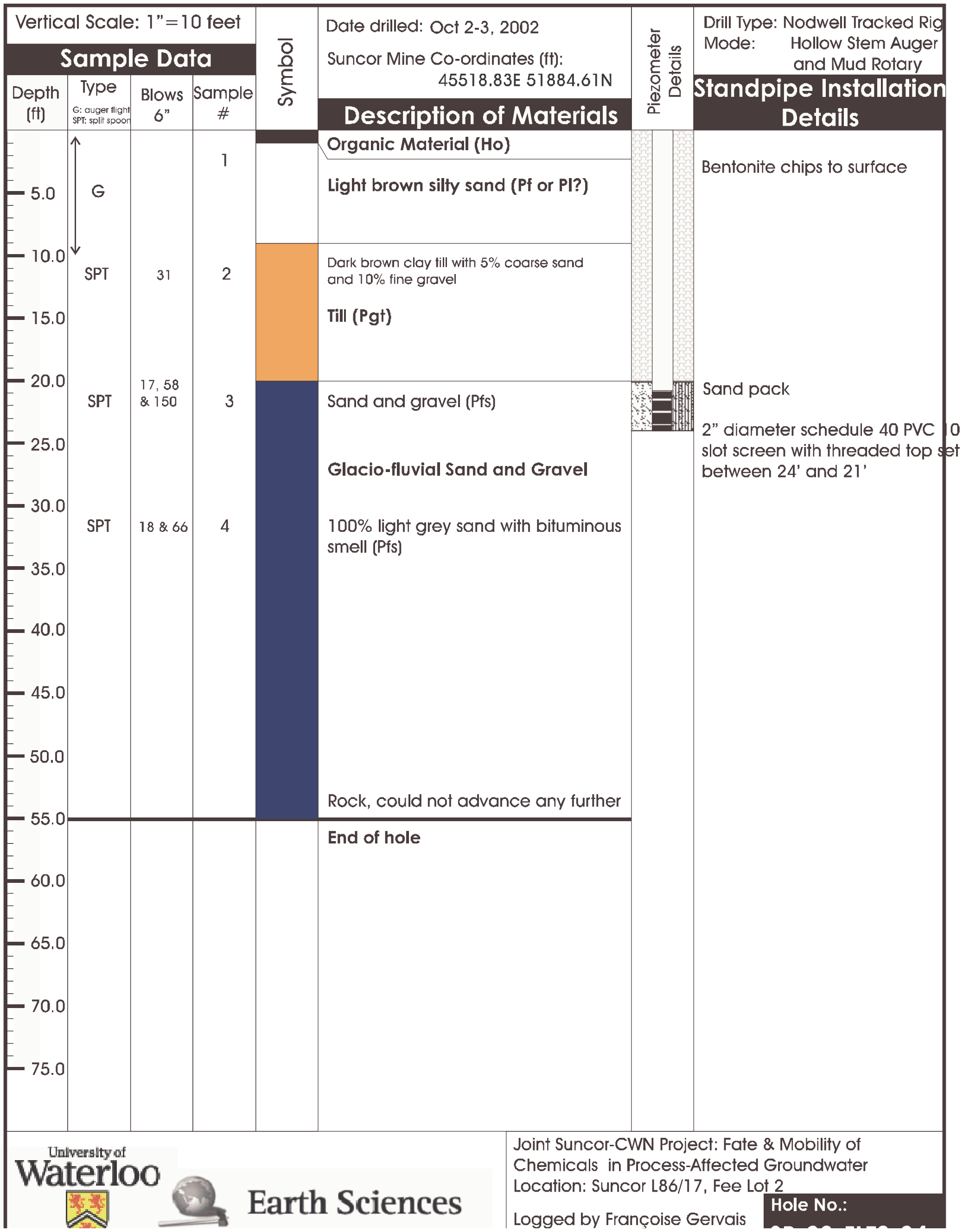
No standpipe installed due t
installation difficulties.

University of Waterloo Earth Sciences

Joint Suncor-CWN Project: Fate & Mobility of Chemicals in Process-Affected Groundwater
Location: Suncor L86/17, Fee Lot 2
Logged by Françoise Gervais
Drilling Co.: Layne Christensen

Hole No.: **SP-02-FLT2-03**

FIGURE E.3: Borehole log for SP-02-FLT2-03



Date drilled: Oct 2-3, 2002

Suncor Mine Co-ordinates (ft): 45518.83E 51884.61N

Drill Type: Nodwell Tracked Rig

Mode: Hollow Stem Auger and Mud Rotary

Type	Blows 6"	Sample #
G		1
SPT	31	2
SPT	17, 58 & 150	3
SPT	18 & 66	4

Description of Materials

Organic Material (Ho)

Light brown silty sand (Pf or Pl?)

Dark brown clay till with 5% coarse sand and 10% fine gravel

Till (Pgt)

Sand and gravel (Pfs)

Glacio-fluvial Sand and Gravel

100% light grey sand with bituminous smell (Pfs)

Rock, could not advance any further

End of hole

Standpipe Installation Details

Bentonite chips to surface

Sand pack

2" diameter schedule 40 PVC 10 slot screen with threaded top set between 24' and 21'

Joint Suncor-CWN Project: Fate & Mobility of Chemicals in Process-Affected Groundwater

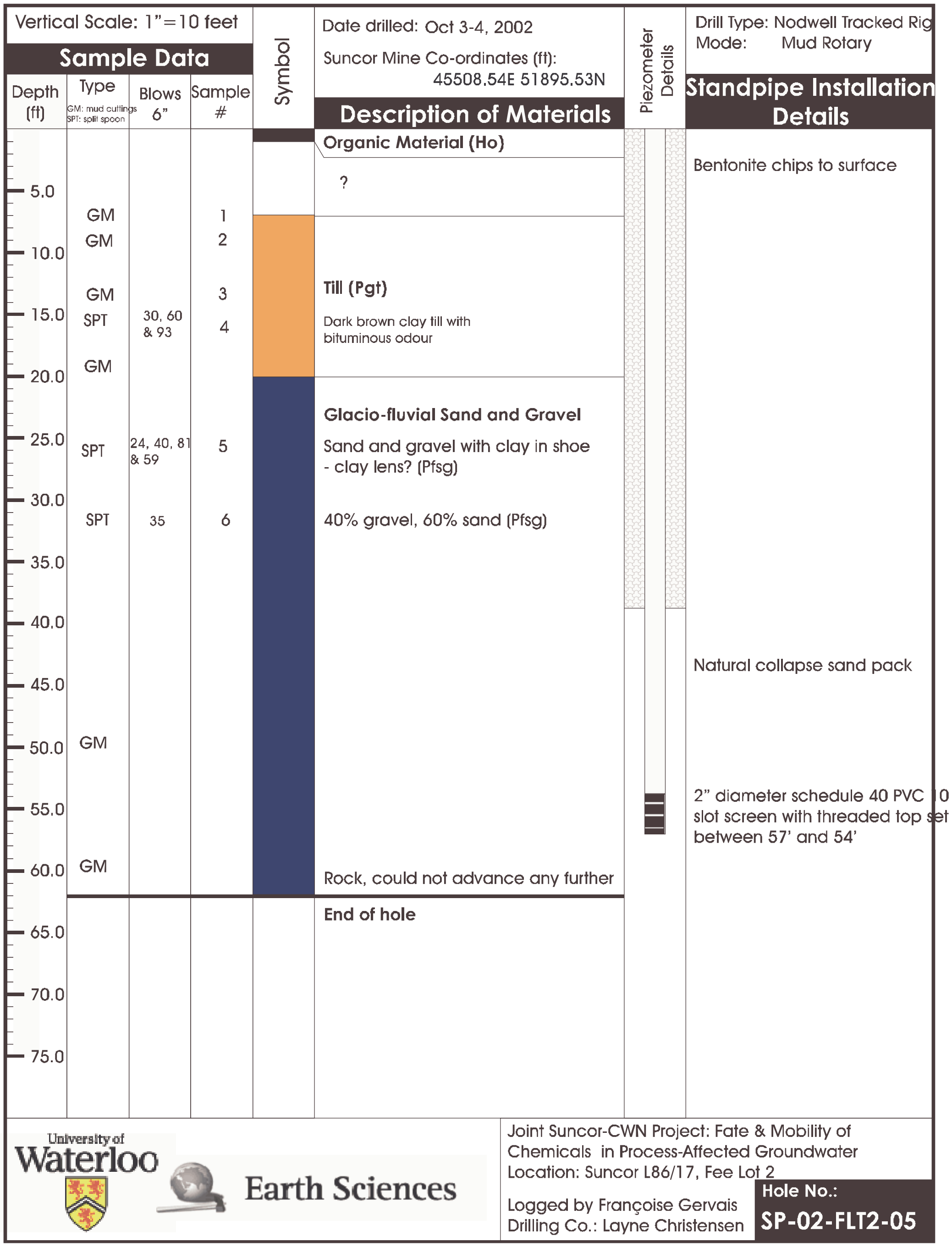
Location: Suncor L86/17, Fee Lot 2

Logged by Françoise Gervais

Hole No.:

University of Waterloo Earth Sciences

Figure E.4: Borehole log for SP-02-FLT2-04



Vertical Scale: 1”=10 feet

Sample Data

Depth (ft)	Type GM: mud cuttings SPT: split spoon	Blows 6”	Sample #
	GM		1
	GM		2
	GM		3
	SPT	30, 60 & 93	4
	GM		
	SPT	24, 40, 81 & 59	5
	SPT	35	6
	GM		
	GM		

Date drilled: Oct 3-4, 2002

Suncor Mine Co-ordinates (ft):
45508.54E 51895.53N

Description of Materials

Organic Material (Ho)

?

Till (Pgt)

Dark brown clay till with bituminous odour

Glacio-fluvial Sand and Gravel

Sand and gravel with clay in shoe - clay lens? (Pfsg)

40% gravel, 60% sand (Pfsg)

Rock, could not advance any further

End of hole

Drill Type: Nodwell Tracked Rig
Mode: Mud Rotary

Standpipe Installation Details

Bentonite chips to surface

Natural collapse sand pack

2” diameter schedule 40 PVC 10 slot screen with threaded top set between 57’ and 54’

University of Waterloo Earth Sciences

Joint Suncor-CWN Project: Fate & Mobility of Chemicals in Process-Affected Groundwater
Location: Suncor L86/17, Fee Lot 2

Logged by Françoise Gervais
Drilling Co.: Layne Christensen

Hole No.:
SP-02-FLT2-05

FIGURE E.5: Borehole log for SP-02-FLT2-05

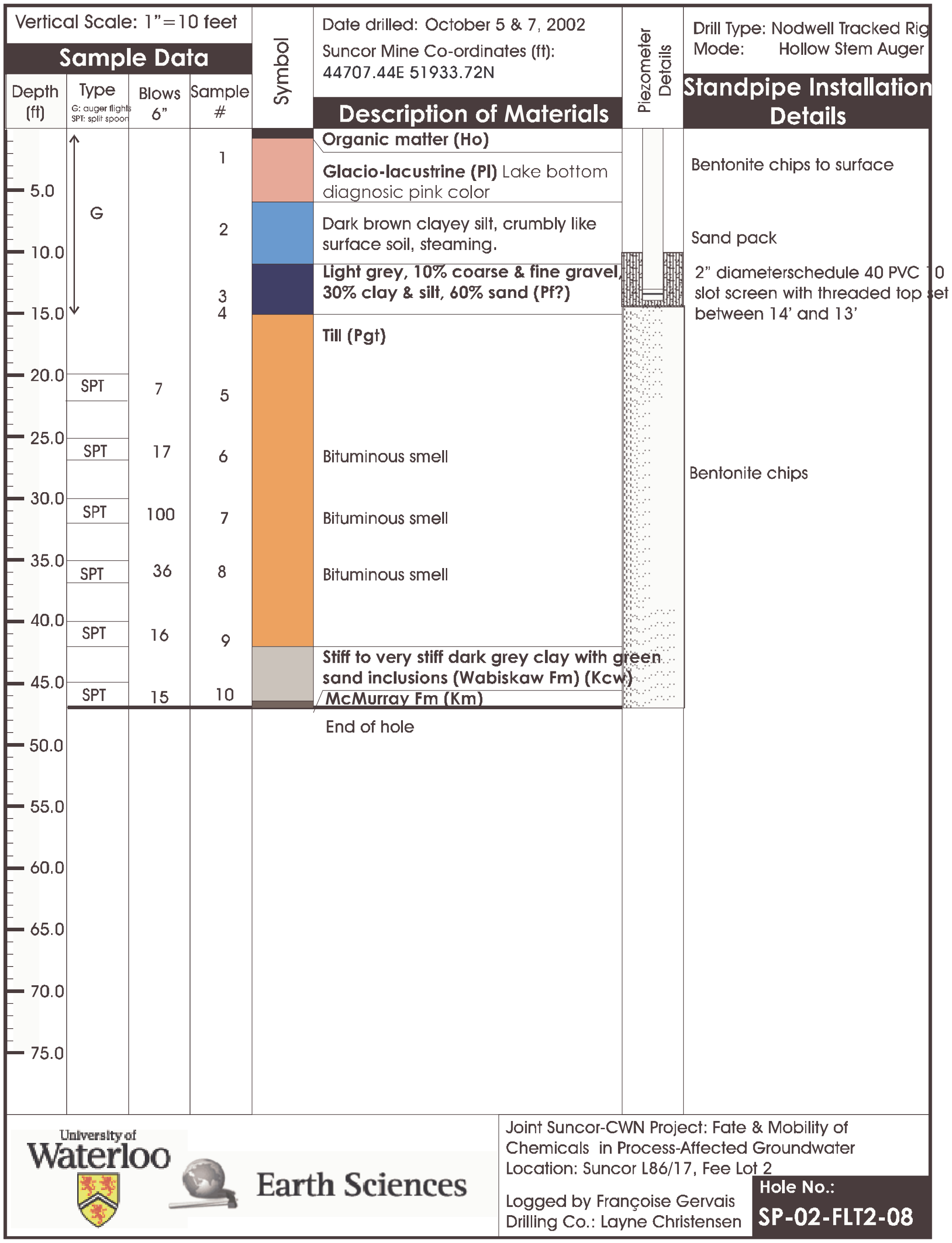
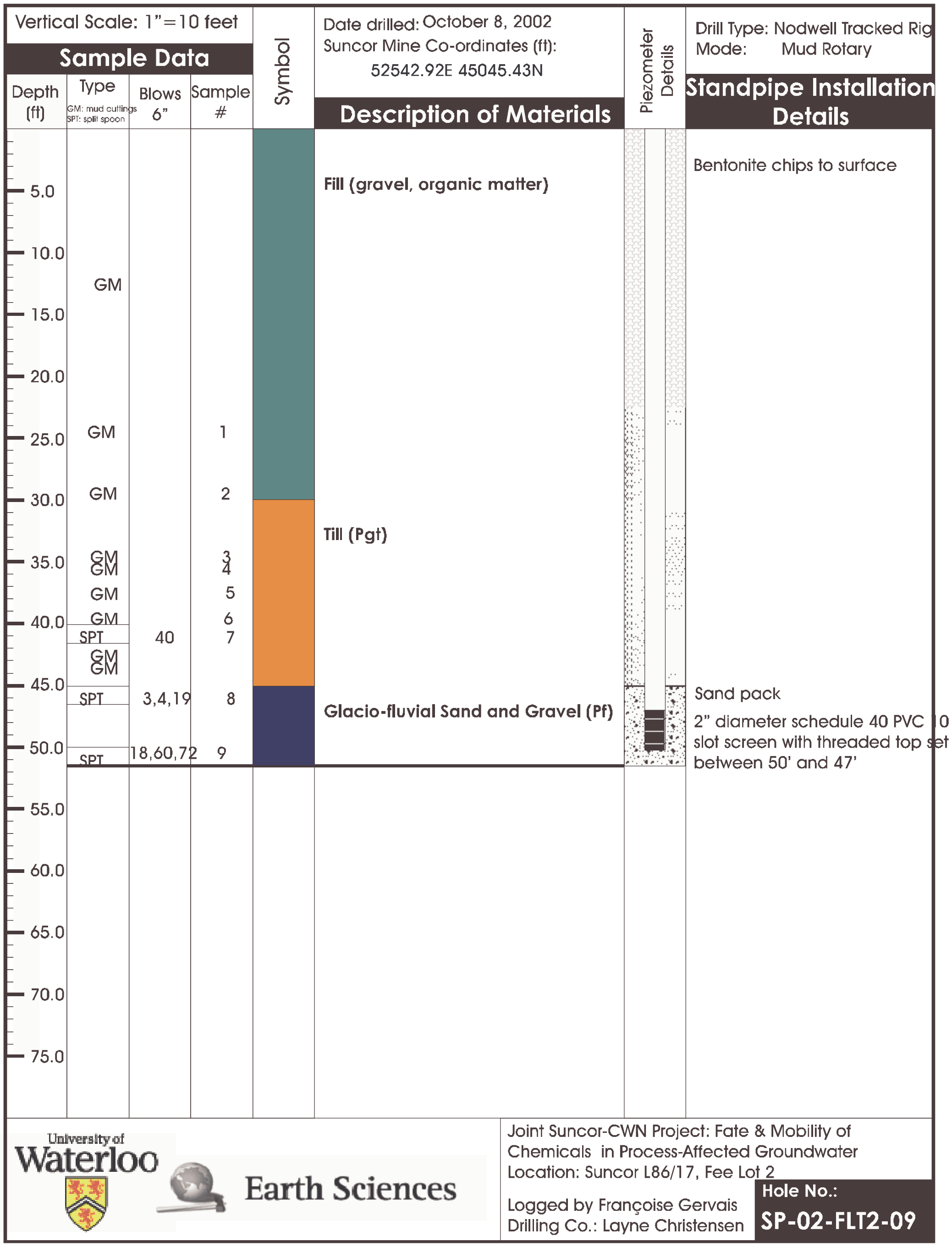


Figure E.6: Borehole log for SP-02-FLT2-08



Vertical Scale: 1"=10 feet

Date drilled: October 8, 2002
Suncor Mine Co-ordinates (ft):
52542.92E 45045.43N

Drill Type: Nodwell Tracked Rig
Mode: Mud Rotary

Description of Materials

Fill (gravel, organic matter)

Till (Pgt)

Glacio-fluvial Sand and Gravel (Pf)

Standpipe Installation Details

Bentonite chips to surface

Sand pack

2" diameter schedule 40 PVC 10 slot screen with threaded top set between 50' and 47'

Joint Suncor-CWN Project: Fate & Mobility of Chemicals in Process-Affected Groundwater
Location: Suncor L86/17, Fee Lot 2

Logged by Françoise Gervais
Drilling Co.: Layne Christensen

Hole No.: SP-02-FLT2-09

FIGURE E.7: Borehole log for SP-02-FLT2-09

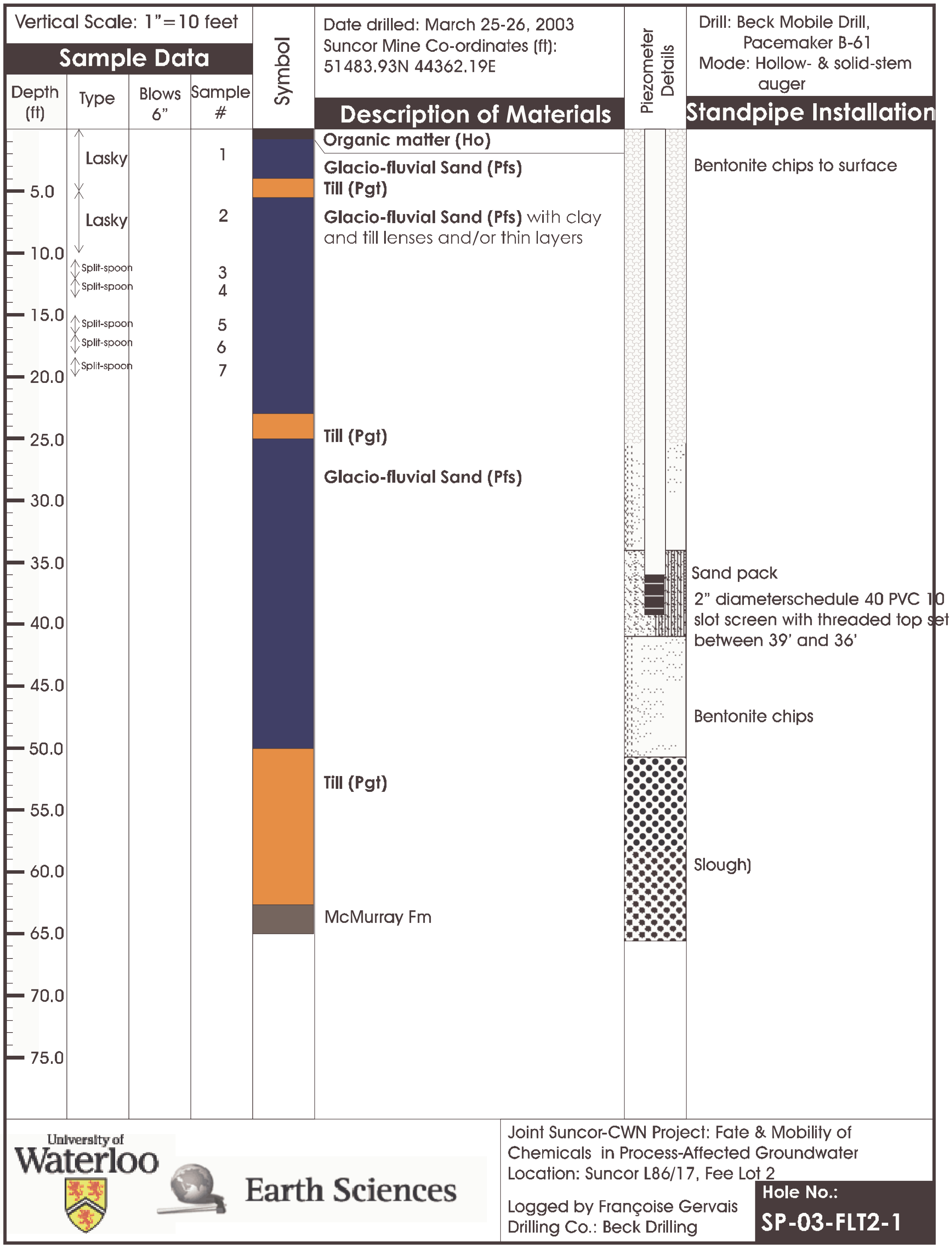
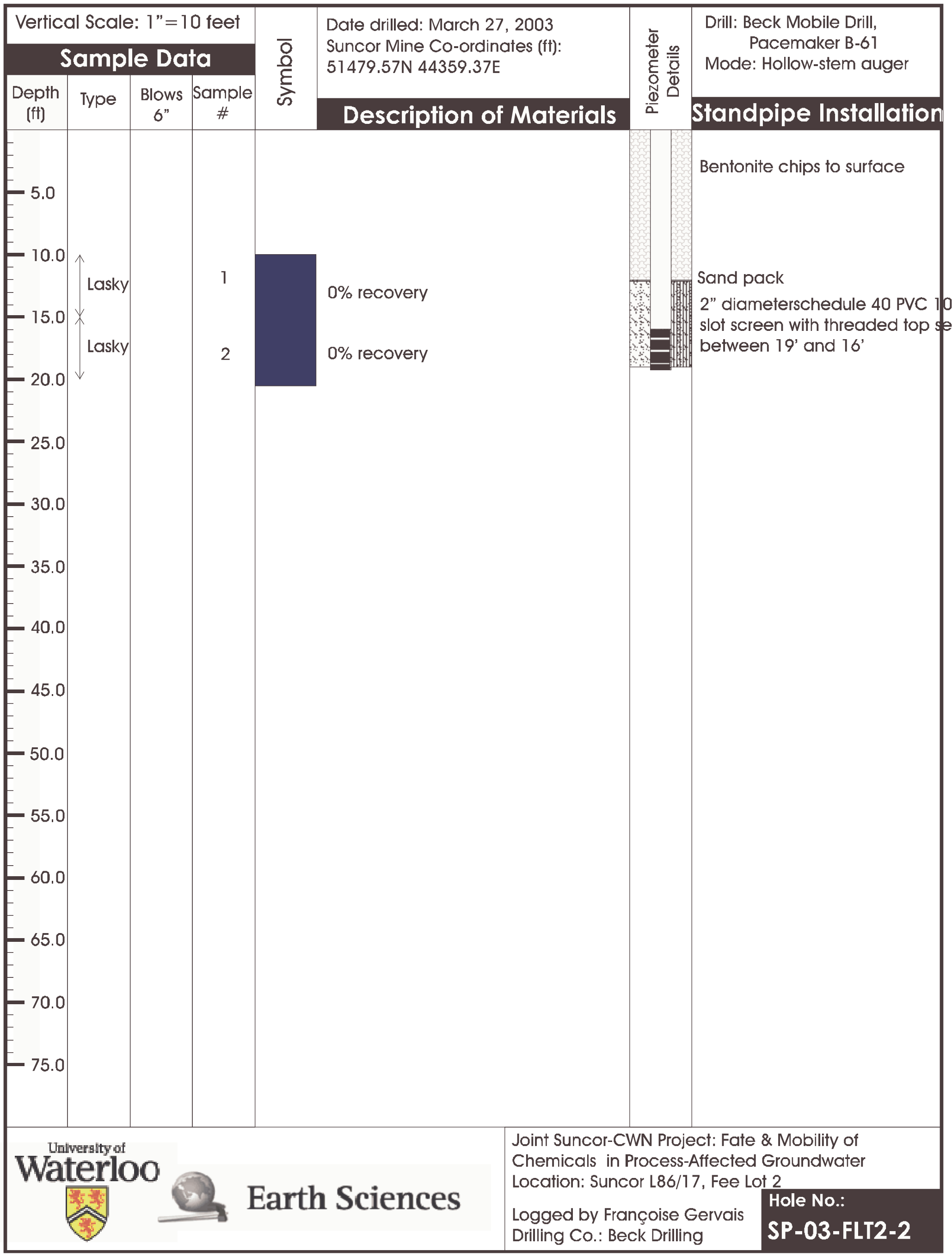


Figure E.8: Borehole log for SP-03-FLT2-01



Vertical Scale: 1”=10 feet

Date drilled: March 27, 2003
Suncor Mine Co-ordinates (ft):
51479.57N 44359.37E

Drill: Beck Mobile Drill,
Pacemaker B-61
Mode: Hollow-stem auger

Sample Data

Depth (ft)	Type	Blows 6”	Sample #	Description of Materials
10.0–15.0	Lasky		1	0% recovery
15.0–20.0	Lasky		2	0% recovery

Standpipe Installation

Bentonite chips to surface

Sand pack

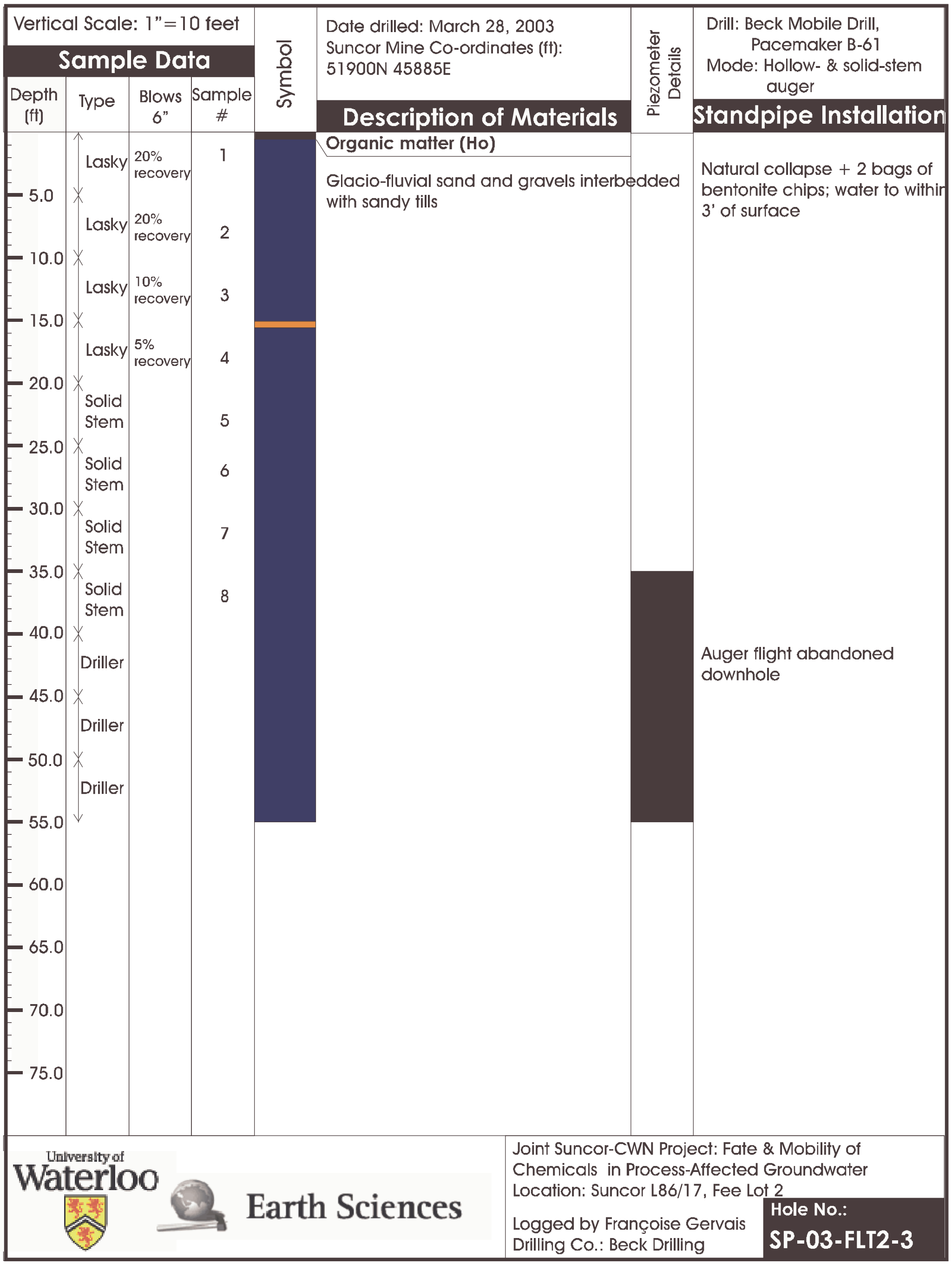
2” diameterschedule 40 PVC 10 slot screen with threaded top set between 19’ and 16’

Joint Suncor-CWN Project: Fate & Mobility of Chemicals in Process-Affected Groundwater
Location: Suncor L86/17, Fee Lot 2

Logged by Françoise Gervais
Drilling Co.: Beck Drilling

Hole No.: SP-03-FLT2-2

Figure E.9: Borehole log for SP-03-FLT2-02



Vertical Scale: 1"=10 feet

Sample Data

Depth (ft)	Type	Blows 6"	Sample #
	Lasky	20% recovery	1
5.0	Lasky	20% recovery	2
10.0	Lasky	10% recovery	3
15.0	Lasky	5% recovery	4
20.0	Solid Stem		5
25.0	Solid Stem		6
30.0	Solid Stem		7
35.0	Solid Stem		8
40.0	Driller		
45.0	Driller		
50.0	Driller		
55.0			
60.0			
65.0			
70.0			
75.0			

Symbol

Date drilled: March 28, 2003
Suncor Mine Co-ordinates (ft):
51900N 45885E

Description of Materials

Organic matter (Ho)

Glacio-fluvial sand and gravels interbedded with sandy tills

Piezometer Details

Drill: Beck Mobile Drill,
Pacemaker B-61
Mode: Hollow- & solid-stem auger

Standpipe Installation

Natural collapse + 2 bags of bentonite chips; water to within 3' of surface

Auger flight abandoned downhole

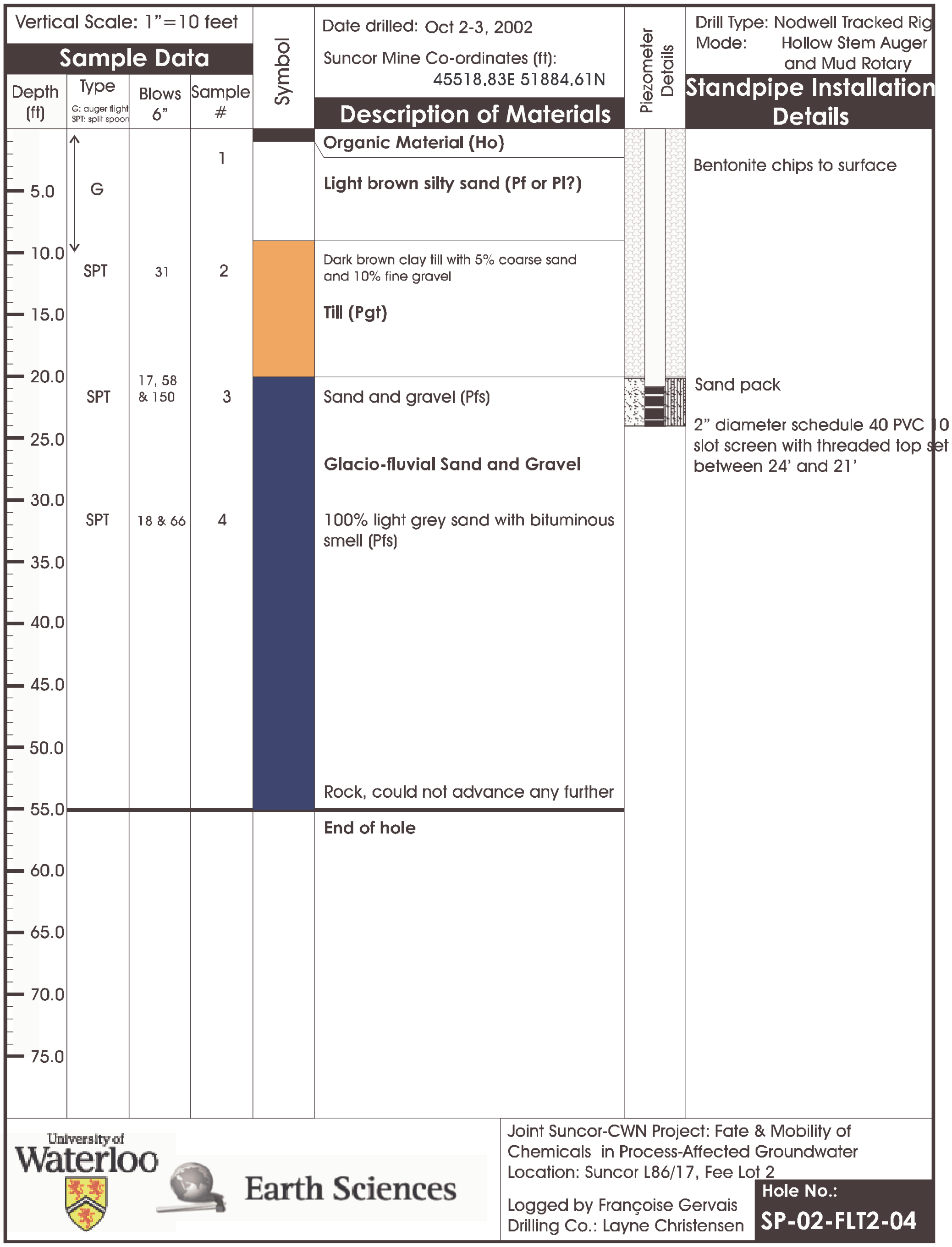
University of Waterloo
Earth Sciences

Joint Suncor-CWN Project: Fate & Mobility of Chemicals in Process-Affected Groundwater
Location: Suncor L86/17, Fee Lot 2

Logged by Françoise Gervais
Drilling Co.: Beck Drilling

Hole No.:
SP-03-FLT2-3

FIGURE E.10: Borehole log for SP-03-FLT2-03


Vertical Scale: 1"=10 feet

Sample Data

Depth (ft)	Type (G: auger flight, SPT: split spoon)	Blows 6"	Sample #
	G		1
10.0	SPT	31	2
20.0	SPT	17, 58 & 150	3
30.0	SPT	18 & 66	4

Date drilled: Oct 2-3, 2002
Suncor Mine Co-ordinates (ft): 45518.83E 51884.61N

Description of Materials

Organic Material (Ho)

Light brown silty sand (Pf or Pl?)

Dark brown clay till with 5% coarse sand and 10% fine gravel

Till (Pgt)

Sand and gravel (Pfs)

Glacio-fluvial Sand and Gravel

100% light grey sand with bituminous smell (Pfs)

Rock, could not advance any further

End of hole

Drill Type: Nodwell Tracked Rig
Mode: Hollow Stem Auger and Mud Rotary

Standpipe Installation Details

Bentonite chips to surface

Sand pack

2" diameter schedule 40 PVC 10 slot screen with threaded top set between 24' and 21'

Joint Suncor-CWN Project: Fate & Mobility of Chemicals in Process-Affected Groundwater
Location: Suncor L86/17, Fee Lot 2
Logged by Françoise Gervais
Drilling Co.: Layne Christensen

Hole No.: SP-02-FLT2-04

Figure E.11: Borehole log for SP-03-FLT2-04

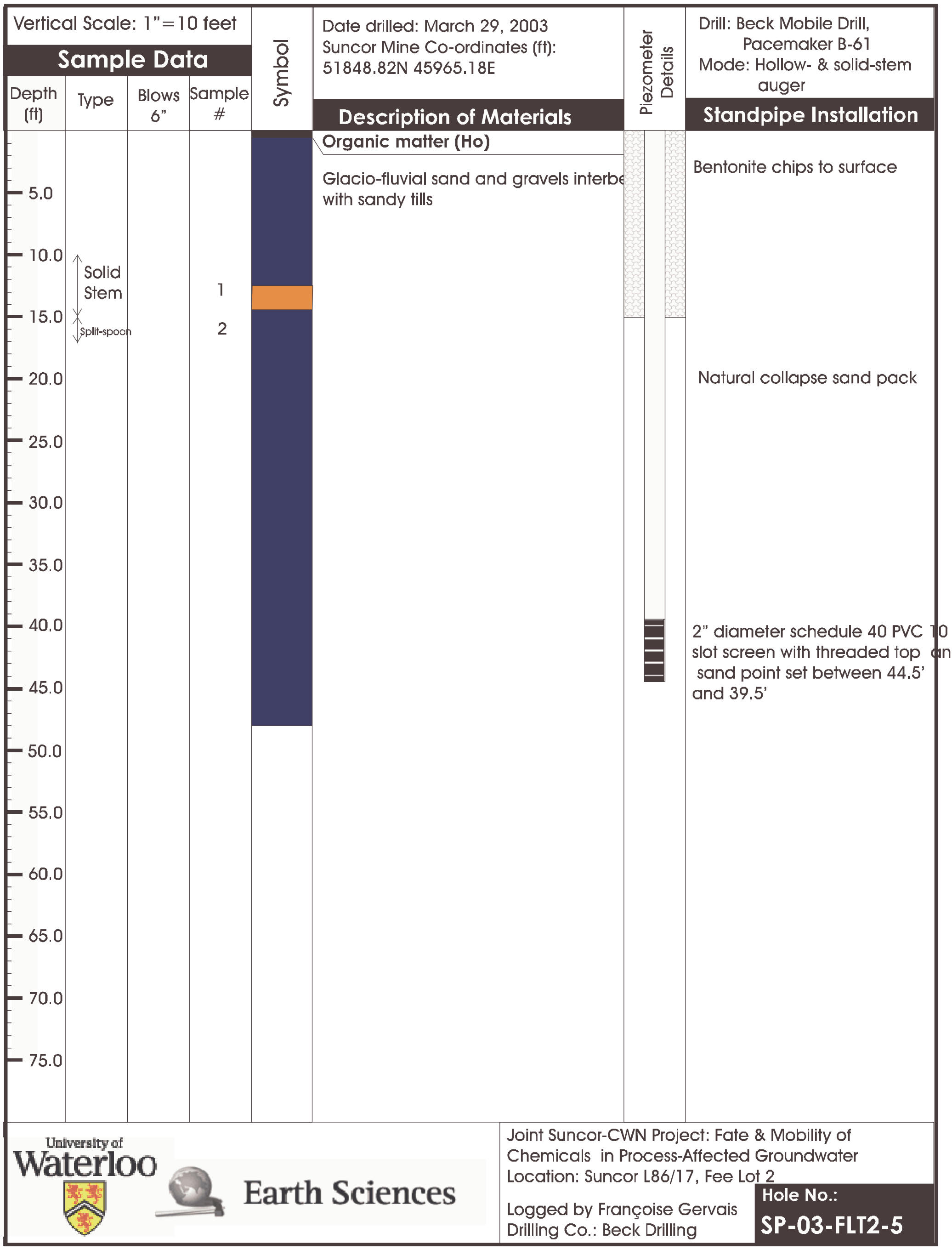
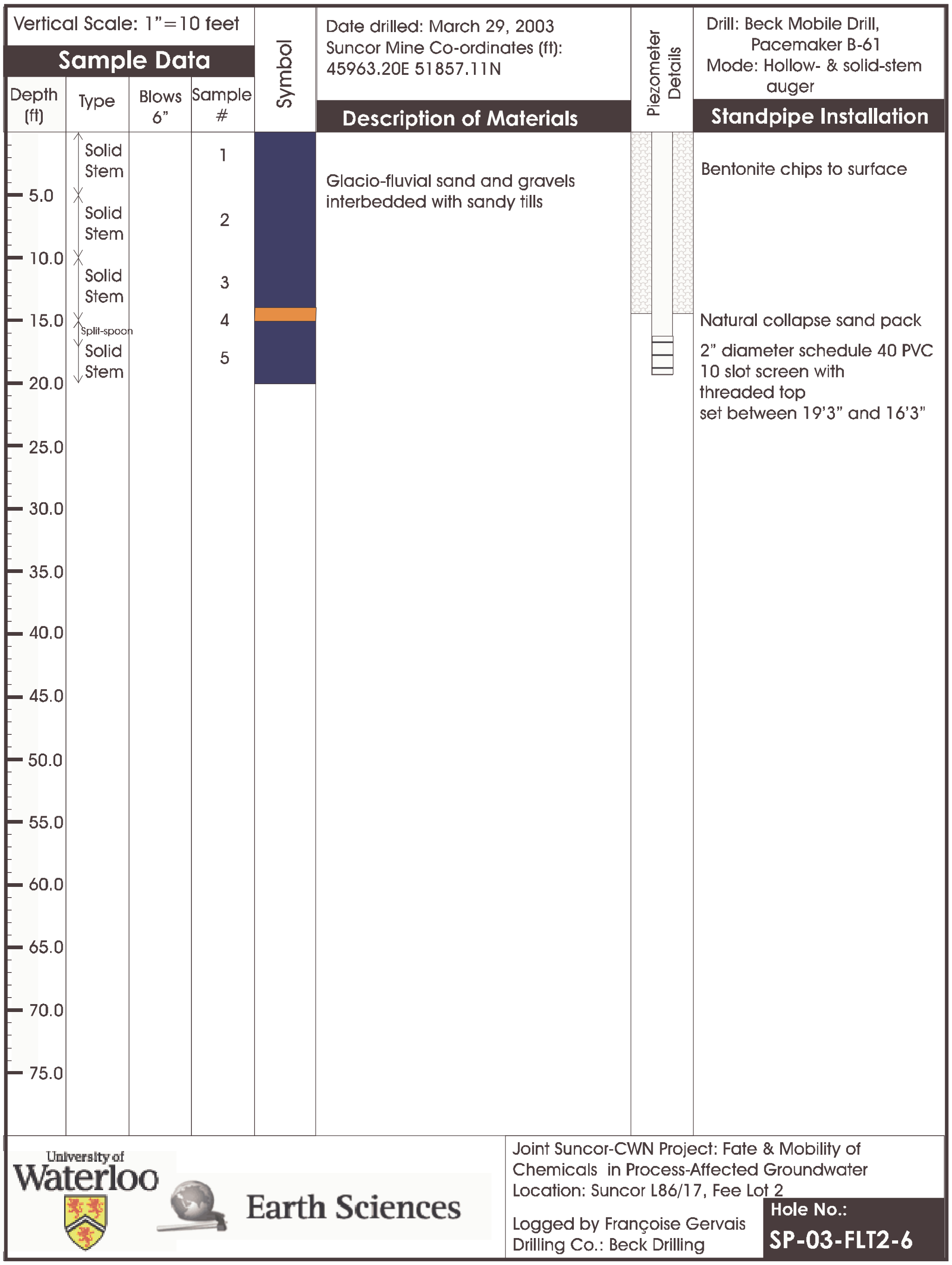


Figure E.12: Borehole log for SP-03-FLT2-05



Date drilled: March 29, 2003
Suncor Mine Co-ordinates (ft):
45963.20E 51857.11N

Drill: Beck Mobile Drill,
Pacemaker B-61
Mode: Hollow- & solid-stem auger

Glacio-fluvial sand and gravels interbedded with sandy tills

Bentonite chips to surface

Natural collapse sand pack

2" diameter schedule 40 PVC
10 slot screen with
threaded top
set between 19'3" and 16'3"

Joint Suncor-CWN Project: Fate & Mobility of Chemicals in Process-Affected Groundwater
Location: Suncor L86/17, Fee Lot 2

Logged by Françoise Gervais
Drilling Co.: Beck Drilling

Hole No.:
SP-03-FLT2-6

Figure E.13: Borehole log for SP-03-FLT2-06

Appendix F

Method for Laboratory Tests to Determine Hydraulic conductivity

F.1 Falling Head Permeameter

1. The day before
   - Dry the soil sample
   - Verify there is enough degassed water.
   - Find marker and wrench.
2. Weigh dry sample. Break up any clumps formed during the drying process.
3. Cut out and replace the filter paper for every new sample.
4. Homogenize sample and pour into graduated permeameter cylinder. Even out the top of the sample by gently tamping/shimmying the cylinder. A glacier deposited these samples. You cannot compact it more than a glacier, so don't be gentle.
5. Seal the system by tightening the top screw, then the three bottom screws.
6. Note the height of the sample.
7. Displace O2 in pores with CO2:

- Turn knob on top of tank to open airflow.
- Turn knob under meter to open airflow to the permeameter – slowly!
- Degas soil sample for 10 seconds.
- Look at soil sample. Any cracks? Any bubbling at the seam when you block airflow/

8. Make sure there is water in the tube up to the handle. Plug in the appropriate tube. Turn pump on.
9. Turn on the water knob with slow flow and fill the de-aired cylinder with water, SLOWLY, and continue to fill until the water level is in the tube and up to H1.
10. Stop water flow. If the water level decreases before you open the valve, there is a leak in the system. Look at the soil. Are there any cracks? Look at cylinder. Any leaks?
11. Set the stopwatch and time how long it takes to drain the water in the tube to the second black mark (H0). Record H0, H1 and the time, t, taken for the water level to fall between these two points.
12. Refill the tube and repeat steps 9 to 11 two more times.
13. Turn off the pump. Drain the cylinder completely before removing the sediment and thoroughly clean the apparatus.
14. If this is your last sample, bleed CO2 tank to relieve pressure.
15. Degas water if running low for next set of measurements.

F.2 Sieve Analysis

F.2.1 Materials

- Small hotplate or oven
- Accurate scale accurate to about one gram
- Containers for soil samples

- Weighing pan
- Instruments to homogenize soil sample and crush clods
- Appropriate set of standard testing sieves

F.2.2 Method

1. Homogenize sample. Weigh out approximately 100 g of soil into a container.
    - Samples were thoroughly shaken and mixed in the bag, and the soil sampled from at least three different areas in the bag.
2. Dry the soil sample in the oven overnight, at 120^oC. Crush any clods that form in order to separate all the particles. Verify dryness.
3. Choosing sieve sizes
    - Make an initial soil analysis visually, using the Wentworth scale.
    - Use this information to select 5 to 8 sieves with a series of openings that will separate the sample into various grain sizes. The coarsest sieve should not retain more than 20% of the sample.
    - If there are any large rocks, take them out, measure them and weigh them separately.
4. Verify that the required sieves are present. Stack the sieves with the finest one resting on the bottom pan and the coarsest at the top.
5. Weigh the dried sample, record this weight, and pour the sediment onto the top sieve.
6. Place the set of sieves into the mechanical shaker, make sure it is well secured and shake mechanically for at least 5 minutes.
    - Because the shaker in the BFG only shakes from side to side and not up and down, you need to mechanically shake for 2 minutes, take the sieves and manually shake it up and down, shake 2 minutes, manually shake up/down and then shake mechanically for 2 minutes.

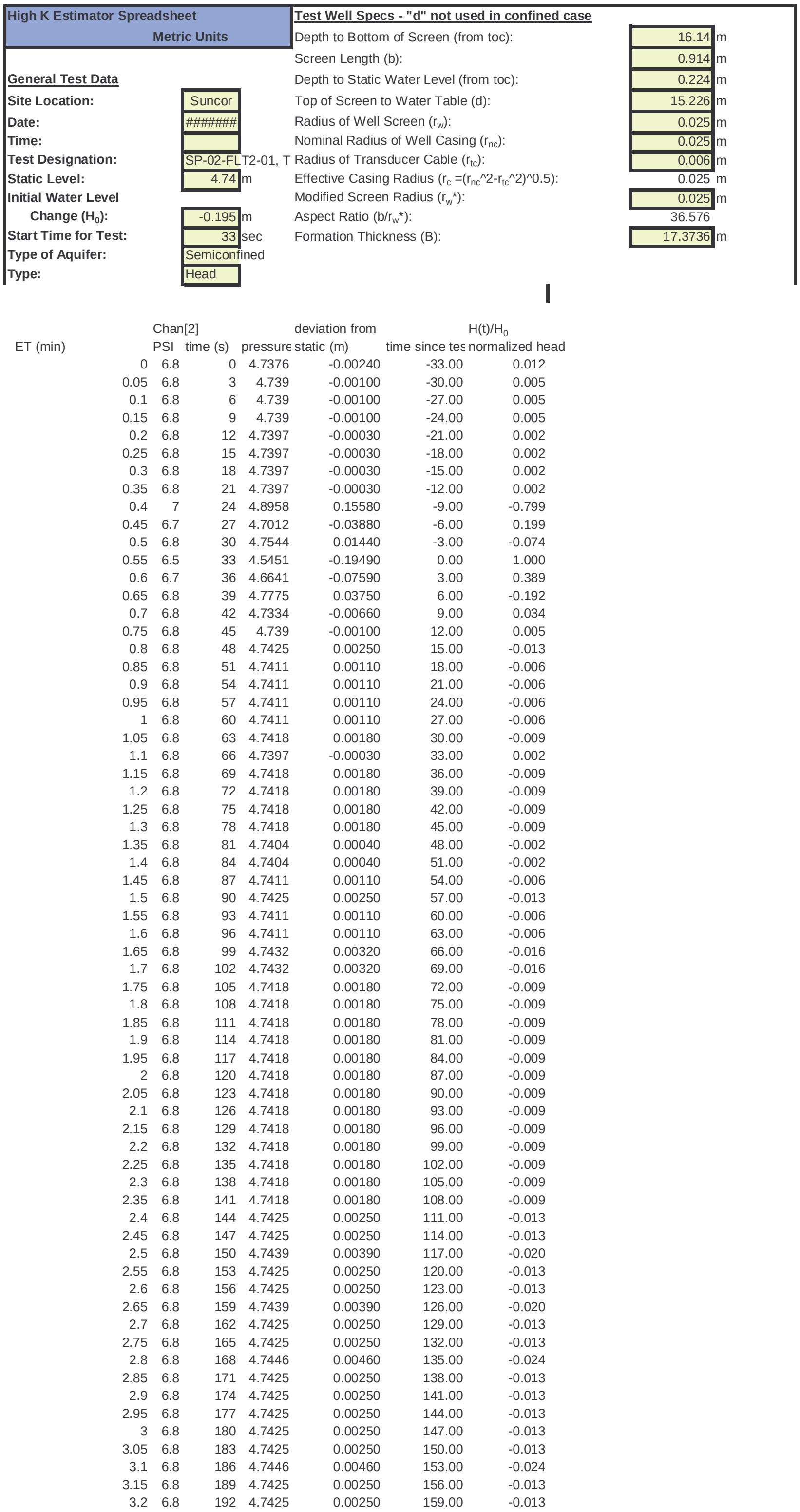
7. Empty the sample material retained on the top sieve into a pan or onto a large sheet of paper. Dislodge any particles caught in the sieve, but be careful to avoid damaging the wire mesh.
8. Tare the weighing pan on the balance. Transfer this material to the weighing pan and weigh it. Record this weight and the size of the sieve opening on which the material was retained.
9. Empty the sample material retained on the next sieve into a pan or onto a large sheet of paper. Dislodge any particles caught in the sieve, but be careful to avoid damaging the wire mesh.
10. Add the material to that already in the weighing pan on the balance. Record the combined weight and size of the sieve opening.
11. Empty each sieve successively and the record the weight of the accumulated sample in each case, as well as the sieve size.
12. Add the finest material from the bottom pan and weigh.
13. The accumulated weight should equal the weight of the original sample within two or three grams.

Appendix G

Single Well Response Tests Data

Well ID	Depth to Water	Stick-up	Depth of Logger	Calculated pressure head (m)	Test Type
SP02-FLT2-01	0.224	0.9	5	4.776	head
SP02-FLT2-02	0.31	1.04	5	4.69	head
SP02-FLT2-09 T1	3.39	0.61	5.4	2.01	slug
T2	3.39		6.4	3.01	
T3	3.39		5.4	2.01	
SP02-FLT2-04	2.285	1.115	5.29	3.005	slug
SP02-FLT2-05	2.167	1.09	5.29	3.123	slug
SP03-FLT2-06	0.815	0.67	3	2.185	head
SP03-FLT2-05	0.87	0.77	3	2.13	head
SP03-FLT2-04	0.845	0.67	3	2.155	head
SP03-FLT2-02	0.48	0.71	5	4.52	head
SP03-FLT2-01	1.29	0.81	5	3.71	head

ALL UNITS IN METERS



High K Estimator Spreadsheet
Metric Units

General Test Data

Site Location:	Suncor	
Date:	#######	
Time:		
Test Designation:	SP-02-FLT2-01, T	
Static Level:	4.74	m
Initial Water Level Change (H_0):	-0.195	m
Start Time for Test:	33	sec
Type of Aquifer:	Semiconfined	
Type:	Head	

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	16.14	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	0.224	m
Top of Screen to Water Table (d):	15.226	m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	17.3736	m

ET (min)	Chan[2] PSI	time (s)	pressure	deviation from static (m)	time since tes	$H(t)/H_0$ normalized head
0	6.8	0	4.7376	-0.00240	-33.00	0.012
0.05	6.8	3	4.739	-0.00100	-30.00	0.005
0.1	6.8	6	4.739	-0.00100	-27.00	0.005
0.15	6.8	9	4.739	-0.00100	-24.00	0.005
0.2	6.8	12	4.7397	-0.00030	-21.00	0.002
0.25	6.8	15	4.7397	-0.00030	-18.00	0.002
0.3	6.8	18	4.7397	-0.00030	-15.00	0.002
0.35	6.8	21	4.7397	-0.00030	-12.00	0.002
0.4	7	24	4.8958	0.15580	-9.00	-0.799
0.45	6.7	27	4.7012	-0.03880	-6.00	0.199
0.5	6.8	30	4.7544	0.01440	-3.00	-0.074
0.55	6.5	33	4.5451	-0.19490	0.00	1.000
0.6	6.7	36	4.6641	-0.07590	3.00	0.389
0.65	6.8	39	4.7775	0.03750	6.00	-0.192
0.7	6.8	42	4.7334	-0.00660	9.00	0.034
0.75	6.8	45	4.739	-0.00100	12.00	0.005
0.8	6.8	48	4.7425	0.00250	15.00	-0.013
0.85	6.8	51	4.7411	0.00110	18.00	-0.006
0.9	6.8	54	4.7411	0.00110	21.00	-0.006
0.95	6.8	57	4.7411	0.00110	24.00	-0.006
1	6.8	60	4.7411	0.00110	27.00	-0.006
1.05	6.8	63	4.7418	0.00180	30.00	-0.009
1.1	6.8	66	4.7397	-0.00030	33.00	0.002
1.15	6.8	69	4.7418	0.00180	36.00	-0.009
1.2	6.8	72	4.7418	0.00180	39.00	-0.009
1.25	6.8	75	4.7418	0.00180	42.00	-0.009
1.3	6.8	78	4.7418	0.00180	45.00	-0.009
1.35	6.8	81	4.7404	0.00040	48.00	-0.002
1.4	6.8	84	4.7404	0.00040	51.00	-0.002
1.45	6.8	87	4.7411	0.00110	54.00	-0.006
1.5	6.8	90	4.7425	0.00250	57.00	-0.013
1.55	6.8	93	4.7411	0.00110	60.00	-0.006
1.6	6.8	96	4.7411	0.00110	63.00	-0.006
1.65	6.8	99	4.7432	0.00320	66.00	-0.016
1.7	6.8	102	4.7432	0.00320	69.00	-0.016
1.75	6.8	105	4.7418	0.00180	72.00	-0.009
1.8	6.8	108	4.7418	0.00180	75.00	-0.009
1.85	6.8	111	4.7418	0.00180	78.00	-0.009
1.9	6.8	114	4.7418	0.00180	81.00	-0.009
1.95	6.8	117	4.7418	0.00180	84.00	-0.009
2	6.8	120	4.7418	0.00180	87.00	-0.009
2.05	6.8	123	4.7418	0.00180	90.00	-0.009
2.1	6.8	126	4.7418	0.00180	93.00	-0.009
2.15	6.8	129	4.7418	0.00180	96.00	-0.009
2.2	6.8	132	4.7418	0.00180	99.00	-0.009
2.25	6.8	135	4.7418	0.00180	102.00	-0.009
2.3	6.8	138	4.7418	0.00180	105.00	-0.009
2.35	6.8	141	4.7418	0.00180	108.00	-0.009
2.4	6.8	144	4.7425	0.00250	111.00	-0.013
2.45	6.8	147	4.7425	0.00250	114.00	-0.013
2.5	6.8	150	4.7439	0.00390	117.00	-0.020
2.55	6.8	153	4.7425	0.00250	120.00	-0.013
2.6	6.8	156	4.7425	0.00250	123.00	-0.013
2.65	6.8	159	4.7439	0.00390	126.00	-0.020
2.7	6.8	162	4.7425	0.00250	129.00	-0.013
2.75	6.8	165	4.7425	0.00250	132.00	-0.013
2.8	6.8	168	4.7446	0.00460	135.00	-0.024
2.85	6.8	171	4.7425	0.00250	138.00	-0.013
2.9	6.8	174	4.7425	0.00250	141.00	-0.013
2.95	6.8	177	4.7425	0.00250	144.00	-0.013
3	6.8	180	4.7425	0.00250	147.00	-0.013
3.05	6.8	183	4.7425	0.00250	150.00	-0.013
3.1	6.8	186	4.7446	0.00460	153.00	-0.024
3.15	6.8	189	4.7425	0.00250	156.00	-0.013
3.2	6.8	192	4.7425	0.00250	159.00	-0.013

Data for Test 1, SP-02-FLT2-01

High K Estimator Spreadsheet Metric Units			Test Well Specs - "d" not used in confined case		
			Depth to Bottom of Screen (from toc):	16.14	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	0.224	m
Site Location:	Suncor		Top of Screen to Water Table (d):	15.226	m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP02-FLT2-01-TEST2		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	4.75	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level Change (H_0):	-0.478	m	Modified Screen Radius (r_w*):	0.025	m
			Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	30	sec	Formation Thickness (B):	17.3736	m
Type of Aquifer:	Unconfined				
Type:	Rising				

ET (min)	Celsius	PSI	time (s)	pressure head (m)	deviation from static (m)	time since tes	$H(t)/H_0$ normalized head
0	6.95	6.782	0	4.7474	0.00	-30.00	0.005
0.05	6.95	6.782	3	4.7474	0.00	-27.00	0.005
0.1	6.95	6.782	6	4.7474	0.00	-24.00	0.005
0.15	6.97	6.782	9	4.7474	0.00	-21.00	0.005
0.2	6.97	6.784	12	4.7488	0.00	-18.00	0.003
0.25	6.97	6.784	15	4.7488	0.00	-15.00	0.003
0.3	6.97	6.784	18	4.7488	0.00	-12.00	0.003
0.35	6.97	6.756	21	4.7292	-0.02	-9.00	0.044
0.4	6.97	6.721	24	4.7047	-0.05	-6.00	0.095
0.45	6.97	6.774	27	4.7418	-0.01	-3.00	0.017
0.5	6.97	6.103	30	4.2721	-0.48	0.00	1.000
0.55	6.97	6.465	33	4.5255	-0.22	3.00	0.470
0.6	6.97	6.837	36	4.7859	0.04	6.00	-0.075
0.65	6.95	6.772	39	4.7404	-0.01	9.00	0.020
0.7	6.93	6.77	42	4.739	-0.01	12.00	0.023
0.75	6.92	6.783	45	4.7481	0.00	15.00	0.004
0.8	6.89	6.78	48	4.746	0.00	18.00	0.008
0.85	6.85	6.779	51	4.7453	0.00	21.00	0.010
0.9	6.83	6.779	54	4.7453	0.00	24.00	0.010
0.95	6.8	6.78	57	4.746	0.00	27.00	0.008
1	6.78	6.78	60	4.746	0.00	30.00	0.008
1.05	6.74	6.781	63	4.7467	0.00	33.00	0.007
1.1	6.72	6.778	66	4.7446	-0.01	36.00	0.011
1.15	6.7	6.779	69	4.7453	0.00	39.00	0.010
1.2	6.67	6.779	72	4.7453	0.00	42.00	0.010
1.25	6.66	6.78	75	4.746	0.00	45.00	0.008
1.3	6.64	6.78	78	4.746	0.00	48.00	0.008
1.35	6.62	6.78	81	4.746	0.00	51.00	0.008
1.4	6.6	6.781	84	4.7467	0.00	54.00	0.007
1.45	6.58	6.778	87	4.7446	-0.01	57.00	0.011
1.5	6.57	6.781	90	4.7467	0.00	60.00	0.007
1.55	6.56	6.781	93	4.7467	0.00	63.00	0.007
1.6	6.55	6.782	96	4.7474	0.00	66.00	0.005
1.65	6.53	6.779	99	4.7453	0.00	69.00	0.010
1.7	6.52	6.78	102	4.746	0.00	72.00	0.008
1.75	6.51	6.78	105	4.746	0.00	75.00	0.008
1.8	6.5	6.78	108	4.746	0.00	78.00	0.008
1.85	6.48	6.78	111	4.746	0.00	81.00	0.008
1.9	6.47	6.783	114	4.7481	0.00	84.00	0.004
1.95	6.46	6.781	117	4.7467	0.00	87.00	0.007
2	6.46	6.781	120	4.7467	0.00	90.00	0.007
2.05	6.44	6.781	123	4.7467	0.00	93.00	0.007
2.1	6.44	6.781	126	4.7467	0.00	96.00	0.007
2.15	6.43	6.781	129	4.7467	0.00	99.00	0.007
2.2	6.42	6.781	132	4.7467	0.00	102.00	0.007
2.25	6.42	6.781	135	4.7467	0.00	105.00	0.007
2.3	6.41	6.782	138	4.7474	0.00	108.00	0.005
2.35	6.41	6.782	141	4.7474	0.00	111.00	0.005
2.4	6.39	6.782	144	4.7474	0.00	114.00	0.005
2.45	6.39	6.782	147	4.7474	0.00	117.00	0.005
2.5	6.39	6.782	150	4.7474	0.00	120.00	0.005
2.55	6.38	6.782	153	4.7474	0.00	123.00	0.005
2.6	6.38	6.782	156	4.7474	0.00	126.00	0.005
2.65	6.37	6.782	159	4.7474	0.00	129.00	0.005
2.7	6.37	6.782	162	4.7474	0.00	132.00	0.005
2.75	6.37	6.782	165	4.7474	0.00	135.00	0.005
2.8	6.35	6.783	168	4.7481	0.00	138.00	0.004

High K Estimator Spreadsheet			**Test Well Specs - "d" not used in confined case**		
Metric Units			Depth to Bottom of Screen (from toc):	16.14	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	0.224	m
Site Location:	Suncor		Top of Screen to Water Table (d):	15.226	m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP02-FLT2-01-TEST3		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	4.75	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level			Modified Screen Radius (r_w*):	0.025	m
Change (H_0):	-0.611	m	Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	6	sec	Formation Thickness (B):	17.3736	m
Type of Aquifer:	Semi-confined				
Type:	Head				

			Chan[1]	Chan[2]		pressure head	
ET (min)	Celsius	PSI	time (s)	(m)	deviation from		$H(t)/H_0$
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0	6.33	6.783	0	4.7481	0.00	-6.00	0.000
0.05	6.33	6.783	3	4.7481	0.00	-3.00	0.000
0.1	6.34	5.91	6	4.137	-0.61	0.00	1.000
0.15	6.34	6.659	9	4.6613	-0.09	3.00	0.142
0.2	6.34	6.836	12	4.7852	0.04	6.00	-0.061
0.25	6.34	6.773	15	4.7411	-0.01	9.00	0.011
0.3	6.33	6.778	18	4.7446	0.00	12.00	0.006
0.35	6.33	6.786	21	4.7502	0.00	15.00	-0.003
0.4	6.32	6.783	24	4.7481	0.00	18.00	0.000
0.45	6.32	6.783	27	4.7481	0.00	21.00	0.000
0.5	6.3	6.784	30	4.7488	0.00	24.00	-0.001
0.55	6.29	6.781	33	4.7467	0.00	27.00	0.002
0.6	6.29	6.781	36	4.7467	0.00	30.00	0.002
0.65	6.28	6.781	39	4.7467	0.00	33.00	0.002
0.7	6.28	6.784	42	4.7488	0.00	36.00	-0.001
0.75	6.27	6.782	45	4.7474	0.00	39.00	0.001
0.8	6.27	6.782	48	4.7474	0.00	42.00	0.001
0.85	6.25	6.782	51	4.7474	0.00	45.00	0.001
0.9	6.25	6.784	54	4.7488	0.00	48.00	-0.001
0.95	6.24	6.782	57	4.7474	0.00	51.00	0.001
1	6.24	6.785	60	4.7495	0.00	54.00	-0.002
1.05	6.24	6.785	63	4.7495	0.00	57.00	-0.002
1.1	6.23	6.785	66	4.7495	0.00	60.00	-0.002
1.15	6.23	6.785	69	4.7495	0.00	63.00	-0.002
1.2	6.23	6.782	72	4.7474	0.00	66.00	0.001
1.25	6.21	6.783	75	4.7481	0.00	69.00	0.000
1.3	6.21	6.783	78	4.7481	0.00	72.00	0.000
1.35	6.21	6.783	81	4.7481	0.00	75.00	0.000
1.4	6.21	6.783	84	4.7481	0.00	78.00	0.000
1.45	6.2	6.785	87	4.7495	0.00	81.00	-0.002
1.5	6.2	6.783	90	4.7481	0.00	84.00	0.000
1.55	6.2	6.783	93	4.7481	0.00	87.00	0.000
1.6	6.2	6.785	96	4.7495	0.00	90.00	-0.002
1.65	6.19	6.783	99	4.7481	0.00	93.00	0.000
1.7	6.19	6.783	102	4.7481	0.00	96.00	0.000
1.75	6.19	6.783	105	4.7481	0.00	99.00	0.000
1.8	6.19	6.783	108	4.7481	0.00	102.00	0.000
1.85	6.19	6.783	111	4.7481	0.00	105.00	0.000
1.9	6.19	6.783	114	4.7481	0.00	108.00	0.000
1.95	6.19	6.786	117	4.7502	0.00	111.00	-0.003
2	6.19	6.783	120	4.7481	0.00	114.00	0.000
2.05	6.18	6.783	123	4.7481	0.00	117.00	0.000
2.1	6.18	6.783	126	4.7481	0.00	120.00	0.000
2.15	6.18	6.783	129	4.7481	0.00	123.00	0.000
2.2	6.18	6.783	132	4.7481	0.00	126.00	0.000
2.25	6.18	6.783	135	4.7481	0.00	129.00	0.000
2.3	6.18	6.783	138	4.7481	0.00	132.00	0.000
2.35	6.18	6.783	141	4.7481	0.00	135.00	0.000
2.4	6.18	6.783	144	4.7481	0.00	138.00	0.000
2.45	6.18	6.783	147	4.7481	0.00	141.00	0.000
2.5	6.18	6.786	150	4.7502	0.00	144.00	-0.003
2.55	6.18	6.783	153	4.7481	0.00	147.00	0.000
2.6	6.18	6.783	156	4.7481	0.00	150.00	0.000
2.65	6.18	6.783	159	4.7481	0.00	153.00	0.000
2.7	6.18	6.783	162	4.7481	0.00	156.00	0.000
2.75	6.16	6.784	165	4.7488	0.00	159.00	-0.001
2.8	6.18	6.783	168	4.7481	0.00	162.00	0.000

High K Estimator Spreadsheet		**Test Well Specs - "d" not used in confined case**		
Metric Units		Depth to Bottom of Screen (from toc):	14.35	m
		Screen Length (b):	0.914	m
General Test Data		Depth to Static Water Level (from toc):	0.31	m
Site Location:	Suncor	Top of Screen to Water Table (d):		m
Date:	10/14/2003	Radius of Well Screen (r_w):	0.025	m
Time:		Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP02-FLT2-02:TEST1	Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	4.75 m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level Change (H_0):	-0.493 m	Modified Screen Radius (r_w*):	0.025	m
		Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	10 sec	Formation Thickness (B):	17.374	m
Type of Aquifer:	Confined			
Type:	Head			

			Chan[1]	Chan[2]		pressure head	
ET (min)	Celsius	PSI	time (s)	(m)	deviation from		$H(t)/H_0$
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0	6.51	6.777	0	4.7439	-0.01	-10.00	0.012
0.0167	6.53	6.782	1.002	4.7474	0.00	-9.00	0.005
0.0333	6.55	6.858	1.998	4.8006	0.05	-8.00	-0.103
0.05	6.55	6.969	3	4.8783	0.13	-7.00	-0.260
0.0667	6.56	6.835	4.002	4.7845	0.03	-6.00	-0.070
0.0833	6.57	6.801	4.998	4.7607	0.01	-5.00	-0.022
0.1	6.57	6.807	6	4.7649	0.01	-4.00	-0.030
0.1167	6.58	6.806	7.002	4.7642	0.01	-3.00	-0.029
0.1333	6.58	6.804	7.998	4.7628	0.01	-2.00	-0.026
0.15	6.6	6.373	9	4.4611	-0.29	-1.00	0.586
0.1667	6.6	6.107	10.002	4.2749	-0.48	0.00	0.964
0.1833	6.61	6.246	10.998	4.3722	-0.38	1.00	0.766
0.2	6.62	6.353	12	4.4471	-0.30	2.00	0.614
0.2167	6.62	6.436	13.002	4.5052	-0.24	3.00	0.497
0.2333	6.64	6.502	13.998	4.5514	-0.20	4.00	0.403
0.25	6.64	6.555	15	4.5885	-0.16	5.00	0.328
0.2667	6.65	6.595	16.002	4.6165	-0.13	6.00	0.271
0.2833	6.65	6.628	16.998	4.6396	-0.11	7.00	0.224
0.3	6.66	6.656	18	4.6592	-0.09	8.00	0.184
0.3167	6.66	6.678	19.002	4.6746	-0.08	9.00	0.153
0.3333	6.67	6.696	19.998	4.6872	-0.06	10.00	0.127
0.35	6.67	6.711	21	4.6977	-0.05	11.00	0.106
0.3667	6.69	6.721	22.002	4.7047	-0.05	12.00	0.092
0.3833	6.69	6.731	22.998	4.7117	-0.04	13.00	0.078
0.4	6.7	6.738	24	4.7166	-0.03	14.00	0.068
0.4167	6.7	6.743	25.002	4.7201	-0.03	15.00	0.061
0.4333	6.71	6.751	25.998	4.7257	-0.02	16.00	0.049
0.45	6.71	6.753	27	4.7271	-0.02	17.00	0.046
0.4667	6.71	6.756	28.002	4.7292	-0.02	18.00	0.042
0.4833	6.72	6.761	28.998	4.7327	-0.02	19.00	0.035
0.5	6.72	6.763	30	4.7341	-0.02	20.00	0.032
0.5167	6.72	6.766	31.002	4.7362	-0.01	21.00	0.028
0.5333	6.72	6.766	31.998	4.7362	-0.01	22.00	0.028
0.55	6.74	6.768	33	4.7376	-0.01	23.00	0.025
0.5667	6.74	6.771	34.002	4.7397	-0.01	24.00	0.021
0.5833	6.74	6.771	34.998	4.7397	-0.01	25.00	0.021
0.6	6.75	6.77	36	4.739	-0.01	26.00	0.022
0.6167	6.75	6.773	37.002	4.7411	-0.01	27.00	0.018
0.6333	6.75	6.773	37.998	4.7411	-0.01	28.00	0.018
0.65	6.76	6.773	39	4.7411	-0.01	29.00	0.018
0.6667	6.76	6.773	40.002	4.7411	-0.01	30.00	0.018
0.6833	6.76	6.773	40.998	4.7411	-0.01	31.00	0.018
0.7	6.76	6.775	42	4.7425	-0.01	32.00	0.015
0.7167	6.78	6.775	43.002	4.7425	-0.01	33.00	0.015
0.7333	6.78	6.775	43.998	4.7425	-0.01	34.00	0.015
0.75	6.78	6.775	45	4.7425	-0.01	35.00	0.015
0.7667	6.78	6.775	46.002	4.7425	-0.01	36.00	0.015
0.7833	6.78	6.775	46.998	4.7425	-0.01	37.00	0.015
0.8	6.78	6.778	48	4.7446	-0.01	38.00	0.011
0.8167	6.79	6.777	49.002	4.7439	-0.01	39.00	0.012
0.8333	6.79	6.777	49.998	4.7439	-0.01	40.00	0.012
0.85	6.79	6.777	51	4.7439	-0.01	41.00	0.012
0.8667	6.79	6.777	52.002	4.7439	-0.01	42.00	0.012
0.8833	6.79	6.777	52.998	4.7439	-0.01	43.00	0.012
0.9	6.8	6.777	54	4.7439	-0.01	44.00	0.012
0.9167	6.8	6.777	55.002	4.7439	-0.01	45.00	0.012
0.9333	6.8	6.777	55.998	4.7439	-0.01	46.00	0.012

High K Estimator Spreadsheet			**Test Well Specs - "d" not used in confined case**		
Metric Units			Depth to Bottom of Screen (from toc):	14.35	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	0.31	m
Site Location:	Suncor		Top of Screen to Water Table (d):		m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP02-FLT2-02: TEST2		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	4.74	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level			Modified Screen Radius (r_w*):	0.025	m
Change (H_0):	-0.987	m	Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	27	sec	Formation Thickness (B):	17.374	m
Type of Aquifer:	Confined				
Type:	Rising				

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	H(t)/H_0 normalized head
0	6.87	6.773	0	4.7411	0.00	-27.00	0.002
0.0167	6.87	6.776	1.002	4.7432	0.00	-26.00	0.000
0.0333	6.87	6.776	1.998	4.7432	0.00	-25.00	0.000
0.05	6.87	6.776	3	4.7432	0.00	-24.00	0.000
0.0667	6.88	6.776	4.002	4.7432	0.00	-23.00	0.000
0.0833	6.88	6.887	4.998	4.8209	0.08	-22.00	-0.079
0.1	6.88	6.882	6	4.8174	0.07	-21.00	-0.075
0.1167	6.88	6.945	7.002	4.8615	0.12	-20.00	-0.120
0.1333	6.88	7.095	7.998	4.9665	0.22	-19.00	-0.226
0.15	6.88	6.841	9	4.7887	0.05	-18.00	-0.046
0.1667	6.88	6.735	10.002	4.7145	-0.03	-17.00	0.029
0.1833	6.88	6.697	10.998	4.6879	-0.06	-16.00	0.056
0.2	6.88	6.895	12	4.8265	0.08	-15.00	-0.085
0.2167	6.88	6.786	13.002	4.7502	0.01	-14.00	-0.007
0.2333	6.88	6.796	13.998	4.7572	0.01	-13.00	-0.014
0.25	6.88	6.725	15	4.7075	-0.04	-12.00	0.036
0.2667	6.88	6.748	16.002	4.7236	-0.02	-11.00	0.020
0.2833	6.88	6.755	16.998	4.7285	-0.01	-10.00	0.015
0.3	6.88	6.766	18	4.7362	-0.01	-9.00	0.007
0.3167	6.88	6.771	19.002	4.7397	0.00	-8.00	0.003
0.3333	6.88	6.771	19.998	4.7397	0.00	-7.00	0.003
0.35	6.88	6.776	21	4.7432	0.00	-6.00	0.000
0.3667	6.88	6.776	22.002	4.7432	0.00	-5.00	0.000
0.3833	6.89	6.778	22.998	4.7446	0.00	-4.00	-0.002
0.4	6.89	6.778	24	4.7446	0.00	-3.00	-0.002
0.4167	6.89	6.011	25.002	4.2077	-0.54	-2.00	0.542
0.4333	6.89	5.538	25.998	3.8766	-0.87	-1.00	0.878
0.45	6.89	5.447	27	3.8129	-0.93	0.00	0.942
0.4667	6.89	5.685	28.002	3.9795	-0.76	1.00	0.774
0.4833	6.89	5.869	28.998	4.1083	-0.63	2.00	0.643
0.5	6.89	6.019	30	4.2133	-0.53	3.00	0.537
0.5167	6.89	6.143	31.002	4.3001	-0.44	4.00	0.449
0.5333	6.89	6.244	31.998	4.3708	-0.37	5.00	0.377
0.55	6.89	6.33	33	4.431	-0.31	6.00	0.316
0.5667	6.89	6.401	34.002	4.4807	-0.26	7.00	0.266
0.5833	6.89	6.462	34.998	4.5234	-0.22	8.00	0.222
0.6	6.89	6.51	36	4.557	-0.19	9.00	0.188
0.6167	6.88	6.55	37.002	4.585	-0.16	10.00	0.160
0.6333	6.88	6.586	37.998	4.6102	-0.13	11.00	0.135
0.65	6.88	6.614	39	4.6298	-0.11	12.00	0.115
0.6667	6.87	6.637	40.002	4.6459	-0.10	13.00	0.098
0.6833	6.87	6.659	40.998	4.6613	-0.08	14.00	0.083
0.7	6.85	6.675	42	4.6725	-0.07	15.00	0.071
0.7167	6.85	6.688	43.002	4.6816	-0.06	16.00	0.062
0.7333	6.84	6.7	43.998	4.69	-0.05	17.00	0.054
0.75	6.84	6.708	45	4.6956	-0.05	18.00	0.048
0.7667	6.83	6.718	46.002	4.7026	-0.04	19.00	0.041
0.7833	6.81	6.724	46.998	4.7068	-0.04	20.00	0.037
0.8	6.81	6.731	48	4.7117	-0.03	21.00	0.032
0.8167	6.8	6.737	49.002	4.7159	-0.03	22.00	0.027
0.8333	6.79	6.739	49.998	4.7173	-0.03	23.00	0.026
0.85	6.79	6.744	51	4.7208	-0.02	24.00	0.022
0.8667	6.78	6.747	52.002	4.7229	-0.02	25.00	0.020
0.8833	6.76	6.75	52.998	4.725	-0.02	26.00	0.018
0.9	6.76	6.752	54	4.7264	-0.02	27.00	0.017
0.9167	6.75	6.753	55.002	4.7271	-0.02	28.00	0.016
0.9333	6.74	6.755	55.998	4.7285	-0.01	29.00	0.015

High K Estimator Spreadsheet

Metric Units

General Test Data

Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP02-FLT2-02: TEST3	
Static Level:	4.75	m
Initial Water Level Change (H_0):	-0.493	m
Start Time for Test:	21	sec
Type of Aquifer:	Confined	
Type:	Head	

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	14.35	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	0.31	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	17.374	m

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	H(t)/H_0 normalized head
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0	6.19	6.775	0	4.7425	0.00	-21.00	0.005
0.0167	6.2	6.778	1.002	4.7446	0.00	-20.00	0.001
0.0333	6.2	6.778	1.998	4.7446	0.00	-19.00	0.001
0.05	6.2	6.778	3	4.7446	0.00	-18.00	0.001
0.0667	6.2	6.884	4.002	4.8188	0.07	-17.00	-0.150
0.0833	6.2	6.849	4.998	4.7943	0.05	-16.00	-0.100
0.1	6.2	6.833	6	4.7831	0.04	-15.00	-0.077
0.1167	6.2	6.811	7.002	4.7677	0.02	-14.00	-0.046
0.1333	6.2	6.811	7.998	4.7677	0.02	-13.00	-0.046
0.15	6.2	6.808	9	4.7656	0.02	-12.00	-0.042
0.1667	6.2	6.803	10.002	4.7621	0.02	-11.00	-0.035
0.1833	6.21	6.795	10.998	4.7565	0.01	-10.00	-0.023
0.2	6.2	6.783	12	4.7481	0.00	-9.00	-0.006
0.2167	6.21	6.785	13.002	4.7495	0.00	-8.00	-0.009
0.2333	6.2	6.788	13.998	4.7516	0.01	-7.00	-0.013
0.25	6.21	6.788	15	4.7516	0.01	-6.00	-0.013
0.2667	6.21	6.788	16.002	4.7516	0.01	-5.00	-0.013
0.2833	6.2	6.788	16.998	4.7516	0.01	-4.00	-0.013
0.3	6.21	6.783	18	4.7481	0.00	-3.00	-0.006
0.3167	6.21	6.783	19.002	4.7481	0.00	-2.00	-0.006
0.3333	6.21	6.56	19.998	4.592	-0.15	-1.00	0.310
0.35	6.21	6.087	21	4.2609	-0.48	0.00	0.982
0.3667	6.21	6.221	22.002	4.3547	-0.39	1.00	0.792
0.3833	6.21	6.33	22.998	4.431	-0.31	2.00	0.637
0.4	6.21	6.413	24	4.4891	-0.26	3.00	0.519
0.4167	6.21	6.479	25.002	4.5353	-0.21	4.00	0.425
0.4333	6.21	6.532	25.998	4.5724	-0.17	5.00	0.350
0.45	6.21	6.578	27	4.6046	-0.14	6.00	0.285
0.4667	6.21	6.61	28.002	4.627	-0.12	7.00	0.239
0.4833	6.21	6.641	28.998	4.6487	-0.10	8.00	0.195
0.5	6.21	6.664	30	4.6648	-0.08	9.00	0.163
0.5167	6.21	6.684	31.002	4.6788	-0.07	10.00	0.134
0.5333	6.21	6.699	31.998	4.6893	-0.06	11.00	0.113
0.55	6.21	6.712	33	4.6984	-0.05	12.00	0.095
0.5667	6.21	6.722	34.002	4.7054	-0.04	13.00	0.080
0.5833	6.21	6.729	34.998	4.7103	-0.03	14.00	0.070
0.6	6.2	6.737	36	4.7159	-0.03	15.00	0.059
0.6167	6.2	6.742	37.002	4.7194	-0.03	16.00	0.052
0.6333	6.2	6.747	37.998	4.7229	-0.02	17.00	0.045
0.65	6.2	6.752	39	4.7264	-0.02	18.00	0.038
0.6667	6.2	6.755	40.002	4.7285	-0.02	19.00	0.033
0.6833	6.2	6.758	40.998	4.7306	-0.01	20.00	0.029
0.7	6.2	6.76	42	4.732	-0.01	21.00	0.026
0.7167	6.2	6.763	43.002	4.7341	-0.01	22.00	0.022
0.7333	6.19	6.763	43.998	4.7341	-0.01	23.00	0.022
0.75	6.19	6.765	45	4.7355	-0.01	24.00	0.019
0.7667	6.19	6.765	46.002	4.7355	-0.01	25.00	0.019
0.7833	6.19	6.768	46.998	4.7376	-0.01	26.00	0.015
0.8	6.19	6.768	48	4.7376	-0.01	27.00	0.015
0.8167	6.19	6.77	49.002	4.739	-0.01	28.00	0.012
0.8333	6.18	6.768	49.998	4.7376	-0.01	29.00	0.015
0.85	6.18	6.768	51	4.7376	-0.01	30.00	0.015
0.8667	6.18	6.771	52.002	4.7397	-0.01	31.00	0.011
0.8833	6.18	6.771	52.998	4.7397	-0.01	32.00	0.011
0.9	6.18	6.771	54	4.7397	-0.01	33.00	0.011
0.9167	6.18	6.771	55.002	4.7397	-0.01	34.00	0.011
0.9333	6.18	6.773	55.998	4.7411	0.00	35.00	0.008

High K Estimator Spreadsheet			**Test Well Specs - "d" not used in confined case**		
Metric Units			Depth to Bottom of Screen (from toc):	8.58	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	2.285	m
Site Location:	Suncor		Top of Screen to Water Table (d):		m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP02-FLT2-04TEST1		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	2.99	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level Change (H_0):	0.170	m	Modified Screen Radius (r_w*):	0.025	m
			Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	9	sec	Formation Thickness (B):	------>	m
Type of Aquifer:	Confined		did not go to McMurray, look at historical data		
Type:	Slug				

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	$H(t)/H_0$ normalized head
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0	1.71	-0.043	0	-0.0301	-3.02	-9.00	-17.765
0.0167	1.72	-0.043	1.002	-0.0301	-3.02	-8.00	-17.765
0.0333	1.74	-0.041	1.998	-0.0287	-3.02	-7.00	-17.757
0.05	1.74	-0.036	3	-0.0252	-3.02	-6.00	-17.736
0.0667	1.75	2.156	4.002	1.5092	-1.48	-5.00	-8.711
0.0833	1.76	2.589	4.998	1.8123	-1.18	-4.00	-6.928
0.1	1.79	3.634	6	2.5438	-0.45	-3.00	-2.625
0.1167	1.81	4.619	7.002	3.2333	0.24	-2.00	1.431
0.1333	1.84	4.418	7.998	3.0926	0.10	-1.00	0.604
0.15	1.88	4.514	9	3.1598	0.17	0.00	0.999
0.1667	1.92	4.48	10.002	3.136	0.15	1.00	0.859
0.1833	1.97	4.462	10.998	3.1234	0.13	2.00	0.785
0.2	2.03	4.445	12	3.1115	0.12	3.00	0.715
0.2167	2.1	4.429	13.002	3.1003	0.11	4.00	0.649
0.2333	2.17	4.415	13.998	3.0905	0.10	5.00	0.591
0.25	2.24	4.404	15	3.0828	0.09	6.00	0.546
0.2667	2.33	4.39	16.002	3.073	0.08	7.00	0.488
0.2833	2.4	4.383	16.998	3.0681	0.08	8.00	0.459
0.3	2.48	4.375	18	3.0625	0.07	9.00	0.426
0.3167	2.56	4.366	19.002	3.0562	0.07	10.00	0.389
0.3333	2.63	4.357	19.998	3.0499	0.06	11.00	0.352
0.35	2.71	4.35	21	3.045	0.05	12.00	0.324
0.3667	2.79	4.344	22.002	3.0408	0.05	13.00	0.299
0.3833	2.86	4.34	22.998	3.038	0.05	14.00	0.282
0.4	2.93	4.334	24	3.0338	0.04	15.00	0.258
0.4167	3	4.33	25.002	3.031	0.04	16.00	0.241
0.4333	3.07	4.324	25.998	3.0268	0.04	17.00	0.216
0.45	3.13	4.32	27	3.024	0.03	18.00	0.200
0.4667	3.21	4.319	28.002	3.0233	0.03	19.00	0.196
0.4833	3.26	4.316	28.998	3.0212	0.03	20.00	0.184
0.5	3.32	4.312	30	3.0184	0.03	21.00	0.167
0.5167	3.39	4.311	31.002	3.0177	0.03	22.00	0.163
0.5333	3.44	4.308	31.998	3.0156	0.03	23.00	0.151
0.55	3.49	4.307	33	3.0149	0.02	24.00	0.146
0.5667	3.55	4.306	34.002	3.0142	0.02	25.00	0.142
0.5833	3.61	4.302	34.998	3.0114	0.02	26.00	0.126
0.6	3.66	4.301	36	3.0107	0.02	27.00	0.122
0.6167	3.71	4.3	37.002	3.01	0.02	28.00	0.118
0.6333	3.75	4.3	37.998	3.01	0.02	29.00	0.118
0.65	3.8	4.296	39	3.0072	0.02	30.00	0.101
0.6667	3.84	4.296	40.002	3.0072	0.02	31.00	0.101
0.6833	3.89	4.295	40.998	3.0065	0.02	32.00	0.097
0.7	3.93	4.294	42	3.0058	0.02	33.00	0.093
0.7167	3.96	4.291	43.002	3.0037	0.01	34.00	0.081
0.7333	4.02	4.293	43.998	3.0051	0.02	35.00	0.089
0.75	4.05	4.292	45	3.0044	0.01	36.00	0.085
0.7667	4.09	4.289	46.002	3.0023	0.01	37.00	0.072
0.7833	4.12	4.288	46.998	3.0016	0.01	38.00	0.068
0.8	4.16	4.285	48	2.9995	0.01	39.00	0.056
0.8167	4.19	4.287	49.002	3.0009	0.01	40.00	0.064
0.8333	4.22	4.289	49.998	3.0023	0.01	41.00	0.072
0.85	4.26	4.291	51	3.0037	0.01	42.00	0.081
0.8667	4.3	4.29	52.002	3.003	0.01	43.00	0.076
0.8833	4.32	4.287	52.998	3.0009	0.01	44.00	0.064
0.9	4.36	4.287	54	3.0009	0.01	45.00	0.064
0.9167	4.39	4.289	55.002	3.0023	0.01	46.00	0.072
0.9333	4.41	4.288	55.998	3.0016	0.01	47.00	0.068

High K Estimator Spreadsheet

Metric Units

General Test Data		
Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP02-FLT2-04TEST2	
Static Level:	2.99	m
Initial Water Level Change (H_0):	0.325	m
Start Time for Test:	13	sec
Type of Aquifer:	Confined	
Type:	Slug	

Test Well Specs - "d" not used in confined case		
Depth to Bottom of Screen (from toc):	8.58	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	2.285	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	------>	m

			Chan[1]	Chan[2]		pressure head	
ET (min)	Celsius	PSI	time (s)	(m)	deviation from		$H(t)/H_0$
------------	---------------	---------------	------------	------------	static (m)	time since tes	normalized head
0	5.79	0.002	0	0.0014	-2.99	-13.00	-9.196
0.0167	5.79	0.002	1.002	0.0014	-2.99	-12.00	-9.196
0.0333	5.79	0.005	1.998	0.0035	-2.99	-11.00	-9.189
0.05	5.81	0.005	3	0.0035	-2.99	-10.00	-9.189
0.0667	5.81	0.005	4.002	0.0035	-2.99	-9.00	-9.189
0.0833	5.81	0.005	4.998	0.0035	-2.99	-8.00	-9.189
0.1	5.81	0	6	0	-2.99	-7.00	-9.200
0.1167	5.81	3.575	7.002	2.5025	-0.49	-6.00	-1.500
0.1333	5.82	4.271	7.998	2.9897	0.00	-5.00	-0.001
0.15	5.82	4.203	9	2.9421	-0.05	-4.00	-0.147
0.1667	5.83	4.762	10.002	3.3334	0.34	-3.00	1.057
0.1833	5.84	4.82	10.998	3.374	0.38	-2.00	1.182
0.2	5.86	4.696	12	3.2872	0.30	-1.00	0.914
0.2167	5.87	4.736	13.002	3.3152	0.33	0.00	1.001
0.2333	5.88	4.685	13.998	3.2795	0.29	1.00	0.891
0.25	5.89	4.647	15	3.2529	0.26	2.00	0.809
0.2667	5.91	4.614	16.002	3.2298	0.24	3.00	0.738
0.2833	5.92	4.586	16.998	3.2102	0.22	4.00	0.678
0.3	5.95	4.562	18	3.1934	0.20	5.00	0.626
0.3167	5.96	4.537	19.002	3.1759	0.19	6.00	0.572
0.3333	5.98	4.519	19.998	3.1633	0.17	7.00	0.533
0.35	6	4.498	21	3.1486	0.16	8.00	0.488
0.3667	6.01	4.48	22.002	3.136	0.15	9.00	0.449
0.3833	6.02	4.465	22.998	3.1255	0.14	10.00	0.417
0.4	6.04	4.45	24	3.115	0.13	11.00	0.385
0.4167	6.06	4.436	25.002	3.1052	0.12	12.00	0.354
0.4333	6.07	4.424	25.998	3.0968	0.11	13.00	0.329
0.45	6.09	4.413	27	3.0891	0.10	14.00	0.305
0.4667	6.1	4.4	28.002	3.08	0.09	15.00	0.277
0.4833	6.11	4.39	28.998	3.073	0.08	16.00	0.255
0.5	6.12	4.382	30	3.0674	0.08	17.00	0.238
0.5167	6.14	4.372	31.002	3.0604	0.07	18.00	0.217
0.5333	6.15	4.364	31.998	3.0548	0.06	19.00	0.199
0.55	6.15	4.359	33	3.0513	0.06	20.00	0.189
0.5667	6.16	4.354	34.002	3.0478	0.06	21.00	0.178
0.5833	6.18	4.346	34.998	3.0422	0.05	22.00	0.161
0.6	6.19	4.338	36	3.0366	0.05	23.00	0.143
0.6167	6.2	4.335	37.002	3.0345	0.04	24.00	0.137
0.6333	6.2	4.33	37.998	3.031	0.04	25.00	0.126
0.65	6.21	4.327	39	3.0289	0.04	26.00	0.120
0.6667	6.23	4.322	40.002	3.0254	0.04	27.00	0.109
0.6833	6.24	4.317	40.998	3.0219	0.03	28.00	0.098
0.7	6.24	4.314	42	3.0198	0.03	29.00	0.092
0.7167	6.25	4.312	43.002	3.0184	0.03	30.00	0.087
0.7333	6.25	4.309	43.998	3.0163	0.03	31.00	0.081
0.75	6.27	4.306	45	3.0142	0.02	32.00	0.074
0.7667	6.28	4.303	46.002	3.0121	0.02	33.00	0.068
0.7833	6.28	4.301	46.998	3.0107	0.02	34.00	0.064
0.8	6.29	4.298	48	3.0086	0.02	35.00	0.057
0.8167	6.29	4.296	49.002	3.0072	0.02	36.00	0.053
0.8333	6.3	4.295	49.998	3.0065	0.02	37.00	0.051
0.85	6.32	4.29	51	3.003	0.01	38.00	0.040
0.8667	6.32	4.29	52.002	3.003	0.01	39.00	0.040
0.8833	6.33	4.29	52.998	3.003	0.01	40.00	0.040
0.9	6.33	4.29	54	3.003	0.01	41.00	0.040
0.9167	6.34	4.285	55.002	2.9995	0.01	42.00	0.029
0.9333	6.34	4.287	55.998	3.0009	0.01	43.00	0.034

High K Estimator Spreadsheet
Metric Units

General Test Data

Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP02-FLT2-04TEST3	
Static Level:	2.99	m
Initial Water Level Change (H_0):	0.177	m
Start Time for Test:	18	sec
Type of Aquifer:	Confined	
Type:	Slug	

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	8.58	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	2.285	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	------>	m

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	$H(t)/H_0$ normalized head	
------------	---------------	---------------	------------	------------				
0	6.38	0.005	0	0.0035	-2.99	-18.00	-16.892	
0.05	6.35	0.005	3	0.0035	-2.99	-15.00	-16.892	
0.1	6.33	0.006	6	0.0042	-2.99	-12.00	-16.888	
0.15	6.3	0.004	9	0.0028	-2.99	-9.00	-16.896	still
0.2	6.28	0.012	12	0.0084	-2.98	-6.00	-16.864	disturbed
0.25	6.27	4.008	15	2.8056	-0.18	-3.00	-1.043	from
0.3	6.25	4.524	18	3.1668	0.17680	0.00	1.000	previous
0.35	6.24	4.448	21	3.1136	0.12360	3.00	0.699	test?
0.4	6.25	4.4	24	3.08	0.09	6.00	0.509	
0.45	6.25	4.365	27	3.0555	0.07	9.00	0.370	
0.5	6.25	4.337	30	3.0359	0.05	12.00	0.260	
0.55	6.25	4.319	33	3.0233	0.03	15.00	0.188	
0.6	6.25	4.301	36	3.0107	0.02	18.00	0.117	
0.65	6.24	4.292	39	3.0044	0.01	21.00	0.081	
0.7	6.24	4.284	42	2.9988	0.01	24.00	0.050	
0.75	6.24	4.276	45	2.9932	0.00	27.00	0.018	
0.8	6.24	4.274	48	2.9918	0.00	30.00	0.010	
0.85	6.24	4.269	51	2.9883	0.00	33.00	-0.010	
0.9	6.24	4.269	54	2.9883	0.00	36.00	-0.010	
0.95	6.24	4.266	57	2.9862	0.00	39.00	-0.021	
1	6.25	4.263	60	2.9841	-0.01	42.00	-0.033	
1.05	6.24	4.261	63	2.9827	-0.01	45.00	-0.041	
1.1	6.25	4.261	66	2.9827	-0.01	48.00	-0.041	
1.15	6.25	4.261	69	2.9827	-0.01	51.00	-0.041	
1.2	6.25	4.261	72	2.9827	-0.01	54.00	-0.041	
1.25	6.25	4.261	75	2.9827	-0.01	57.00	-0.041	
1.3	6.25	4.261	78	2.9827	-0.01	60.00	-0.041	
1.35	6.25	4.261	81	2.9827	-0.01	63.00	-0.041	
1.4	6.25	4.261	84	2.9827	-0.01	66.00	-0.041	
1.45	6.25	4.261	87	2.9827	-0.01	69.00	-0.041	
1.5	6.25	4.261	90	2.9827	-0.01	72.00	-0.041	
1.55	6.25	4.261	93	2.9827	-0.01	75.00	-0.041	
1.6	6.25	4.261	96	2.9827	-0.01	78.00	-0.041	
1.65	6.27	4.263	99	2.9841	-0.01	81.00	-0.033	

High K Estimator Spreadsheet			**Test Well Specs - "d" not used in confined case**		
Metric Units			Depth to Bottom of Screen (from toc):	18.47	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	2.167	m
Site Location:	Suncor		Top of Screen to Water Table (d):		m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP02-FLT2-05TEST1		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	3.57	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level			Modified Screen Radius (r_w*):	0.025	m
Change (H_0):	0.047	m	Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	42	sec	Formation Thickness (B):	see previous	m
Type of Aquifer:	Confined				
Type:	Slug				

			Chan[1]	Chan[2]		pressure head	
ET (min)	Celsius	PSI	time (s)	(m)	deviation from		H(t)/H_0
------------	---------------	---------------	------------	------------	static (m)	time since tes	normalized head
0	5.28	0.014	0	0.0098	-3.56	-42.00	-75.910
0.0167	5.28	0.016	1.002	0.0112	-3.56	-41.00	-75.881
0.0333	5.27	0.014	1.998	0.0098	-3.56	-40.00	-75.910
0.05	5.26	0.014	3	0.0098	-3.56	-39.00	-75.910
0.0667	5.24	0.017	4.002	0.0119	-3.56	-38.00	-75.866
0.0833	5.23	0.02	4.998	0.014	-3.56	-37.00	-75.821
0.1	5.22	0.015	6	0.0105	-3.56	-36.00	-75.896
0.1167	5.2	0.015	7.002	0.0105	-3.56	-35.00	-75.896
0.1333	5.19	0.015	7.998	0.0105	-3.56	-34.00	-75.896
0.15	5.19	0.013	9	0.0091	-3.56	-33.00	-75.925
0.1667	5.18	0.018	10.002	0.0126	-3.56	-32.00	-75.851
0.1833	5.17	0.016	10.998	0.0112	-3.56	-31.00	-75.881
0.2	5.15	0.013	12	0.0091	-3.56	-30.00	-75.925
0.2167	5.14	0.014	13.002	0.0098	-3.56	-29.00	-75.910
0.2333	5.13	0.016	13.998	0.0112	-3.56	-28.00	-75.881
0.25	5.11	0.014	15	0.0098	-3.56	-27.00	-75.910
0.2667	5.1	0.014	16.002	0.0098	-3.56	-26.00	-75.910
0.2833	5.09	0.014	16.998	0.0098	-3.56	-25.00	-75.910
0.3	5.08	0.015	18	0.0105	-3.56	-24.00	-75.896
0.3167	5.08	0.012	19.002	0.0084	-3.56	-23.00	-75.940
0.3333	5.05	0.01	19.998	0.007	-3.56	-22.00	-75.970
0.35	5.05	0.01	21	0.007	-3.56	-21.00	-75.970
0.3667	5.04	0.01	22.002	0.007	-3.56	-20.00	-75.970
0.3833	5.03	0.008	22.998	0.0056	-3.56	-19.00	-76.000
0.4	5.01	0.008	24	0.0056	-3.56	-18.00	-76.000
0.4167	5	0.008	25.002	0.0056	-3.56	-17.00	-76.000
0.4333	5	0.008	25.998	0.0056	-3.56	-16.00	-76.000
0.45	4.99	0.009	27	0.0063	-3.56	-15.00	-75.985
0.4667	4.97	0.009	28.002	0.0063	-3.56	-14.00	-75.985
0.4833	4.96	0.009	28.998	0.0063	-3.56	-13.00	-75.985
0.5	4.96	0.009	30	0.0063	-3.56	-12.00	-75.985
0.5167	4.95	0.009	31.002	0.0063	-3.56	-11.00	-75.985
0.5333	4.94	0.009	31.998	0.0063	-3.56	-10.00	-75.985
0.55	4.92	0.005	33	0.0035	-3.57	-9.00	-76.045
0.5667	4.92	2.809	34.002	1.9663	-1.60	-8.00	-34.194
0.5833	4.92	3.56	34.998	2.492	-1.08	-7.00	-22.985
0.6	4.92	4.765	36	3.3355	-0.23	-6.00	-5.000
0.6167	4.92	5.059	37.002	3.5413	-0.03	-5.00	-0.612
0.6333	4.92	5.029	37.998	3.5203	-0.05	-4.00	-1.060
0.65	4.94	5.2	39	3.64	0.07	-3.00	1.493
0.6667	4.95	5.177	40.002	3.6239	0.05	-2.00	1.149
0.6833	4.96	5.195	40.998	3.6365	0.07	-1.00	1.418
0.7	4.97	5.167	42	3.6169	0.05	0.00	1.000
0.7167	5	5.161	43.002	3.6127	0.04	1.00	0.910
0.7333	5.04	5.158	43.998	3.6106	0.04	2.00	0.866
0.75	5.06	5.158	45	3.6106	0.04	3.00	0.866
0.7667	5.09	5.155	46.002	3.6085	0.04	4.00	0.821
0.7833	5.13	5.154	46.998	3.6078	0.04	5.00	0.806
0.8	5.15	5.154	48	3.6078	0.04	6.00	0.806
0.8167	5.19	5.153	49.002	3.6071	0.04	7.00	0.791
0.8333	5.22	5.153	49.998	3.6071	0.04	8.00	0.791
0.85	5.24	5.15	51	3.605	0.04	9.00	0.746
0.8667	5.28	5.149	52.002	3.6043	0.03	10.00	0.731
0.8833	5.31	5.148	52.998	3.6036	0.03	11.00	0.716
0.9	5.34	5.148	54	3.6036	0.03	12.00	0.716
0.9167	5.37	5.145	55.002	3.6015	0.03	13.00	0.672
0.9333	5.4	5.144	55.998	3.6008	0.03	14.00	0.657

High K Estimator Spreadsheet
Metric Units

General Test Data

Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP02-FLT2-05TEST1	
Static Level:	4.13	m
Initial Water Level Change (H_0):	0.034	m
Start Time for Test:	10.998	sec
Type of Aquifer:	Confined	
Type:	Slug	

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	18.47	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	2.167	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	see previous	m

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	$H(t)/H_0$ normalized head
------------	---------------	---------------	------------	------------			
0	5.66	0.005	0	0.0035	-4.13	-11.00	-122.813
0.0167	5.66	0.005	1.002	0.0035	-4.13	-10.00	-122.813
0.0333	5.66	3.907	1.998	2.7349	-1.40	-9.00	-41.521
0.05	5.66	4.34	3	3.038	-1.09	-8.00	-32.500
0.0667	5.68	5.316	4.002	3.7212	-0.41	-7.00	-12.167
0.0833	5.68	5.921	4.998	4.1447	0.01	-6.00	0.438
0.1	5.69	6.764	6	4.7348	0.60	-5.00	18.000
0.1167	5.69	5.911	7.002	4.1377	0.01	-4.00	0.229
0.1333	5.7	5.941	7.998	4.1587	0.03	-3.00	0.854
0.15	5.72	5.913	9	4.1391	0.01	-2.00	0.271
0.1667	5.74	5.946	10.002	4.1622	0.032	-1.00	0.958
0.1833	5.77	5.948	10.998	4.1636	0.03360	0.00	1.000
0.2	5.78	5.947	12	4.1629	0.033	1.00	0.979
0.2167	5.81	5.942	13.002	4.1594	0.029	2.00	0.875
0.2333	5.83	5.944	13.998	4.1608	0.031	3.00	0.917
0.25	5.86	5.941	15	4.1587	0.029	4.00	0.854
0.2667	5.88	5.941	16.002	4.1587	0.029	5.00	0.854
0.2833	5.89	5.94	16.998	4.158	0.028	6.00	0.833
0.3	5.92	5.94	18	4.158	0.028	7.00	0.833
0.3167	5.95	5.939	19.002	4.1573	0.03	8.00	0.813
0.3333	5.96	5.939	19.998	4.1573	0.03	9.00	0.813
0.35	5.98	5.936	21	4.1552	0.03	10.00	0.750
0.3667	6	5.939	22.002	4.1573	0.03	11.00	0.813
0.3833	6.02	5.933	22.998	4.1531	0.02	12.00	0.687
0.4	6.04	5.935	24	4.1545	0.02	13.00	0.729
0.4167	6.05	5.935	25.002	4.1545	0.02	14.00	0.729
0.4333	6.06	5.932	25.998	4.1524	0.02	15.00	0.667
0.45	6.09	5.929	27	4.1503	0.02	16.00	0.604
0.4667	6.1	5.932	28.002	4.1524	0.02	17.00	0.667
0.4833	6.11	5.924	28.998	4.1468	0.02	18.00	0.500
0.5	6.12	5.926	30	4.1482	0.02	19.00	0.542
0.5167	6.14	5.926	31.002	4.1482	0.02	20.00	0.542
0.5333	6.15	5.926	31.998	4.1482	0.02	21.00	0.542
0.55	6.16	5.928	33	4.1496	0.02	22.00	0.583
0.5667	6.18	5.925	34.002	4.1475	0.02	23.00	0.521
0.5833	6.19	5.922	34.998	4.1454	0.02	24.00	0.458
0.6	6.2	5.925	36	4.1475	0.02	25.00	0.521
0.6167	6.2	5.925	37.002	4.1475	0.02	26.00	0.521
0.6333	6.21	5.925	37.998	4.1475	0.02	27.00	0.521
0.65	6.23	5.927	39	4.1489	0.02	28.00	0.562
0.6667	6.24	5.922	40.002	4.1454	0.02	29.00	0.458
0.6833	6.25	5.921	40.998	4.1447	0.01	30.00	0.438
0.7	6.25	5.921	42	4.1447	0.01	31.00	0.438
0.7167	6.27	5.919	43.002	4.1433	0.01	32.00	0.396
0.7333	6.27	5.919	43.998	4.1433	0.01	33.00	0.396
0.75	6.28	5.918	45	4.1426	0.01	34.00	0.375
0.7667	6.29	5.921	46.002	4.1447	0.01	35.00	0.438
0.7833	6.29	5.918	46.998	4.1426	0.01	36.00	0.375
0.8	6.3	5.918	48	4.1426	0.01	37.00	0.375
0.8167	6.32	5.918	49.002	4.1426	0.01	38.00	0.375
0.8333	6.32	5.915	49.998	4.1405	0.01	39.00	0.312
0.85	6.33	5.917	51	4.1419	0.01	40.00	0.354
0.8667	6.33	5.917	52.002	4.1419	0.01	41.00	0.354
0.8833	6.34	5.912	52.998	4.1384	0.01	42.00	0.250
0.9	6.34	5.915	54	4.1405	0.01	43.00	0.312
0.9167	6.35	5.912	55.002	4.1384	0.01	44.00	0.250
0.9333	6.35	5.914	55.998	4.1398	0.01	45.00	0.292

High K Estimator Spreadsheet

Metric Units

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	18.47	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	2.167	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	see previous	m

General Test Data

Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP02-FLT2-05TEST3	
Static Level:	3.62	m
Initial Water Level Change (H_0):	0.032	m
Start Time for Test:	85.002	sec
Type of Aquifer:	Confined	
Type:	Slug	

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	$H(t)/H_0$ normalized head
0	6.21	-0.002	0	-0.0014	-3.62	-85.00	-113.524
0.0167	6.21	0.005	1.002	0.0035	-3.62	-84.00	-113.370
0.0333	6.2	0.008	1.998	0.0056	-3.61	-83.00	-113.304
0.05	6.19	1.896	3	1.3272	-2.29	-82.00	-71.875
0.0667	6.18	2.02	4.002	1.414	-2.21	-81.00	-69.154
0.0833	6.16	2.089	4.998	1.4623	-2.16	-80.00	-67.639
0.1	6.16	2.101	6	1.4707	-2.15	-79.00	-67.376
0.1167	6.15	2.124	7.002	1.4868	-2.13	-78.00	-66.871
0.1333	6.15	2.114	7.998	1.4798	-2.14	-77.00	-67.091
0.15	6.16	2.076	9	1.4532	-2.17	-76.00	-67.925
0.1667	6.16	0.307	10.002	0.2149	-3.41	-75.00	-106.743
0.1833	6.16	0.016	10.998	0.0112	-3.61	-74.00	-113.129
0.2	6.18	0.024	12	0.0168	-3.60	-73.00	-112.953
0.2167	6.19	0.018	13.002	0.0126	-3.61	-72.00	-113.085
0.2333	6.21	0.02	13.998	0.014	-3.61	-71.00	-113.041
0.25	6.23	0.02	15	0.014	-3.61	-70.00	-113.041
0.2667	6.24	0.017	16.002	0.0119	-3.61	-69.00	-113.107
0.2833	6.27	0.019	16.998	0.0133	-3.61	-68.00	-113.063
0.3	6.28	0.019	18	0.0133	-3.61	-67.00	-113.063
0.3167	6.3	0.021	19.002	0.0147	-3.61	-66.00	-113.019
0.3333	6.33	0.021	19.998	0.0147	-3.61	-65.00	-113.019
0.35	6.34	0.018	21	0.0126	-3.61	-64.00	-113.085
0.3667	6.37	0.018	22.002	0.0126	-3.61	-63.00	-113.085
0.3833	6.39	0.015	22.998	0.0105	-3.61	-62.00	-113.150
0.4	6.41	0.017	24	0.0119	-3.61	-61.00	-113.107
0.4167	6.43	0.017	25.002	0.0119	-3.61	-60.00	-113.107
0.4333	6.44	0.016	25.998	0.0112	-3.61	-59.00	-113.129
0.45	6.47	0.018	27	0.0126	-3.61	-58.00	-113.085
0.4667	6.48	0.016	28.002	0.0112	-3.61	-57.00	-113.129
0.4833	6.5	0.015	28.998	0.0105	-3.61	-56.00	-113.150
0.5	6.52	0.015	30	0.0105	-3.61	-55.00	-113.150
0.5167	6.53	0.015	31.002	0.0105	-3.61	-54.00	-113.150
0.5333	6.55	0.015	31.998	0.0105	-3.61	-53.00	-113.150
0.55	6.56	0.116	33	0.0812	-3.54	-52.00	-110.934
0.5667	6.57	1.251	34.002	0.8757	-2.74	-51.00	-86.028
0.5833	6.58	1.656	34.998	1.1592	-2.46	-50.00	-77.141
0.6	6.6	1.803	36	1.2621	-2.36	-49.00	-73.915
0.6167	6.61	1.797	37.002	1.2579	-2.36	-48.00	-74.047
0.6333	6.62	1.2	37.998	0.84	-2.78	-47.00	-87.147
0.65	6.64	0.969	39	0.6783	-2.94	-46.00	-92.216
0.6667	6.65	0.003	40.002	0.0021	-3.62	-45.00	-113.414
0.6833	6.66	-0.005	40.998	-0.0035	-3.62	-44.00	-113.589
0.7	6.69	0.005	42	0.0035	-3.62	-43.00	-113.370
0.7167	6.7	0.002	43.002	0.0014	-3.62	-42.00	-113.436
0.7333	6.71	0.002	43.998	0.0014	-3.62	-41.00	-113.436
0.75	6.72	0.001	45	0.0007	-3.62	-40.00	-113.458
0.7667	6.75	0.003	46.002	0.0021	-3.62	-39.00	-113.414
0.7833	6.76	0.013	46.998	0.0091	-3.61	-38.00	-113.194
0.8	6.78	0.008	48	0.0056	-3.61	-37.00	-113.304
0.8167	6.79	0.003	49.002	0.0021	-3.62	-36.00	-113.414
0.8333	6.8	0	49.998	0	-3.62	-35.00	-113.480
0.85	6.81	0.002	51	0.0014	-3.62	-34.00	-113.436
0.8667	6.83	0.002	52.002	0.0014	-3.62	-33.00	-113.436
0.8833	6.84	0.004	52.998	0.0028	-3.62	-32.00	-113.392
0.9	6.85	0.002	54	0.0014	-3.62	-31.00	-113.436
0.9167	6.85	0.004	55.002	0.0028	-3.62	-30.00	-113.392
0.9333	6.87	0.004	55.998	0.0028	-3.62	-29.00	-113.392

High K Estimator Spreadsheet			**Test Well Specs - "d" not used in confined case**		
Metric Units			Depth to Bottom of Screen (from toc):	16.55	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	3.39	m
Site Location:	Suncor		Top of Screen to Water Table (d):		m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP02-FLT2-09-TEST1		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	2.00	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level			Modified Screen Radius (r_w*):	0.025	m
Change (H_0):	0.015	m	Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	28.002	sec	Formation Thickness (B):	look at histori	m
Type of Aquifer:	Confined				
Type:	Slug				

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	H(t)/H_0 normalized head
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0	3.99	0.005	0	0.0035	-2.00	-28.00	-136.747
0.0167	3.99	0.008	1.002	0.0056	-1.99	-27.00	-136.603
0.0333	3.99	0.005	1.998	0.0035	-2.00	-26.00	-136.747
0.05	3.99	0.008	3	0.0056	-1.99	-25.00	-136.603
0.0667	3.98	0.005	4.002	0.0035	-2.00	-24.00	-136.747
0.0833	3.98	0.008	4.998	0.0056	-1.99	-23.00	-136.603
0.1	3.98	0.005	6	0.0035	-2.00	-22.00	-136.747
0.1167	3.96	0.006	7.002	0.0042	-2.00	-21.00	-136.699
0.1333	3.95	0.006	7.998	0.0042	-2.00	-20.00	-136.699
0.15	3.95	0.006	9	0.0042	-2.00	-19.00	-136.699
0.1667	3.95	0.006	10.002	0.0042	-2.00	-18.00	-136.699
0.1833	3.94	0.004	10.998	0.0028	-2.00	-17.00	-136.795
0.2	3.94	0.006	12	0.0042	-2.00	-16.00	-136.699
0.2167	3.93	0.006	13.002	0.0042	-2.00	-15.00	-136.699
0.2333	3.93	0.009	13.998	0.0063	-1.99	-14.00	-136.555
0.25	3.93	0.009	15	0.0063	-1.99	-13.00	-136.555
0.2667	3.91	0.012	16.002	0.0084	-1.99	-12.00	-136.411
0.2833	3.91	0.017	16.998	0.0119	-1.99	-11.00	-136.171
0.3	3.9	0.014	18	0.0098	-1.99	-10.00	-136.315
0.3167	3.9	0.012	19.002	0.0084	-1.99	-9.00	-136.411
0.3333	3.9	0.014	19.998	0.0098	-1.99	-8.00	-136.315
0.35	3.9	2.611	21	1.8277	-0.17	-7.00	-11.801
0.3667	3.9	2.912	22.002	2.0384	0.04	-6.00	2.630
0.3833	3.91	2.803	22.998	1.9621	-0.04	-5.00	-2.596
0.4	3.93	2.821	24	1.9747	-0.03	-4.00	-1.733
0.4167	3.94	2.846	25.002	1.9922	-0.01	-3.00	-0.534
0.4333	3.95	2.874	25.998	2.0118	0.0118	-2.00	0.808
0.45	3.98	2.876	27	2.0132	0.0132	-1.00	0.904
0.4667	4.02	2.878	28.002	2.0146	0.0146	0.00	1.000
0.4833	4.04	2.872	28.998	2.0104	0.0104	1.00	0.712
0.5	4.08	2.869	30	2.0083	0.0083	2.00	0.568
0.5167	4.13	2.865	31.002	2.0055	0.0055	3.00	0.377
0.5333	4.17	2.867	31.998	2.0069	0.0069	4.00	0.473
0.55	4.22	2.866	33	2.0062	0.0062	5.00	0.425
0.5667	4.27	2.868	34.002	2.0076	0.0076	6.00	0.521
0.5833	4.32	2.867	34.998	2.0069	0.0069	7.00	0.473
0.6	4.37	2.866	36	2.0062	0.0062	8.00	0.425
0.6167	4.42	2.865	37.002	2.0055	0.0055	9.00	0.377
0.6333	4.48	2.867	37.998	2.0069	0.0069	10.00	0.473
0.65	4.53	2.866	39	2.0062	0.01	11.00	0.425
0.6667	4.58	2.865	40.002	2.0055	0.01	12.00	0.377
0.6833	4.64	2.867	40.998	2.0069	0.01	13.00	0.473
0.7	4.69	2.866	42	2.0062	0.01	14.00	0.425
0.7167	4.73	2.868	43.002	2.0076	0.01	15.00	0.521
0.7333	4.78	2.867	43.998	2.0069	0.01	16.00	0.473
0.75	4.83	2.868	45	2.0076	0.01	17.00	0.521
0.7667	4.87	2.868	46.002	2.0076	0.01	18.00	0.521
0.7833	4.92	2.867	46.998	2.0069	0.01	19.00	0.473
0.8	4.96	2.869	48	2.0083	0.01	20.00	0.568
0.8167	5.01	2.868	49.002	2.0076	0.01	21.00	0.521
0.8333	5.05	2.867	49.998	2.0069	0.01	22.00	0.473
0.85	5.09	2.867	51	2.0069	0.01	23.00	0.473
0.8667	5.13	2.868	52.002	2.0076	0.01	24.00	0.521
0.8833	5.18	2.865	52.998	2.0055	0.01	25.00	0.377
0.9	5.22	2.867	54	2.0069	0.01	26.00	0.473
0.9167	5.24	2.869	55.002	2.0083	0.01	27.00	0.568
0.9333	5.29	2.868	55.998	2.0076	0.01	28.00	0.521

High K Estimator Spreadsheet
Metric Units

General Test Data		
Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP02-FLT2-09-TEST2	
Static Level:	3.00	m
Initial Water Level Change (H_0):	-0.001	m
Start Time for Test:	1.002	sec
Type of Aquifer:	Confined	
Type:	Slug	

Test Well Specs - "d" not used in confined case		
Depth to Bottom of Screen (from toc):	16.55	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	3.39	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	look at histori	m

			Chan[1]	Chan[2]		pressure head	
ET (min)	Celsius	PSI	time (s)	(m)	deviation from		$H(t)/H_0$
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0	6.04	-0.012	0	-0.0084	-3.0084	-1.00	6016.800
0.0167	6.04	4.318	1.002	3.0226	0.0226	0.00	-45.200
0.0333	6.04	4.804	1.998	3.3628	0.3628	1.00	-725.600
0.05	6.04	4.245	3	2.9715	-0.0285	2.00	57.000
0.0667	6.04	4.169	4.002	2.9183	-0.0817	3.00	163.400
0.0833	6.04	4.217	4.998	2.9519	-0.0481	4.00	96.200
0.1	6.04	4.285	6	2.9995	-0.0005	5.00	1.000
0.1167	6.05	4.31	7.002	3.017	0.0170	6.00	-34.000
0.1333	6.06	4.317	7.998	3.0219	0.0219	7.00	-43.800
0.15	6.07	4.315	9	3.0205	0.0205	8.00	-41.000
0.1667	6.09	4.307	10.002	3.0149	0.0149	9.00	-29.800
0.1833	6.1	4.299	10.998	3.0093	0.0093	10.00	-18.600
0.2	6.12	4.299	12	3.0093	0.0093	11.00	-18.600
0.2167	6.14	4.296	13.002	3.0072	0.0072	12.00	-14.400
0.2333	6.15	4.293	13.998	3.0051	0.0051	13.00	-10.200
0.25	6.18	4.3	15	3.01	0.0100	14.00	-20.000
0.2667	6.2	4.292	16.002	3.0044	0.0044	15.00	-8.800
0.2833	6.21	4.292	16.998	3.0044	0.0044	16.00	-8.800
0.3	6.24	4.304	18	3.0128	0.0128	17.00	-25.600
0.3167	6.25	4.294	19.002	3.0058	0.0058	18.00	-11.600
0.3333	6.28	4.301	19.998	3.0107	0.0107	19.00	-21.400
0.35	6.29	4.293	21	3.0051	0.0051	20.00	-10.200
0.3667	6.32	4.293	22.002	3.0051	0.0051	21.00	-10.200
0.3833	6.33	4.292	22.998	3.0044	0.0044	22.00	-8.800
0.4	6.34	4.285	24	2.9995	-0.0005	23.00	1.000
0.4167	6.37	4.294	25.002	3.0058	0.0058	24.00	-11.600
0.4333	6.38	4.292	25.998	3.0044	0.0044	25.00	-8.800
0.45	6.41	4.296	27	3.0072	0.0072	26.00	-14.400
0.4667	6.42	4.288	28.002	3.0016	0.0016	27.00	-3.200
0.4833	6.43	4.293	28.998	3.0051	0.0051	28.00	-10.200
0.5	6.44	4.288	30	3.0016	0.0016	29.00	-3.200
0.5167	6.46	4.29	31.002	3.003	0.0030	30.00	-6.000
0.5333	6.48	4.28	31.998	2.996	-0.0040	31.00	8.000
0.55	6.5	4.297	33	3.0079	0.0079	32.00	-15.800
0.5667	6.51	4.287	34.002	3.0009	0.0009	33.00	-1.800
0.5833	6.52	4.292	34.998	3.0044	0.0044	34.00	-8.800
0.6	6.53	4.289	36	3.0023	0.0023	35.00	-4.600
0.6167	6.55	4.296	37.002	3.0072	0.0072	36.00	-14.400
0.6333	6.56	4.288	37.998	3.0016	0.0016	37.00	-3.200
0.65	6.56	4.291	39	3.0037	0.0037	38.00	-7.400
0.6667	6.57	4.293	40.002	3.0051	0.0051	39.00	-10.200
0.6833	6.58	4.288	40.998	3.0016	0.0016	40.00	-3.200
0.7	6.6	4.29	42	3.003	0.0030	41.00	-6.000
0.7167	6.61	4.287	43.002	3.0009	0.0009	42.00	-1.800
0.7333	6.62	4.29	43.998	3.003	0.0030	43.00	-6.000
0.75	6.62	4.292	45	3.0044	0.0044	44.00	-8.800
0.7667	6.64	4.295	46.002	3.0065	0.0065	45.00	-13.000
0.7833	6.65	4.292	46.998	3.0044	0.0044	46.00	-8.800
0.8	6.65	4.284	48	2.9988	-0.0012	47.00	2.400
0.8167	6.66	4.289	49.002	3.0023	0.0023	48.00	-4.600
0.8333	6.67	4.294	49.998	3.0058	0.0058	49.00	-11.600
0.85	6.69	4.284	51	2.9988	-0.0012	50.00	2.400
0.8667	6.69	4.286	52.002	3.0002	0.0002	51.00	-0.400
0.8833	6.7	4.293	52.998	3.0051	0.0051	52.00	-10.200
0.9	6.71	4.291	54	3.0037	0.0037	53.00	-7.400
0.9167	6.71	4.291	55.002	3.0037	0.00	54.00	-7.400
0.9333	6.72	4.285	55.998	2.9995	0.00	55.00	1.000

High K Estimator Spreadsheet
Metric Units

General Test Data

Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP02-FLT2-09-TEST3	
Static Level:	2.03	m
Initial Water Level Change (H_0):	0.008	m
Start Time for Test:	19.002	sec
Type of Aquifer:	Confined	
Type:	Slug	

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	16.55	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	3.39	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	look at histori	m

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	$H(t)/H_0$ normalized head
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0	5.89	-0.005	0	-0.0035	-2.03	-19.00	-264.091
0.0167	5.88	-0.004	1.002	-0.0028	-2.03	-18.00	-264.000
0.0333	5.87	-0.004	1.998	-0.0028	-2.03	-17.00	-264.000
0.05	5.84	-0.004	3	-0.0028	-2.03	-16.00	-264.000
0.0667	5.83	-0.003	4.002	-0.0021	-2.03	-15.00	-263.909
0.0833	5.82	-0.003	4.998	-0.0021	-2.03	-14.00	-263.909
0.1	5.79	-0.003	6	-0.0021	-2.03	-13.00	-263.909
0.1167	5.78	-0.003	7.002	-0.0021	-2.03	-12.00	-263.909
0.1333	5.77	-0.002	7.998	-0.0014	-2.03	-11.00	-263.818
0.15	5.75	-0.005	9	-0.0035	-2.03	-10.00	-264.091
0.1667	5.74	-0.004	10.002	-0.0028	-2.03	-9.00	-264.000
0.1833	5.73	2.44	10.998	1.708	-0.32	-8.00	-41.818
0.2	5.72	2.967	12	2.0769	0.0469	-7.00	6.091
0.2167	5.72	2.97	13.002	2.079	0.0490	-6.00	6.364
0.2333	5.72	2.838	13.998	1.9866	-0.04	-5.00	-5.636
0.25	5.72	2.866	15	2.0062	-0.02	-4.00	-3.091
0.2667	5.72	2.894	16.002	2.0258	-0.004	-3.00	-0.545
0.2833	5.73	2.906	16.998	2.0342	0.004	-2.00	0.545
0.3	5.73	2.909	18	2.0363	0.006	-1.00	0.818
0.3167	5.74	2.911	19.002	2.0377	0.008	0.00	1.000
0.3333	5.75	2.901	19.998	2.0307	0.001	1.00	0.091
0.35	5.78	2.9	21	2.03	0.000	2.00	0.000
0.3667	5.79	2.897	22.002	2.0279	-0.002	3.00	-0.273
0.3833	5.81	2.897	22.998	2.0279	-0.002	4.00	-0.273
0.4	5.83	2.899	24	2.0293	-0.001	5.00	-0.091
0.4167	5.86	2.899	25.002	2.0293	-0.001	6.00	-0.091
0.4333	5.88	2.898	25.998	2.0286	-0.001	7.00	-0.182
0.45	5.89	2.898	27	2.0286	-0.001	8.00	-0.182
0.4667	5.92	2.895	28.002	2.0265	-0.003	9.00	-0.455
0.4833	5.95	2.897	28.998	2.0279	-0.002	10.00	-0.273
0.5	5.97	2.902	30	2.0314	0.001	11.00	0.182
0.5167	5.98	2.902	31.002	2.0314	0.00	12.00	0.182
0.5333	6.01	2.901	31.998	2.0307	0.00	13.00	0.091
0.55	6.04	2.901	33	2.0307	0.00	14.00	0.091
0.5667	6.06	2.898	34.002	2.0286	0.00	15.00	-0.182
0.5833	6.07	2.897	34.998	2.0279	0.00	16.00	-0.273
0.6	6.1	2.9	36	2.03	0.00	17.00	0.000
0.6167	6.11	2.899	37.002	2.0293	0.00	18.00	-0.091
0.6333	6.14	2.896	37.998	2.0272	0.00	19.00	-0.364
0.65	6.15	2.899	39	2.0293	0.00	20.00	-0.091
0.6667	6.18	2.901	40.002	2.0307	0.00	21.00	0.091
0.6833	6.19	2.895	40.998	2.0265	0.00	22.00	-0.455
0.7	6.21	2.897	42	2.0279	0.00	23.00	-0.273
0.7167	6.23	2.895	43.002	2.0265	0.00	24.00	-0.455
0.7333	6.24	2.902	43.998	2.0314	0.00	25.00	0.182
0.75	6.27	2.909	45	2.0363	0.01	26.00	0.818
0.7667	6.28	2.899	46.002	2.0293	0.00	27.00	-0.091
0.7833	6.29	2.901	46.998	2.0307	0.00	28.00	0.091
0.8	6.3	2.898	48	2.0286	0.00	29.00	-0.182
0.8167	6.32	2.901	49.002	2.0307	0.00	30.00	0.091
0.8333	6.33	2.901	49.998	2.0307	0.00	31.00	0.091
0.85	6.34	2.898	51	2.0286	0.00	32.00	-0.182
0.8667	6.35	2.898	52.002	2.0286	0.00	33.00	-0.182
0.8833	6.38	2.902	52.998	2.0314	0.00	34.00	0.182
0.9	6.39	2.904	54	2.0328	0.00	35.00	0.364
0.9167	6.39	2.902	55.002	2.0314	0.00	36.00	0.182
0.9333	6.42	2.901	55.998	2.0307	0.00	37.00	0.091

High K Estimator Spreadsheet

Metric Units

General Test Data

Site Location:	Suncor
Date:	10/14/2003
Time:	
Test Designation:	SP03-FLT2-01-TEST1
Static Level:	4.58 m
Initial Water Level Change (H_0):	-0.521 m
Start Time for Test:	5 sec
Type of Aquifer:	Confined
Type:	Head

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	12.43	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	1.29	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	19.2024	m

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	$H(t)/H_0$ normalized head
0	6.5	6.54	0	4.578	0.00	-5.00	0.004
0.0167	6.5	6.547	1.002	4.5829	0.00	-4.00	-0.006
0.0333	6.5	6.542	1.998	4.5794	0.00	-3.00	0.001
0.05	6.5	6.555	3	4.5885	0.01	-2.00	-0.016
0.0667	6.51	6.263	4.002	4.3841	-0.20	-1.00	0.376
0.0833	6.51	5.798	4.998	4.0586	-0.52140	0.00	1.000
0.1	6.51	5.864	6	4.1048	-0.47520	1.00	0.911
0.1167	6.51	5.914	7.002	4.1398	-0.44	2.00	0.844
0.1333	6.51	5.96	7.998	4.172	-0.41	3.00	0.783
0.15	6.51	6	9	4.2	-0.38	4.00	0.729
0.1667	6.51	6.036	10.002	4.2252	-0.35	5.00	0.680
0.1833	6.51	6.071	10.998	4.2497	-0.33	6.00	0.633
0.2	6.51	6.101	12	4.2707	-0.31	7.00	0.593
0.2167	6.51	6.132	13.002	4.2924	-0.29	8.00	0.552
0.2333	6.51	6.16	13.998	4.312	-0.27	9.00	0.514
0.25	6.51	6.182	15	4.3274	-0.25	10.00	0.484
0.2667	6.51	6.208	16.002	4.3456	-0.23	11.00	0.450
0.2833	6.51	6.228	16.998	4.3596	-0.22	12.00	0.423
0.3	6.51	6.248	18	4.3736	-0.21	13.00	0.396
0.3167	6.52	6.266	19.002	4.3862	-0.19	14.00	0.372
0.3333	6.52	6.283	19.998	4.3981	-0.18	15.00	0.349
0.35	6.52	6.299	21	4.4093	-0.17	16.00	0.327
0.3667	6.52	6.316	22.002	4.4212	-0.16	17.00	0.305
0.3833	6.52	6.329	22.998	4.4303	-0.15	18.00	0.287
0.4	6.52	6.342	24	4.4394	-0.14	19.00	0.270
0.4167	6.51	6.352	25.002	4.4464	-0.13	20.00	0.256
0.4333	6.52	6.364	25.998	4.4548	-0.13	21.00	0.240
0.45	6.51	6.375	27	4.4625	-0.12	22.00	0.225
0.4667	6.52	6.385	28.002	4.4695	-0.11	23.00	0.212
0.4833	6.52	6.395	28.998	4.4765	-0.10	24.00	0.199
0.5	6.52	6.402	30	4.4814	-0.10	25.00	0.189
0.5167	6.51	6.41	31.002	4.487	-0.09	26.00	0.178
0.5333	6.51	6.42	31.998	4.494	-0.09	27.00	0.165
0.55	6.51	6.425	33	4.4975	-0.08	28.00	0.158
0.5667	6.51	6.433	34.002	4.5031	-0.08	29.00	0.147
0.5833	6.51	6.438	34.998	4.5066	-0.07	30.00	0.141
0.6	6.51	6.446	36	4.5122	-0.07	31.00	0.130
0.6167	6.51	6.451	37.002	4.5157	-0.06	32.00	0.123
0.6333	6.51	6.453	37.998	4.5171	-0.06	33.00	0.121
0.65	6.51	6.458	39	4.5206	-0.06	34.00	0.114
0.6667	6.51	6.463	40.002	4.5241	-0.06	35.00	0.107
0.6833	6.51	6.469	40.998	4.5283	-0.05	36.00	0.099
0.7	6.51	6.474	42	4.5318	-0.05	37.00	0.092
0.7167	6.51	6.476	43.002	4.5332	-0.05	38.00	0.090
0.7333	6.51	6.479	43.998	4.5353	-0.04	39.00	0.086
0.75	6.51	6.484	45	4.5388	-0.04	40.00	0.079
0.7667	6.51	6.486	46.002	4.5402	-0.04	41.00	0.076
0.7833	6.51	6.489	46.998	4.5423	-0.04	42.00	0.072
0.8	6.51	6.491	48	4.5437	-0.04	43.00	0.070
0.8167	6.5	6.494	49.002	4.5458	-0.03	44.00	0.066
0.8333	6.5	6.497	49.998	4.5479	-0.03	45.00	0.062
0.85	6.5	6.499	51	4.5493	-0.03	46.00	0.059
0.8667	6.5	6.502	52.002	4.5514	-0.03	47.00	0.055
0.8833	6.5	6.502	52.998	4.5514	-0.03	48.00	0.055
0.9	6.5	6.504	54	4.5528	-0.03	49.00	0.052
0.9167	6.5	6.504	55.002	4.5528	-0.03	50.00	0.052
0.9333	6.5	6.507	55.998	4.5549	-0.03	51.00	0.048

High K Estimator Spreadsheet			**Test Well Specs - "d" not used in confined case**		
Metric Units			Depth to Bottom of Screen (from toc):	12.43	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	1.29	m
Site Location:	Suncor		Top of Screen to Water Table (d):		m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP03-FLT2-01-TEST1		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	4.57	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level			Modified Screen Radius (r_w*):	0.025	m
Change (H_0):	-1.154	m	Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	4	sec	Formation Thickness (B):	19.2024	m
Type of Aquifer:	Confined				
Type:	Head				

			Chan[1]	Chan[2]		pressure head	
ET (min)	Celsius	PSI	time (s)	(m)	deviation from		H(t)/H_0
------------	---------------	---------------	------------	------------	static (m)	time since tes	normalized head
0	6.32	6.518	0	4.5626	-0.01	-4.00	0.006
0.0167	6.32	6.523	1.002	4.5661	0.00	-3.00	0.003
0.0333	6.32	6.523	1.998	4.5661	0.00	-2.00	0.003
0.05	6.32	3.888	3	2.7216	-1.85	-1.00	1.602
0.0667	6.32	4.88	4.002	3.416	-1.1540	0.00	1.000
0.0833	6.32	5.027	4.998	3.5189	-1.05	1.00	0.911
0.1	6.32	5.133	6	3.5931	-0.9769	2.00	0.847
0.1167	6.33	5.224	7.002	3.6568	-0.91	3.00	0.791
0.1333	6.32	5.308	7.998	3.7156	-0.85	4.00	0.740
0.15	6.33	5.383	9	3.7681	-0.80	5.00	0.695
0.1667	6.33	5.454	10.002	3.8178	-0.75	6.00	0.652
0.1833	6.32	5.52	10.998	3.864	-0.71	7.00	0.612
0.2	6.32	5.581	12	3.9067	-0.66	8.00	0.575
0.2167	6.33	5.636	13.002	3.9452	-0.62	9.00	0.541
0.2333	6.32	5.692	13.998	3.9844	-0.59	10.00	0.507
0.25	6.32	5.74	15	4.018	-0.55	11.00	0.478
0.2667	6.32	5.786	16.002	4.0502	-0.52	12.00	0.450
0.2833	6.32	5.832	16.998	4.0824	-0.49	13.00	0.423
0.3	6.3	5.872	18	4.1104	-0.46	14.00	0.398
0.3167	6.3	5.91	19.002	4.137	-0.43	15.00	0.375
0.3333	6.3	5.946	19.998	4.1622	-0.41	16.00	0.353
0.35	6.3	5.981	21	4.1867	-0.38	17.00	0.332
0.3667	6.29	6.012	22.002	4.2084	-0.36	18.00	0.313
0.3833	6.29	6.042	22.998	4.2294	-0.34	19.00	0.295
0.4	6.29	6.07	24	4.249	-0.32	20.00	0.278
0.4167	6.29	6.095	25.002	4.2665	-0.30	21.00	0.263
0.4333	6.28	6.118	25.998	4.2826	-0.29	22.00	0.249
0.45	6.28	6.144	27	4.3008	-0.27	23.00	0.233
0.4667	6.27	6.164	28.002	4.3148	-0.26	24.00	0.221
0.4833	6.27	6.184	28.998	4.3288	-0.24	25.00	0.209
0.5	6.27	6.205	30	4.3435	-0.23	26.00	0.196
0.5167	6.25	6.223	31.002	4.3561	-0.21	27.00	0.185
0.5333	6.25	6.238	31.998	4.3666	-0.20	28.00	0.176
0.55	6.24	6.256	33	4.3792	-0.19	29.00	0.165
0.5667	6.24	6.268	34.002	4.3876	-0.18	30.00	0.158
0.5833	6.23	6.284	34.998	4.3988	-0.17	31.00	0.148
0.6	6.23	6.296	36	4.4072	-0.16	32.00	0.141
0.6167	6.23	6.312	37.002	4.4184	-0.15	33.00	0.131
0.6333	6.21	6.322	37.998	4.4254	-0.14	34.00	0.125
0.65	6.2	6.335	39	4.4345	-0.14	35.00	0.117
0.6667	6.2	6.345	40.002	4.4415	-0.13	36.00	0.111
0.6833	6.19	6.355	40.998	4.4485	-0.12	37.00	0.105
0.7	6.19	6.363	42	4.4541	-0.12	38.00	0.100
0.7167	6.18	6.371	43.002	4.4597	-0.11	39.00	0.096
0.7333	6.18	6.381	43.998	4.4667	-0.10	40.00	0.090
0.75	6.16	6.389	45	4.4723	-0.10	41.00	0.085
0.7667	6.16	6.396	46.002	4.4772	-0.09	42.00	0.080
0.7833	6.15	6.402	46.998	4.4814	-0.09	43.00	0.077
0.8	6.15	6.409	48	4.4863	-0.08	44.00	0.073
0.8167	6.14	6.414	49.002	4.4898	-0.08	45.00	0.069
0.8333	6.14	6.419	49.998	4.4933	-0.08	46.00	0.066
0.85	6.12	6.427	51	4.4989	-0.07	47.00	0.062
0.8667	6.11	6.433	52.002	4.5031	-0.07	48.00	0.058
0.8833	6.11	6.438	52.998	4.5066	-0.06	49.00	0.055
0.9	6.1	6.443	54	4.5101	-0.06	50.00	0.052
0.9167	6.1	6.448	55.002	4.5136	-0.06	51.00	0.049
0.9333	6.09	6.451	55.998	4.5157	-0.05	52.00	0.047

High K Estimator Spreadsheet			**Test Well Specs - "d" not used in confined case**		
Metric Units			Depth to Bottom of Screen (from toc):	12.43	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	1.29	m
Site Location:	Suncor		Top of Screen to Water Table (d):		m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP03-FLT2-01-TEST1		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	4.50	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level			Modified Screen Radius (r_w*):	0.025	m
Change (H_0):	-0.448	m	Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	4	sec	Formation Thickness (B):	19.2024	m
Type of Aquifer:	Confined				
Type:	Head				

			Chan[1]	Chan[2]		pressure head	
ET (min)	Celsius	PSI	time (s)	(m)	deviation from		H(t)/H_0
------------	---------------	---------------	------------	------------	static (m)	time since tes	normalized head
0	5.61	6.543	0	4.5801	0.08	-4.00	-0.179
0.0167	5.61	6.555	1.002	4.5885	0.09	-3.00	-0.197
0.0333	5.61	4.948	1.998	3.4636	-1.04	-2.00	2.311
0.05	5.63	5.396	3	3.7772	-0.72	-1.00	1.612
0.0667	5.63	5.788	4.002	4.0516	-0.4484	0.00	1.000
0.0833	5.63	5.844	4.998	4.0908	-0.41	1.00	0.913
0.1	5.61	5.882	6	4.1174	-0.38	2.00	0.853
0.1167	5.63	5.917	7.002	4.1419	-0.36	3.00	0.799
0.1333	5.63	5.953	7.998	4.1671	-0.33	4.00	0.742
0.15	5.63	5.981	9	4.1867	-0.31	5.00	0.699
0.1667	5.61	6.011	10.002	4.2077	-0.29	6.00	0.652
0.1833	5.61	6.037	10.998	4.2259	-0.27	7.00	0.611
0.2	5.61	6.059	12	4.2413	-0.26	8.00	0.577
0.2167	5.61	6.082	13.002	4.2574	-0.24	9.00	0.541
0.2333	5.61	6.105	13.998	4.2735	-0.23	10.00	0.505
0.25	5.61	6.123	15	4.2861	-0.21	11.00	0.477
0.2667	5.61	6.14	16.002	4.298	-0.20	12.00	0.450
0.2833	5.61	6.158	16.998	4.3106	-0.19	13.00	0.422
0.3	5.61	6.176	18	4.3232	-0.18	14.00	0.394
0.3167	5.61	6.191	19.002	4.3337	-0.17	15.00	0.371
0.3333	5.6	6.204	19.998	4.3428	-0.16	16.00	0.351
0.35	5.61	6.219	21	4.3533	-0.15	17.00	0.327
0.3667	5.6	6.229	22.002	4.3603	-0.14	18.00	0.312
0.3833	5.6	6.242	22.998	4.3694	-0.13	19.00	0.291
0.4	5.6	6.252	24	4.3764	-0.12	20.00	0.276
0.4167	5.6	6.262	25.002	4.3834	-0.12	21.00	0.260
0.4333	5.6	6.272	25.998	4.3904	-0.11	22.00	0.244
0.45	5.6	6.28	27	4.396	-0.10	23.00	0.232
0.4667	5.6	6.29	28.002	4.403	-0.10	24.00	0.216
0.4833	5.59	6.298	28.998	4.4086	-0.09	25.00	0.204
0.5	5.59	6.305	30	4.4135	-0.09	26.00	0.193
0.5167	5.59	6.31	31.002	4.417	-0.08	27.00	0.185
0.5333	5.59	6.318	31.998	4.4226	-0.08	28.00	0.173
0.55	5.59	6.326	33	4.4282	-0.07	29.00	0.160
0.5667	5.58	6.331	34.002	4.4317	-0.07	30.00	0.152
0.5833	5.58	6.336	34.998	4.4352	-0.06	31.00	0.145
0.6	5.58	6.341	36	4.4387	-0.06	32.00	0.137
0.6167	5.58	6.346	37.002	4.4422	-0.06	33.00	0.129
0.6333	5.56	6.351	37.998	4.4457	-0.05	34.00	0.121
0.65	5.56	6.354	39	4.4478	-0.05	35.00	0.116
0.6667	5.56	6.359	40.002	4.4513	-0.05	36.00	0.109
0.6833	5.56	6.364	40.998	4.4548	-0.05	37.00	0.101
0.7	5.56	6.367	42	4.4569	-0.04	38.00	0.096
0.7167	5.55	6.369	43.002	4.4583	-0.04	39.00	0.093
0.7333	5.55	6.372	43.998	4.4604	-0.04	40.00	0.088
0.75	5.55	6.377	45	4.4639	-0.04	41.00	0.081
0.7667	5.54	6.38	46.002	4.466	-0.03	42.00	0.076
0.7833	5.54	6.382	46.998	4.4674	-0.03	43.00	0.073
0.8	5.54	6.385	48	4.4695	-0.03	44.00	0.068
0.8167	5.54	6.385	49.002	4.4695	-0.03	45.00	0.068
0.8333	5.54	6.387	49.998	4.4709	-0.03	46.00	0.065
0.85	5.52	6.39	51	4.473	-0.03	47.00	0.060
0.8667	5.52	6.393	52.002	4.4751	-0.02	48.00	0.056
0.8833	5.52	6.393	52.998	4.4751	-0.02	49.00	0.056
0.9	5.52	6.395	54	4.4765	-0.02	50.00	0.052
0.9167	5.51	6.398	55.002	4.4786	-0.02	51.00	0.048
0.9333	5.51	6.4	55.998	4.48	-0.02	52.00	0.045

High K Estimator Spreadsheet
Metric Units

General Test Data

Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP03-FLT2-02-TEST1	
Static Level:	3.87	m
Initial Water Level Change (H_0):	-0.522	m
Start Time for Test:	9	sec
Type of Aquifer:	Confined	
Type:	Head	

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	6.31	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	0.48	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	19.2024	m

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	$H(t)/H_0$ normalized head
0	6.35	5.532	0	3.8724	0.00	-9.00	0.000
0.0167	6.37	5.532	1.002	3.8724	0.00	-8.00	0.000
0.0333	6.38	5.532	1.998	3.8724	0.00	-7.00	0.000
0.05	6.38	4.722	3	3.3054	-0.57	-6.00	1.087
0.0667	6.38	4.696	4.002	3.2872	-0.59	-5.00	1.122
0.0833	6.38	4.717	4.998	3.3019	-0.57	-4.00	1.094
0.1	6.39	4.724	6	3.3068	-0.57	-3.00	1.085
0.1167	6.39	4.742	7.002	3.3194	-0.55	-2.00	1.060
0.1333	6.39	4.772	7.998	3.3404	-0.53	-1.00	1.020
0.15	6.39	4.787	9	3.3509	-0.52	0.00	1.000
0.1667	6.41	4.792	10.002	3.3544	-0.52	1.00	0.993
0.1833	6.41	4.797	10.998	3.3579	-0.51	2.00	0.987
0.2	6.41	4.802	12	3.3614	-0.51	3.00	0.980
0.2167	6.41	4.807	13.002	3.3649	-0.51	4.00	0.973
0.2333	6.41	4.812	13.998	3.3684	-0.50	5.00	0.966
0.25	6.41	4.815	15	3.3705	-0.50	6.00	0.962
0.2667	6.42	4.82	16.002	3.374	-0.50	7.00	0.956
0.2833	6.42	4.825	16.998	3.3775	-0.49	8.00	0.949
0.3	6.42	4.827	18	3.3789	-0.49	9.00	0.946
0.3167	6.42	4.832	19.002	3.3824	-0.49	10.00	0.940
0.3333	6.42	4.835	19.998	3.3845	-0.49	11.00	0.936
0.35	6.42	4.84	21	3.388	-0.48	12.00	0.929
0.3667	6.42	4.843	22.002	3.3901	-0.48	13.00	0.925
0.3833	6.43	4.845	22.998	3.3915	-0.48	14.00	0.922
0.4	6.43	4.85	24	3.395	-0.48	15.00	0.915
0.4167	6.43	4.855	25.002	3.3985	-0.47	16.00	0.909
0.4333	6.43	4.858	25.998	3.4006	-0.47	17.00	0.905
0.45	6.43	4.86	27	3.402	-0.47	18.00	0.902
0.4667	6.43	4.863	28.002	3.4041	-0.47	19.00	0.898
0.4833	6.43	4.868	28.998	3.4076	-0.46	20.00	0.891
0.5	6.43	4.87	30	3.409	-0.46	21.00	0.889
0.5167	6.44	4.873	31.002	3.4111	-0.46	22.00	0.885
0.5333	6.44	4.875	31.998	3.4125	-0.46	23.00	0.882
0.55	6.44	4.88	33	3.416	-0.46	24.00	0.875
0.5667	6.44	4.885	34.002	3.4195	-0.45	25.00	0.868
0.5833	6.44	4.888	34.998	3.4216	-0.45	26.00	0.864
0.6	6.44	4.89	36	3.423	-0.45	27.00	0.862
0.6167	6.44	4.893	37.002	3.4251	-0.45	28.00	0.858
0.6333	6.44	4.898	37.998	3.4286	-0.44	29.00	0.851
0.65	6.44	4.9	39	3.43	-0.44	30.00	0.848
0.6667	6.44	4.903	40.002	3.4321	-0.44	31.00	0.844
0.6833	6.44	4.905	40.998	3.4335	-0.44	32.00	0.842
0.7	6.46	4.908	42	3.4356	-0.44	33.00	0.838
0.7167	6.46	4.913	43.002	3.4391	-0.43	34.00	0.831
0.7333	6.46	4.915	43.998	3.4405	-0.43	35.00	0.828
0.75	6.46	4.918	45	3.4426	-0.43	36.00	0.824
0.7667	6.46	4.92	46.002	3.444	-0.43	37.00	0.821
0.7833	6.46	4.92	46.998	3.444	-0.43	38.00	0.821
0.8	6.46	4.925	48	3.4475	-0.42	39.00	0.815
0.8167	6.46	4.928	49.002	3.4496	-0.42	40.00	0.811
0.8333	6.46	4.931	49.998	3.4517	-0.42	41.00	0.807
0.85	6.46	4.933	51	3.4531	-0.42	42.00	0.804
0.8667	6.46	4.936	52.002	3.4552	-0.42	43.00	0.800
0.8833	6.46	4.938	52.998	3.4566	-0.42	44.00	0.797
0.9	6.47	4.943	54	3.4601	-0.41	45.00	0.791
0.9167	6.47	4.943	55.002	3.4601	-0.41	46.00	0.791
0.9333	6.47	4.945	55.998	3.4615	-0.41	47.00	0.788

High K Estimator Spreadsheet		
Metric Units		
General Test Data		
Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP03-FLT2-02-TEST1	
Static Level:	3.73	m
Initial Water Level Change (H_0):	-1.247	m
Start Time for Test:	3	sec
Type of Aquifer:	Confined	
Type:	Rising	

Test Well Specs - "d" not used in confined case		
Depth to Bottom of Screen (from toc):	6.31	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	0.48	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	19.2024	m

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	$H(t)/H_0$ normalized head
------------	---------------	---------------	------------	------------			
0	6.39	5.324	0	3.7268	0.00	-3.00	0.000
0.0167	6.39	5.324	1.002	3.7268	0.00	-2.00	0.000
0.0333	6.41	3.656	1.998	2.5592	-1.17	-1.00	0.936
0.05	6.41	3.542	3	2.4794	-1.25	0.00	1.000
0.0667	6.41	3.575	4.002	2.5025	-1.22	1.00	0.981
0.0833	6.41	3.595	4.998	2.5165	-1.21	2.00	0.970
0.1	6.41	3.613	6	2.5291	-1.20	3.00	0.960
0.1167	6.41	3.628	7.002	2.5396	-1.19	4.00	0.952
0.1333	6.41	3.643	7.998	2.5501	-1.18	5.00	0.943
0.15	6.41	3.658	9	2.5606	-1.17	6.00	0.935
0.1667	6.41	3.671	10.002	2.5697	-1.16	7.00	0.928
0.1833	6.41	3.684	10.998	2.5788	-1.15	8.00	0.920
0.2	6.41	3.696	12	2.5872	-1.14	9.00	0.914
0.2167	6.41	3.709	13.002	2.5963	-1.13	10.00	0.906
0.2333	6.41	3.719	13.998	2.6033	-1.12	11.00	0.901
0.25	6.41	3.729	15	2.6103	-1.12	12.00	0.895
0.2667	6.41	3.742	16.002	2.6194	-1.11	13.00	0.888
0.2833	6.41	3.752	16.998	2.6264	-1.10	14.00	0.882
0.3	6.41	3.762	18	2.6334	-1.09	15.00	0.877
0.3167	6.41	3.772	19.002	2.6404	-1.09	16.00	0.871
0.3333	6.41	3.782	19.998	2.6474	-1.08	17.00	0.865
0.35	6.41	3.793	21	2.6551	-1.07	18.00	0.859
0.3667	6.41	3.803	22.002	2.6621	-1.06	19.00	0.854
0.3833	6.41	3.813	22.998	2.6691	-1.06	20.00	0.848
0.4	6.41	3.823	24	2.6761	-1.05	21.00	0.842
0.4167	6.41	3.833	25.002	2.6831	-1.04	22.00	0.837
0.4333	6.41	3.843	25.998	2.6901	-1.04	23.00	0.831
0.45	6.39	3.851	27	2.6957	-1.03	24.00	0.827
0.4667	6.39	3.861	28.002	2.7027	-1.02	25.00	0.821
0.4833	6.39	3.871	28.998	2.7097	-1.02	26.00	0.815
0.5	6.39	3.879	30	2.7153	-1.01	27.00	0.811
0.5167	6.39	3.886	31.002	2.7202	-1.01	28.00	0.807
0.5333	6.39	3.896	31.998	2.7272	-1.00	29.00	0.801
0.55	6.39	3.904	33	2.7328	-0.99	30.00	0.797
0.5667	6.39	3.914	34.002	2.7398	-0.99	31.00	0.791
0.5833	6.39	3.922	34.998	2.7454	-0.98	32.00	0.787
0.6	6.39	3.932	36	2.7524	-0.97	33.00	0.781
0.6167	6.39	3.94	37.002	2.758	-0.97	34.00	0.777
0.6333	6.39	3.947	37.998	2.7629	-0.96	35.00	0.773
0.65	6.39	3.957	39	2.7699	-0.96	36.00	0.767
0.6667	6.39	3.965	40.002	2.7755	-0.95	37.00	0.763
0.6833	6.39	3.972	40.998	2.7804	-0.95	38.00	0.759
0.7	6.39	3.98	42	2.786	-0.94	39.00	0.754
0.7167	6.39	3.988	43.002	2.7916	-0.94	40.00	0.750
0.7333	6.39	3.995	43.998	2.7965	-0.93	41.00	0.746
0.75	6.39	4.005	45	2.8035	-0.92	42.00	0.740
0.7667	6.39	4.013	46.002	2.8091	-0.92	43.00	0.736
0.7833	6.39	4.018	46.998	2.8126	-0.91	44.00	0.733
0.8	6.38	4.028	48	2.8196	-0.91	45.00	0.727
0.8167	6.38	4.036	49.002	2.8252	-0.90	46.00	0.723
0.8333	6.38	4.044	49.998	2.8308	-0.90	47.00	0.718
0.85	6.38	4.049	51	2.8343	-0.89	48.00	0.715
0.8667	6.38	4.056	52.002	2.8392	-0.89	49.00	0.712
0.8833	6.38	4.064	52.998	2.8448	-0.88	50.00	0.707
0.9	6.38	4.071	54	2.8497	-0.88	51.00	0.703
0.9167	6.38	4.079	55.002	2.8553	-0.87	52.00	0.699
0.9333	6.38	4.087	55.998	2.8609	-0.87	53.00	0.694

High K Estimator Spreadsheet

Metric Units

General Test Data

Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP03-FLT2-02-TEST1	
Static Level:	3.72	m
Initial Water Level Change (H_0):	-0.539	m
Start Time for Test:	9	sec
Type of Aquifer:	Confined	
Type:	Head	

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	6.31	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	0.48	m
Top of Screen to Water Table (d):		m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	19.2024	m

ET (min)	Celsius	PSI	Chan[1] time (s)	Chan[2] (m)	deviation from static (m)	pressure head time since tes	$H(t)/H_0$ normalized head
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0	5.89	5.31	0	3.717	0.00	-9.00	0.000
0.0167	5.91	5.31	1.002	3.717	0.00	-8.00	0.000
0.0333	5.91	5.312	1.998	3.7184	0.00	-7.00	-0.003
0.05	5.91	5.312	3	3.7184	0.00	-6.00	-0.003
0.0667	5.91	5.262	4.002	3.6834	-0.03	-5.00	0.062
0.0833	5.91	4.072	4.998	2.8504	-0.87	-4.00	1.608
0.1	5.92	4.497	6	3.1479	-0.57	-3.00	1.056
0.1167	5.91	4.5	7.002	3.15	-0.57	-2.00	1.052
0.1333	5.92	4.512	7.998	3.1584	-0.56	-1.00	1.036
0.15	5.92	4.54	9	3.178	-0.54	0.00	1.000
0.1667	5.92	4.545	10.002	3.1815	-0.54	1.00	0.994
0.1833	5.92	4.553	10.998	3.1871	-0.53	2.00	0.983
0.2	5.92	4.56	12	3.192	-0.53	3.00	0.974
0.2167	5.92	4.565	13.002	3.1955	-0.52	4.00	0.968
0.2333	5.92	4.571	13.998	3.1997	-0.52	5.00	0.960
0.25	5.92	4.576	15	3.2032	-0.51	6.00	0.953
0.2667	5.92	4.581	16.002	3.2067	-0.51	7.00	0.947
0.2833	5.92	4.586	16.998	3.2102	-0.51	8.00	0.940
0.3	5.92	4.591	18	3.2137	-0.50	9.00	0.934
0.3167	5.92	4.596	19.002	3.2172	-0.50	10.00	0.927
0.3333	5.92	4.598	19.998	3.2186	-0.50	11.00	0.925
0.35	5.92	4.606	21	3.2242	-0.49	12.00	0.914
0.3667	5.92	4.611	22.002	3.2277	-0.49	13.00	0.908
0.3833	5.93	4.616	22.998	3.2312	-0.49	14.00	0.901
0.4	5.93	4.618	24	3.2326	-0.48	15.00	0.899
0.4167	5.93	4.621	25.002	3.2347	-0.48	16.00	0.895
0.4333	5.93	4.629	25.998	3.2403	-0.48	17.00	0.884
0.45	5.93	4.631	27	3.2417	-0.48	18.00	0.882
0.4667	5.93	4.636	28.002	3.2452	-0.47	19.00	0.875
0.4833	5.93	4.641	28.998	3.2487	-0.47	20.00	0.869
0.5	5.93	4.646	30	3.2522	-0.46	21.00	0.862
0.5167	5.93	4.649	31.002	3.2543	-0.46	22.00	0.858
0.5333	5.93	4.654	31.998	3.2578	-0.46	23.00	0.852
0.55	5.93	4.656	33	3.2592	-0.46	24.00	0.849
0.5667	5.93	4.661	34.002	3.2627	-0.45	25.00	0.843
0.5833	5.93	4.666	34.998	3.2662	-0.45	26.00	0.836
0.6	5.93	4.669	36	3.2683	-0.45	27.00	0.832
0.6167	5.93	4.674	37.002	3.2718	-0.45	28.00	0.826
0.6333	5.93	4.677	37.998	3.2739	-0.44	29.00	0.822
0.65	5.93	4.682	39	3.2774	-0.44	30.00	0.816
0.6667	5.95	4.684	40.002	3.2788	-0.44	31.00	0.813
0.6833	5.93	4.689	40.998	3.2823	-0.43	32.00	0.806
0.7	5.95	4.692	42	3.2844	-0.43	33.00	0.803
0.7167	5.95	4.697	43.002	3.2879	-0.43	34.00	0.796
0.7333	5.95	4.699	43.998	3.2893	-0.43	35.00	0.794
0.75	5.95	4.702	45	3.2914	-0.43	36.00	0.790
0.7667	5.95	4.707	46.002	3.2949	-0.42	37.00	0.783
0.7833	5.95	4.712	46.998	3.2984	-0.42	38.00	0.777
0.8	5.95	4.714	48	3.2998	-0.42	39.00	0.774
0.8167	5.95	4.717	49.002	3.3019	-0.42	40.00	0.770
0.8333	5.95	4.722	49.998	3.3054	-0.41	41.00	0.764
0.85	5.95	4.724	51	3.3068	-0.41	42.00	0.761
0.8667	5.95	4.73	52.002	3.311	-0.41	43.00	0.753
0.8833	5.95	4.732	52.998	3.3124	-0.40	44.00	0.751
0.9	5.95	4.735	54	3.3145	-0.40	45.00	0.747
0.9167	5.95	4.74	55.002	3.318	-0.40	46.00	0.740
0.9333	5.95	4.742	55.998	3.3194	-0.40	47.00	0.738

High K Estimator Spreadsheet
Metric Units

General Test Data

Site Location:	Suncor
Date:	10/14/2003
Time:	
Test Designation:	SP03-FLT2-04-TEST1
Static Level:	4.23 m
Initial Water Level Change (H_0):	-0.493 m
Start Time for Test:	2 sec
Type of Aquifer:	Thin till, therefore could be confined or unconfined
Type:	Slug

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	10.86	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	0.845	m
Top of Screen to Water Table (d):	9.1006	m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	16.764	m

ET (min)	Chan[1] Celsius	Chan[2] PSI	time (s)	pressure head (m)	deviation from static (m)	time since tes	$H(t)/H_0$ normalized head
0	5.31	6.045	0	4.2315	0.00	-2.00	-0.003
0.0167	5.31	6.024	1.002	4.2168	-0.01	-1.00	0.027
0.0333	5.32	5.351	1.998	3.7457	-0.48	0.00	0.982
0.05	5.32	5.477	3	3.8339	-0.40	1.00	0.803
0.0667	5.32	5.576	4.002	3.9032	-0.33	2.00	0.663
0.0833	5.32	5.649	4.998	3.9543	-0.28	3.00	0.559
0.1	5.32	5.71	6	3.997	-0.23	4.00	0.473
0.1167	5.33	5.761	7.002	4.0327	-0.20	5.00	0.400
0.1333	5.33	5.804	7.998	4.0628	-0.17	6.00	0.339
0.15	5.33	5.839	9	4.0873	-0.14	7.00	0.289
0.1667	5.33	5.867	10.002	4.1069	-0.12	8.00	0.250
0.1833	5.33	5.892	10.998	4.1244	-0.11	9.00	0.214
0.2	5.33	5.912	12	4.1384	-0.09	10.00	0.186
0.2167	5.33	5.93	13.002	4.151	-0.08	11.00	0.160
0.2333	5.33	5.945	13.998	4.1615	-0.07	12.00	0.139
0.25	5.33	5.958	15	4.1706	-0.06	13.00	0.120
0.2667	5.33	5.968	16.002	4.1776	-0.05	14.00	0.106
0.2833	5.33	5.976	16.998	4.1832	-0.05	15.00	0.095
0.3	5.33	5.983	18	4.1881	-0.04	16.00	0.085
0.3167	5.33	5.988	19.002	4.1916	-0.04	17.00	0.078
0.3333	5.33	5.993	19.998	4.1951	-0.03	18.00	0.071
0.35	5.33	5.998	21	4.1986	-0.03	19.00	0.064
0.3667	5.33	6.004	22.002	4.2028	-0.03	20.00	0.055
0.3833	5.33	6.006	22.998	4.2042	-0.03	21.00	0.052
0.4	5.33	6.009	24	4.2063	-0.02	22.00	0.048
0.4167	5.32	6.011	25.002	4.2077	-0.02	23.00	0.045
0.4333	5.32	6.011	25.998	4.2077	-0.02	24.00	0.045
0.45	5.32	6.014	27	4.2098	-0.02	25.00	0.041
0.4667	5.32	6.016	28.002	4.2112	-0.02	26.00	0.038
0.4833	5.32	6.019	28.998	4.2133	-0.02	27.00	0.034
0.5	5.32	6.019	30	4.2133	-0.02	28.00	0.034
0.5167	5.32	6.019	31.002	4.2133	-0.02	29.00	0.034
0.5333	5.31	6.019	31.998	4.2133	-0.02	30.00	0.034
0.55	5.31	6.019	33	4.2133	-0.02	31.00	0.034
0.5667	5.31	6.022	34.002	4.2154	-0.01	32.00	0.030
0.5833	5.31	6.022	34.998	4.2154	-0.01	33.00	0.030
0.6	5.31	6.022	36	4.2154	-0.01	34.00	0.030
0.6167	5.31	6.022	37.002	4.2154	-0.01	35.00	0.030
0.6333	5.31	6.022	37.998	4.2154	-0.01	36.00	0.030

High K Estimator Spreadsheet **Metric Units**			**Test Well Specs - "d" not used in confined case**		
			Depth to Bottom of Screen (from toc):	10.86	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	0.845	m
Site Location:	Suncor		Top of Screen to Water Table (d):	9.1006	m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP03-FLT2-04-TEST2		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	4.22	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level			Modified Screen Radius (r_w*):	0.025	m
Change (H_0):	-0.987	m	Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	2	sec	Formation Thickness (B):	16.764	m
Type of Aquifer:	Thin till, therefore could be confined or unconfined				
Type:	Rising				

ET (min)	Chan[1] Celsius	Chan[2] PSI	time (s)	pressure head (m)	deviation from static (m)	time since tes	$H(t)/H_0$ normalized head
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0	5.2	6.024	0	4.2168	0.00	-2.00	0.003
0.0167	5.22	3.021	1.002	2.1147	-2.11	-1.00	2.133
0.0333	5.22	4.525	1.998	3.1675	-1.05	0.00	1.066
0.05	5.22	4.78	3	3.346	-0.87	1.00	0.886
0.0667	5.22	4.985	4.002	3.4895	-0.73	2.00	0.740
0.0833	5.22	5.155	4.998	3.6085	-0.61	3.00	0.620
0.1	5.22	5.292	6	3.7044	-0.52	4.00	0.522
0.1167	5.2	5.408	7.002	3.7856	-0.43	5.00	0.440
0.1333	5.2	5.505	7.998	3.8535	-0.37	6.00	0.371
0.15	5.2	5.586	9	3.9102	-0.31	7.00	0.314
0.1667	5.19	5.652	10.002	3.9564	-0.26	8.00	0.267
0.1833	5.19	5.71	10.998	3.997	-0.22	9.00	0.226
0.2	5.18	5.756	12	4.0292	-0.19	10.00	0.193
0.2167	5.18	5.796	13.002	4.0572	-0.16	11.00	0.165
0.2333	5.17	5.829	13.998	4.0803	-0.14	12.00	0.142
0.25	5.15	5.86	15	4.102	-0.12	13.00	0.120
0.2667	5.15	5.883	16.002	4.1181	-0.10	14.00	0.103
0.2833	5.14	5.903	16.998	4.1321	-0.09	15.00	0.089
0.3	5.13	5.921	18	4.1447	-0.08	16.00	0.076
0.3167	5.13	5.936	19.002	4.1552	-0.06	17.00	0.066
0.3333	5.11	5.949	19.998	4.1643	-0.06	18.00	0.056
0.35	5.1	5.96	21	4.172	-0.05	19.00	0.049
0.3667	5.09	5.967	22.002	4.1769	-0.04	20.00	0.044
0.3833	5.09	5.975	22.998	4.1825	-0.04	21.00	0.038
0.4	5.08	5.98	24	4.186	-0.03	22.00	0.034
0.4167	5.06	5.988	25.002	4.1916	-0.03	23.00	0.029
0.4333	5.05	5.991	25.998	4.1937	-0.03	24.00	0.027
0.45	5.04	5.996	27	4.1972	-0.02	25.00	0.023
0.4667	5.04	5.999	28.002	4.1993	-0.02	26.00	0.021
0.4833	5.03	6.001	28.998	4.2007	-0.02	27.00	0.020
0.5	5.01	6.004	30	4.2028	-0.02	28.00	0.017
0.5167	5	6.007	31.002	4.2049	-0.02	29.00	0.015
0.5333	5	6.009	31.998	4.2063	-0.01	30.00	0.014
0.55	4.99	6.01	33	4.207	-0.01	31.00	0.013
0.5667	4.97	6.01	34.002	4.207	-0.01	32.00	0.013
0.5833	4.97	6.012	34.998	4.2084	-0.01	33.00	0.012
0.6	4.96	6.013	36	4.2091	-0.01	34.00	0.011
0.6167	4.95	6.015	37.002	4.2105	-0.01	35.00	0.010
0.6333	4.94	6.016	37.998	4.2112	-0.01	36.00	0.009
0.65	4.94	6.016	39	4.2112	-0.01	37.00	0.009
0.6667	4.92	6.016	40.002	4.2112	-0.01	38.00	0.009
0.6833	4.92	6.016	40.998	4.2112	-0.01	39.00	0.009
0.7	4.91	6.019	42	4.2133	-0.01	40.00	0.007
0.7167	4.9	6.019	43.002	4.2133	-0.01	41.00	0.007
0.7333	4.9	6.019	43.998	4.2133	-0.01	42.00	0.007
0.75	4.88	6.019	45	4.2133	-0.01	43.00	0.007
0.7667	4.88	6.019	46.002	4.2133	-0.01	44.00	0.007
0.7833	4.87	6.019	46.998	4.2133	-0.01	45.00	0.007
0.8	4.87	6.019	48	4.2133	-0.01	46.00	0.007
0.8167	4.86	6.02	49.002	4.214	-0.01	47.00	0.006
0.8333	4.86	6.02	49.998	4.214	-0.01	48.00	0.006
0.85	4.85	6.02	51	4.214	-0.01	49.00	0.006
0.8667	4.85	6.02	52.002	4.214	-0.01	50.00	0.006
0.8833	4.83	6.02	52.998	4.214	-0.01	51.00	0.006
0.9	4.83	6.02	54	4.214	-0.01	52.00	0.006
0.9167	4.83	6.02	55.002	4.214	-0.01	53.00	0.006
0.9333	4.82	6.02	55.998	4.214	-0.01	54.00	0.006

High K Estimator Spreadsheet		**Test Well Specs - "d" not used in confined case**	
Metric Units		Depth to Bottom of Screen (from toc):	10.86 m
		Screen Length (b):	0.914 m
General Test Data		Depth to Static Water Level (from toc):	0.845 m
Site Location:	Suncor	Top of Screen to Water Table (d):	9.1006 m
Date:	10/14/2003	Radius of Well Screen (r_w):	0.025 m
Time:		Nominal Radius of Well Casing (r_{nc}):	0.025 m
Test Designation:	SP03-FLT2-04-TEST3	Radius of Transducer Cable (r_{tc}):	0.006 m
Static Level:	4.21 m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025 m
Initial Water Level		Modified Screen Radius (r_w*):	0.025 m
Change (H_0):	-0.268 m	Aspect Ratio (b/r_w*):	36.576
Start Time for Test:	7 sec	Formation Thickness (B):	16.764 m
Type of Aquifer:	Thin till, therefore could be confined or unconfined		
Type:	Slug		

ET (min)	Chan[1] Celsius	Chan[2] PSI	time (s)	pressure head (m)	deviation from static (m)	time since tes	$H(t)/H_0$ normalized head
0	4.57	6.027	0	4.2189	0.01	-7.00	-0.033
0.0167	4.58	6.03	1.002	4.221	0.01	-6.00	-0.041
0.0333	4.58	6.007	1.998	4.2049	-0.01	-5.00	0.019
0.05	4.58	6.042	3	4.2294	0.02	-4.00	-0.072
0.0667	4.58	4.316	4.002	3.0212	-1.19	-3.00	4.442
0.0833	4.58	4.918	4.998	3.4426	-0.77	-2.00	2.868
0.1	4.58	5.298	6	3.7086	-0.50	-1.00	1.874
0.1167	4.58	5.632	7.002	3.9424	-0.27	0.00	1.000
0.1333	4.58	5.693	7.998	3.9851	-0.22	1.00	0.840
0.15	4.58	5.749	9	4.0243	-0.19	2.00	0.694
0.1667	4.58	5.792	10.002	4.0544	-0.16	3.00	0.581
0.1833	4.58	5.827	10.998	4.0789	-0.13	4.00	0.490
0.2	4.57	5.858	12	4.1006	-0.11	5.00	0.409
0.2167	4.57	5.883	13.002	4.1181	-0.09	6.00	0.343
0.2333	4.57	5.906	13.998	4.1342	-0.08	7.00	0.283
0.25	4.57	5.923	15	4.1461	-0.06	8.00	0.239
0.2667	4.55	5.939	16.002	4.1573	-0.05	9.00	0.197
0.2833	4.55	5.952	16.998	4.1664	-0.04	10.00	0.163
0.3	4.55	5.962	18	4.1734	-0.04	11.00	0.137
0.3167	4.55	5.972	19.002	4.1804	-0.03	12.00	0.111
0.3333	4.54	5.98	19.998	4.186	-0.02	13.00	0.090
0.35	4.54	5.987	21	4.1909	-0.02	14.00	0.071
0.3667	4.54	5.99	22.002	4.193	-0.02	15.00	0.064
0.3833	4.54	5.997	22.998	4.1979	-0.01	16.00	0.045
0.4	4.53	6	24	4.2	-0.01	17.00	0.037
0.4167	4.53	6.005	25.002	4.2035	-0.01	18.00	0.024
0.4333	4.53	6.008	25.998	4.2056	0.00	19.00	0.016
0.45	4.51	6.01	27	4.207	0.00	20.00	0.011
0.4667	4.51	6.01	28.002	4.207	0.00	21.00	0.011
0.4833	4.51	6.013	28.998	4.2091	0.00	22.00	0.003
0.5	4.5	6.016	30	4.2112	0.00	23.00	-0.004
0.5167	4.5	6.016	31.002	4.2112	0.00	24.00	-0.004
0.5333	4.5	6.016	31.998	4.2112	0.00	25.00	-0.004
0.55	4.49	6.018	33	4.2126	0.00	26.00	-0.010
0.5667	4.49	6.018	34.002	4.2126	0.00	27.00	-0.010
0.5833	4.49	6.018	34.998	4.2126	0.00	28.00	-0.010
0.6	4.48	6.021	36	4.2147	0.00	29.00	-0.018
0.6167	4.48	6.019	37.002	4.2133	0.00	30.00	-0.012
0.6333	4.48	6.021	37.998	4.2147	0.00	31.00	-0.018
0.65	4.46	6.021	39	4.2147	0.00	32.00	-0.018
0.6667	4.46	6.021	40.002	4.2147	0.00	33.00	-0.018
0.6833	4.46	6.021	40.998	4.2147	0.00	34.00	-0.018
0.7	4.46	6.021	42	4.2147	0.00	35.00	-0.018
0.7167	4.45	6.022	43.002	4.2154	0.01	36.00	-0.020
0.7333	4.45	6.022	43.998	4.2154	0.01	37.00	-0.020
0.75	4.44	6.024	45	4.2168	0.01	38.00	-0.025
0.7667	4.44	6.022	46.002	4.2154	0.01	39.00	-0.020
0.7833	4.44	6.022	46.998	4.2154	0.01	40.00	-0.020
0.8	4.44	6.024	48	4.2168	0.01	41.00	-0.025

High K Estimator Spreadsheet
Metric Units

General Test Data

Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP03-FLT2-05-TEST1	
Static Level:	4.21	m
Initial Water Level Change (H_0):	-0.455	m
Start Time for Test:	3	sec
Type of Aquifer:	Thin till, therefore could be confined or unconfined	
Type:	Slug	

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	13.93	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	0.87	m
Top of Screen to Water Table (d):	12.146	m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	16.764	m

ET (min)	Chan[1] Celsius	Chan[2] PSI	time (s)	pressure head (m)	deviation from static (m)	time since tes	$H(t)/H_0$ normalized head
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0	5.29	6.014	0	4.2098	0.00	-3.00	0.000
0.0167	5.29	6.012	1.002	4.2084	0.00	-2.00	0.004
0.0333	5.31	4.48	1.998	3.136	-1.07	-1.00	2.359
0.05	5.31	5.364	3	3.7548	-0.4552	0.00	1.000
0.0667	5.31	5.483	4.002	3.8381	-0.37	1.00	0.817
0.0833	5.32	5.576	4.998	3.9032	-0.31	2.00	0.674
0.1	5.32	5.652	6	3.9564	-0.25	3.00	0.557
0.1167	5.32	5.713	7.002	3.9991	-0.21	4.00	0.463
0.1333	5.32	5.761	7.998	4.0327	-0.18	5.00	0.389
0.15	5.32	5.804	9	4.0628	-0.15	6.00	0.323
0.1667	5.32	5.837	10.002	4.0859	-0.12	7.00	0.273
0.1833	5.32	5.865	10.998	4.1055	-0.10	8.00	0.230
0.2	5.33	5.89	12	4.123	-0.09	9.00	0.191
0.2167	5.33	5.907	13.002	4.1349	-0.08	10.00	0.165
0.2333	5.33	5.923	13.998	4.1461	-0.06	11.00	0.140
0.25	5.33	5.938	15	4.1566	-0.05	12.00	0.117
0.2667	5.33	5.948	16.002	4.1636	-0.05	13.00	0.102
0.2833	5.33	5.958	16.998	4.1706	-0.04	14.00	0.087
0.3	5.33	5.966	18	4.1762	-0.03	15.00	0.074
0.3167	5.33	5.971	19.002	4.1797	-0.03	16.00	0.067
0.3333	5.33	5.976	19.998	4.1832	-0.03	17.00	0.059
0.35	5.33	5.981	21	4.1867	-0.02	18.00	0.051
0.3667	5.33	5.986	22.002	4.1902	-0.02	19.00	0.043
0.3833	5.33	5.988	22.998	4.1916	-0.02	20.00	0.040
0.4	5.33	5.988	24	4.1916	-0.02	21.00	0.040
0.4167	5.34	5.993	25.002	4.1951	-0.01	22.00	0.033
0.4333	5.33	5.996	25.998	4.1972	-0.01	23.00	0.028
0.45	5.34	5.996	27	4.1972	-0.01	24.00	0.028
0.4667	5.34	5.996	28.002	4.1972	-0.01	25.00	0.028
0.4833	5.34	5.998	28.998	4.1986	-0.01	26.00	0.025
0.5	5.33	5.998	30	4.1986	-0.01	27.00	0.025
0.5167	5.34	5.998	31.002	4.1986	-0.01	28.00	0.025
0.5333	5.34	5.998	31.998	4.1986	-0.01	29.00	0.025
0.55	5.34	5.998	33	4.1986	-0.01	30.00	0.025
0.5667	5.34	6.001	34.002	4.2007	-0.01	31.00	0.020
0.5833	5.34	6.001	34.998	4.2007	-0.01	32.00	0.020
0.6	5.33	6.001	36	4.2007	-0.01	33.00	0.020
0.6167	5.34	6.001	37.002	4.2007	-0.01	34.00	0.020
0.6333	5.34	6.001	37.998	4.2007	-0.01	35.00	0.020
0.65	5.34	6.003	39	4.2021	-0.01	36.00	0.017
0.6667	5.34	6.001	40.002	4.2007	-0.01	37.00	0.020
0.6833	5.34	6.003	40.998	4.2021	-0.01	38.00	0.017
0.7	5.34	6.001	42	4.2007	-0.01	39.00	0.020
0.7167	5.33	6.004	43.002	4.2028	-0.01	40.00	0.016
0.7333	5.34	6.003	43.998	4.2021	-0.01	41.00	0.017

High K Estimator Spreadsheet			**Test Well Specs - "d" not used in confined case**		
Metric Units			Depth to Bottom of Screen (from toc):	13.93	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	0.87	m
Site Location:	Suncor		Top of Screen to Water Table (d):	12.146	m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP03-FLT2-05-TEST1		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	4.20	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level			Modified Screen Radius (r_w*):	0.025	m
Change (H_0):	-1.019	m	Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	11	sec	Formation Thickness (B):	16.764	m
Type of Aquifer:	Thin till, therefore could be confined or unconfined				
Type:	Rising				

ET (min)	Chan[1] Celsius	Chan[2] PSI	time (s)	pressure head (m)	deviation from static (m)	time since tes	$H(t)/H_0$ normalized head
0	5.24	6.003	0	4.2021	0.00	-11.00	-0.002
0.0167	5.26	6.002	1.002	4.2014	0.00	-10.00	-0.001
0.0333	5.26	6.002	1.998	4.2014	0.00	-9.00	-0.001
0.05	5.26	6.005	3	4.2035	0.00	-8.00	-0.003
0.0667	5.26	6.005	4.002	4.2035	0.00	-7.00	-0.003
0.0833	5.26	6.005	4.998	4.2035	0.00	-6.00	-0.003
0.1	5.26	6.005	6	4.2035	0.00	-5.00	-0.003
0.1167	5.26	6.005	7.002	4.2035	0.00	-4.00	-0.003
0.1333	5.26	6.005	7.998	4.2035	0.00	-3.00	-0.003
0.15	5.26	6.005	9	4.2035	0.00	-2.00	-0.003
0.1667	5.26	4.792	10.002	3.3544	-0.85	-1.00	0.830
0.1833	5.26	4.544	10.998	3.1808	-1.02	0.00	1.000
0.2	5.26	4.8	12	3.36	-0.84	1.00	0.824
0.2167	5.26	5.002	13.002	3.5014	-0.70	2.00	0.685
0.2333	5.26	5.175	13.998	3.6225	-0.58	3.00	0.567
0.25	5.26	5.316	15	3.7212	-0.48	4.00	0.470
0.2667	5.26	5.433	16.002	3.8031	-0.40	5.00	0.389
0.2833	5.26	5.529	16.998	3.8703	-0.33	6.00	0.323
0.3	5.26	5.607	18	3.9249	-0.28	7.00	0.270
0.3167	5.26	5.676	19.002	3.9732	-0.23	8.00	0.223
0.3333	5.24	5.729	19.998	4.0103	-0.19	9.00	0.186
0.35	5.24	5.775	21	4.0425	-0.16	10.00	0.155
0.3667	5.24	5.813	22.002	4.0691	-0.13	11.00	0.128
0.3833	5.24	5.846	22.998	4.0922	-0.11	12.00	0.106
0.4	5.24	5.874	24	4.1118	-0.09	13.00	0.087
0.4167	5.23	5.894	25.002	4.1258	-0.07	14.00	0.073
0.4333	5.23	5.912	25.998	4.1384	-0.06	15.00	0.060
0.45	5.22	5.927	27	4.1489	-0.05	16.00	0.050
0.4667	5.22	5.94	28.002	4.158	-0.04	17.00	0.041
0.4833	5.22	5.95	28.998	4.165	-0.04	18.00	0.034
0.5	5.2	5.958	30	4.1706	-0.03	19.00	0.029
0.5167	5.2	5.965	31.002	4.1755	-0.02	20.00	0.024
0.5333	5.2	5.973	31.998	4.1811	-0.02	21.00	0.019
0.55	5.19	5.976	33	4.1832	-0.02	22.00	0.016
0.5667	5.19	5.981	34.002	4.1867	-0.01	23.00	0.013
0.5833	5.18	5.983	34.998	4.1881	-0.01	24.00	0.012
0.6	5.18	5.986	36	4.1902	-0.01	25.00	0.010
0.6167	5.17	5.989	37.002	4.1923	-0.01	26.00	0.008
0.6333	5.17	5.991	37.998	4.1937	-0.01	27.00	0.006
0.65	5.15	5.994	39	4.1958	0.00	28.00	0.004
0.6667	5.15	5.997	40.002	4.1979	0.00	29.00	0.002
0.6833	5.15	5.994	40.998	4.1958	0.00	30.00	0.004
0.7	5.14	5.997	42	4.1979	0.00	31.00	0.002
0.7167	5.14	5.999	43.002	4.1993	0.00	32.00	0.001
0.7333	5.13	5.997	43.998	4.1979	0.00	33.00	0.002
0.75	5.13	6	45	4.2	0.00	34.00	0.000
0.7667	5.11	6	46.002	4.2	0.00	35.00	0.000
0.7833	5.11	6	46.998	4.2	0.00	36.00	0.000
0.8	5.11	6	48	4.2	0.00	37.00	0.000
0.8167	5.1	6	49.002	4.2	0.00	38.00	0.000
0.8333	5.1	6	49.998	4.2	0.00	39.00	0.000
0.85	5.1	6	51	4.2	0.00	40.00	0.000
0.8667	5.09	6	52.002	4.2	0.00	41.00	0.000
0.8833	5.09	6	52.998	4.2	0.00	42.00	0.000
0.9	5.08	6	54	4.2	0.00	43.00	0.000
0.9167	5.08	6.003	55.002	4.2021	0.00	44.00	-0.002
0.9333	5.06	6.001	55.998	4.2007	0.00	45.00	-0.001

High K Estimator Spreadsheet
Metric Units

General Test Data

Site Location: Suncor
Date: 10/14/2003
Time:
Test Designation: SP03-FLT2-05-TEST1
Static Level: 4.21 m
Initial Water Level Change (H_0): -0.576 m
Start Time for Test: 3 sec
Type of Aquifer: Thin till, therefore could be confined or unconfined
Type: Slug

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc): 13.93 m
Screen Length (b): 0.914 m
Depth to Static Water Level (from toc): 0.87 m
Top of Screen to Water Table (d): 12.146 m
Radius of Well Screen (r_w): 0.025 m
Nominal Radius of Well Casing (r_{nc}): 0.025 m
Radius of Transducer Cable (r_{tc}): 0.006 m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5): 0.025 m
Modified Screen Radius (r_w*): 0.025 m
Aspect Ratio (b/r_w*): 36.576
Formation Thickness (B): 16.764 m

ET (min)	Chan[1] Celsius	Chan[2] PSI	time (s)	pressure head (m)	deviation from static (m)	time since tes	H(t)/H_0 normalized head
------------	---------------	---------------	------------	------------			
0	4.71	6.01	0	4.207	0.00	-3.00	0.005
0.0167	4.72	6.009	1.002	4.2063	0.00	-2.00	0.006
0.0333	4.72	6.009	1.998	4.2063	0.00	-1.00	0.006
0.05	4.72	5.192	3	3.6344	-0.58	0.00	1.000
0.0667	4.72	5.326	4.002	3.7282	-0.48	1.00	0.837
0.0833	4.72	5.447	4.998	3.8129	-0.40	2.00	0.690
0.1	4.72	5.546	6	3.8822	-0.33	3.00	0.569
0.1167	4.71	5.627	7.002	3.9389	-0.27	4.00	0.471
0.1333	4.71	5.693	7.998	3.9851	-0.22	5.00	0.391
0.15	4.71	5.746	9	4.0222	-0.19	6.00	0.326
0.1667	4.71	5.789	10.002	4.0523	-0.16	7.00	0.274
0.1833	4.71	5.827	10.998	4.0789	-0.13	8.00	0.228
0.2	4.71	5.858	12	4.1006	-0.11	9.00	0.190
0.2167	4.71	5.88	13.002	4.116	-0.09	10.00	0.163
0.2333	4.69	5.901	13.998	4.1307	-0.08	11.00	0.138
0.25	4.71	5.918	15	4.1426	-0.07	12.00	0.117
0.2667	4.69	5.934	16.002	4.1538	-0.06	13.00	0.098
0.2833	4.69	5.947	16.998	4.1629	-0.05	14.00	0.082
0.3	4.69	5.954	18	4.1678	-0.04	15.00	0.073
0.3167	4.69	5.964	19.002	4.1748	-0.04	16.00	0.061
0.3333	4.68	5.97	19.998	4.179	-0.03	17.00	0.054
0.35	4.68	5.977	21	4.1839	-0.03	18.00	0.045
0.3667	4.68	5.98	22.002	4.186	-0.02	19.00	0.042
0.3833	4.68	5.985	22.998	4.1895	-0.02	20.00	0.036
0.4	4.68	5.987	24	4.1909	-0.02	21.00	0.033
0.4167	4.68	5.99	25.002	4.193	-0.02	22.00	0.030
0.4333	4.67	5.993	25.998	4.1951	-0.01	23.00	0.026
0.45	4.67	5.995	27	4.1965	-0.01	24.00	0.023
0.4667	4.67	5.995	28.002	4.1965	-0.01	25.00	0.023
0.4833	4.67	5.998	28.998	4.1986	-0.01	26.00	0.020
0.5	4.67	5.998	30	4.1986	-0.01	27.00	0.020
0.5167	4.67	6	31.002	4.2	-0.01	28.00	0.017
0.5333	4.65	6	31.998	4.2	-0.01	29.00	0.017
0.55	4.65	6	33	4.2	-0.01	30.00	0.017
0.5667	4.65	6.003	34.002	4.2021	-0.01	31.00	0.014
0.5833	4.65	6	34.998	4.2	-0.01	32.00	0.017
0.6	4.65	6.003	36	4.2021	-0.01	33.00	0.014
0.6167	4.65	6.003	37.002	4.2021	-0.01	34.00	0.014
0.6333	4.65	6.003	37.998	4.2021	-0.01	35.00	0.014
0.65	4.64	6.003	39	4.2021	-0.01	36.00	0.014
0.6667	4.64	6.003	40.002	4.2021	-0.01	37.00	0.014
0.6833	4.64	6.003	40.998	4.2021	-0.01	38.00	0.014
0.7	4.64	6.003	42	4.2021	-0.01	39.00	0.014
0.7167	4.64	6.003	43.002	4.2021	-0.01	40.00	0.014
0.7333	4.64	6.003	43.998	4.2021	-0.01	41.00	0.014
0.75	4.64	6.003	45	4.2021	-0.01	42.00	0.014
0.7667	4.63	6.003	46.002	4.2021	-0.01	43.00	0.014
0.7833	4.63	6.003	46.998	4.2021	-0.01	44.00	0.014
0.8	4.63	6.003	48	4.2021	-0.01	45.00	0.014
0.8167	4.63	6.003	49.002	4.2021	-0.01	46.00	0.014
0.8333	4.63	6.006	49.998	4.2042	-0.01	47.00	0.010
0.85	4.63	6.006	51	4.2042	-0.01	48.00	0.010
0.8667	4.63	6.003	52.002	4.2021	-0.01	49.00	0.014
0.8833	4.63	6.003	52.998	4.2021	-0.01	50.00	0.014
0.9	4.62	6.006	54	4.2042	-0.01	51.00	0.010

High K Estimator Spreadsheet

Metric Units

Test Well Specs - "d" not used in confined case

			Depth to Bottom of Screen (from toc):	6.65	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	0.815	m
Site Location:	Suncor		Top of Screen to Water Table (d):	15.035	m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP03-FLT2-06-TEST1		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	4.26	m	Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level			Modified Screen Radius (r_w*):	0.025	m
Change (H_0):	-0.402	m	Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	6	sec	Formation Thickness (B):	16.764	m
Type of Aquifer:	Thin till, therefore could be confined or unconfined				
Type:	Head				

ET (min)	Chan[1] Celsius	Chan[2] PSI	time (s)	pressure head (m)	deviation from static (m)	time since tes	H(t)/H_0 normalized head
0	5.37	6.079	0	4.2553	0.00	-6.00	0.012
0.0167	5.38	6.076	1.002	4.2532	-0.01	-5.00	0.017
0.0333	5.38	6.084	1.998	4.2588	0.00	-4.00	0.003
0.05	5.38	6.084	3	4.2588	0.00	-3.00	0.003
0.0667	5.38	6.084	4.002	4.2588	0.00	-2.00	0.003
0.0833	5.38	5.97	4.998	4.179	-0.08	-1.00	0.202
0.1	5.38	5.512	6	3.8584	-0.40	0.00	1.000
0.1167	5.38	5.522	7.002	3.8654	-0.39	1.00	0.983
0.1333	5.38	5.633	7.998	3.9431	-0.32	2.00	0.789
0.15	5.38	5.709	9	3.9963	-0.26	3.00	0.657
0.1667	5.38	5.77	10.002	4.039	-0.22	4.00	0.550
0.1833	5.38	5.818	10.998	4.0726	-0.19	5.00	0.467
0.2	5.38	5.858	12	4.1006	-0.16	6.00	0.397
0.2167	5.38	5.891	13.002	4.1237	-0.14	7.00	0.339
0.2333	5.38	5.917	13.998	4.1419	-0.12	8.00	0.294
0.25	5.38	5.939	15	4.1573	-0.10	9.00	0.256
0.2667	5.38	5.957	16.002	4.1699	-0.09	10.00	0.224
0.2833	5.38	5.972	16.998	4.1804	-0.08	11.00	0.198
0.3	5.38	5.985	18	4.1895	-0.07	12.00	0.176
0.3167	5.38	5.998	19.002	4.1986	-0.06	13.00	0.153
0.3333	5.38	6.008	19.998	4.2056	-0.05	14.00	0.135
0.35	5.38	6.015	21	4.2105	-0.05	15.00	0.123
0.3667	5.38	6.02	22.002	4.214	-0.05	16.00	0.115
0.3833	5.38	6.028	22.998	4.2196	-0.04	17.00	0.101
0.4	5.38	6.033	24	4.2231	-0.04	18.00	0.092
0.4167	5.38	6.036	25.002	4.2252	-0.03	19.00	0.087
0.4333	5.38	6.041	25.998	4.2287	-0.03	20.00	0.078
0.45	5.37	6.043	27	4.2301	-0.03	21.00	0.074
0.4667	5.37	6.046	28.002	4.2322	-0.03	22.00	0.069
0.4833	5.37	6.051	28.998	4.2357	-0.02	23.00	0.061
0.5	5.37	6.051	30	4.2357	-0.02	24.00	0.061
0.5167	5.37	6.053	31.002	4.2371	-0.02	25.00	0.057
0.5333	5.37	6.056	31.998	4.2392	-0.02	26.00	0.052
0.55	5.37	6.059	33	4.2413	-0.02	27.00	0.047
0.5667	5.37	6.059	34.002	4.2413	-0.02	28.00	0.047
0.5833	5.37	6.061	34.998	4.2427	-0.02	29.00	0.043
0.6	5.37	6.061	36	4.2427	-0.02	30.00	0.043
0.6167	5.37	6.064	37.002	4.2448	-0.02	31.00	0.038
0.6333	5.37	6.064	37.998	4.2448	-0.02	32.00	0.038
0.65	5.36	6.064	39	4.2448	-0.02	33.00	0.038
0.6667	5.36	6.064	40.002	4.2448	-0.02	34.00	0.038
0.6833	5.36	6.064	40.998	4.2448	-0.02	35.00	0.038
0.7	5.36	6.066	42	4.2462	-0.01	36.00	0.034
0.7167	5.36	6.066	43.002	4.2462	-0.01	37.00	0.034
0.7333	5.36	6.066	43.998	4.2462	-0.01	38.00	0.034
0.75	5.36	6.069	45	4.2483	-0.01	39.00	0.029
0.7667	5.36	6.069	46.002	4.2483	-0.01	40.00	0.029
0.7833	5.36	6.069	46.998	4.2483	-0.01	41.00	0.029
0.8	5.36	6.069	48	4.2483	-0.01	42.00	0.029
0.8167	5.36	6.069	49.002	4.2483	-0.01	43.00	0.029
0.8333	5.34	6.069	49.998	4.2483	-0.01	44.00	0.029
0.85	5.34	6.069	51	4.2483	-0.01	45.00	0.029
0.8667	5.34	6.069	52.002	4.2483	-0.01	46.00	0.029
0.8833	5.34	6.069	52.998	4.2483	-0.01	47.00	0.029
0.9	5.34	6.069	54	4.2483	-0.01	48.00	0.029
0.9167	5.34	6.072	55.002	4.2504	-0.01	49.00	0.024
0.9333	5.34	6.072	55.998	4.2504	-0.01	50.00	0.024

High K Estimator Spreadsheet

Metric Units

General Test Data

Site Location:	Suncor	
Date:	10/14/2003	
Time:		
Test Designation:	SP03-FLT2-06-TEST2	
Static Level:	4.26	m
Initial Water Level Change (H_0):	-0.938	m
Start Time for Test:	3	sec
Type of Aquifer:	Thin till, therefore could be confined or unconfined	
Type:	Rising	

Test Well Specs - "d" not used in confined case

Depth to Bottom of Screen (from toc):	6.65	m
Screen Length (b):	0.914	m
Depth to Static Water Level (from toc):	0.815	m
Top of Screen to Water Table (d):	15.035	m
Radius of Well Screen (r_w):	0.025	m
Nominal Radius of Well Casing (r_{nc}):	0.025	m
Radius of Transducer Cable (r_{tc}):	0.006	m
Effective Casing Radius (r_c =(r_{nc}^2-r_{tc}^2)^0.5):	0.025	m
Modified Screen Radius (r_w*):	0.025	m
Aspect Ratio (b/r_w*):	36.576	
Formation Thickness (B):	16.764	m

ET (min)	Chan[1] Celsius	Chan[2] PSI	time (s)	pressure head (m)	deviation from static (m)	time since tes	$H(t)/H_0$ normalized head
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0	5.14	6.078	0	4.2546	-0.01	-3.00	0.006
0.0167	5.14	6.078	1.002	4.2546	-0.01	-2.00	0.006
0.0333	5.15	5.931	1.998	4.1517	-0.11	-1.00	0.115
0.05	5.15	4.746	3	3.3222	-0.94	0.00	1.000
0.0667	5.15	4.837	4.002	3.3859	-0.87	1.00	0.932
0.0833	5.15	5.07	4.998	3.549	-0.71	2.00	0.758
0.1	5.15	5.25	6	3.675	-0.59	3.00	0.624
0.1167	5.15	5.387	7.002	3.7709	-0.49	4.00	0.522
0.1333	5.15	5.498	7.998	3.8486	-0.41	5.00	0.439
0.15	5.15	5.584	9	3.9088	-0.35	6.00	0.374
0.1667	5.15	5.655	10.002	3.9585	-0.30	7.00	0.321
0.1833	5.15	5.716	10.998	4.0012	-0.26	8.00	0.276
0.2	5.14	5.766	12	4.0362	-0.22	9.00	0.239
0.2167	5.14	5.804	13.002	4.0628	-0.20	10.00	0.210
0.2333	5.13	5.84	13.998	4.088	-0.17	11.00	0.183
0.25	5.13	5.87	15	4.109	-0.15	12.00	0.161
0.2667	5.13	5.896	16.002	4.1272	-0.13	13.00	0.142
0.2833	5.11	5.916	16.998	4.1412	-0.12	14.00	0.127
0.3	5.11	5.934	18	4.1538	-0.11	15.00	0.113
0.3167	5.1	5.949	19.002	4.1643	-0.10	16.00	0.102
0.3333	5.1	5.965	19.998	4.1755	-0.08	17.00	0.090
0.35	5.09	5.975	21	4.1825	-0.08	18.00	0.083
0.3667	5.09	5.985	22.002	4.1895	-0.07	19.00	0.075
0.3833	5.08	5.995	22.998	4.1965	-0.06	20.00	0.068
0.4	5.08	6.003	24	4.2021	-0.06	21.00	0.062
0.4167	5.06	6.008	25.002	4.2056	-0.05	22.00	0.058
0.4333	5.06	6.013	25.998	4.2091	-0.05	23.00	0.054
0.45	5.05	6.021	27	4.2147	-0.05	24.00	0.048
0.4667	5.05	6.024	28.002	4.2168	-0.04	25.00	0.046
0.4833	5.04	6.029	28.998	4.2203	-0.04	26.00	0.042
0.5	5.04	6.032	30	4.2224	-0.04	27.00	0.040
0.5167	5.03	6.037	31.002	4.2259	-0.03	28.00	0.036
0.5333	5.03	6.039	31.998	4.2273	-0.03	29.00	0.035
0.55	5.01	6.042	33	4.2294	-0.03	30.00	0.033
0.5667	5.01	6.045	34.002	4.2315	-0.03	31.00	0.030
0.5833	5.01	6.045	34.998	4.2315	-0.03	32.00	0.030
0.6	5	6.047	36	4.2329	-0.03	33.00	0.029
0.6167	5	6.05	37.002	4.235	-0.03	34.00	0.027
0.6333	5	6.05	37.998	4.235	-0.03	35.00	0.027
0.65	4.99	6.053	39	4.2371	-0.02	36.00	0.024
0.6667	4.99	6.053	40.002	4.2371	-0.02	37.00	0.024
0.6833	4.97	6.055	40.998	4.2385	-0.02	38.00	0.023
0.7	4.97	6.055	42	4.2385	-0.02	39.00	0.023
0.7167	4.97	6.055	43.002	4.2385	-0.02	40.00	0.023
0.7333	4.96	6.058	43.998	4.2406	-0.02	41.00	0.021
0.75	4.96	6.058	45	4.2406	-0.02	42.00	0.021
0.7667	4.96	6.061	46.002	4.2427	-0.02	43.00	0.018
0.7833	4.96	6.061	46.998	4.2427	-0.02	44.00	0.018
0.8	4.95	6.061	48	4.2427	-0.02	45.00	0.018
0.8167	4.95	6.061	49.002	4.2427	-0.02	46.00	0.018
0.8333	4.95	6.061	49.998	4.2427	-0.02	47.00	0.018
0.85	4.94	6.061	51	4.2427	-0.02	48.00	0.018
0.8667	4.94	6.064	52.002	4.2448	-0.02	49.00	0.016
0.8833	4.94	6.064	52.998	4.2448	-0.02	50.00	0.016
0.9	4.94	6.064	54	4.2448	-0.02	51.00	0.016

High K Estimator Spreadsheet			**Test Well Specs - "d" not used in confined case**		
Metric Units			Depth to Bottom of Screen (from toc):	6.65	m
			Screen Length (b):	0.914	m
General Test Data			Depth to Static Water Level (from toc):	0.815	m
Site Location:	Suncor		Top of Screen to Water Table (d):	15.035	m
Date:	10/14/2003		Radius of Well Screen (r_w):	0.025	m
Time:			Nominal Radius of Well Casing (r_{nc}):	0.025	m
Test Designation:	SP03-FLT2-06-TEST1		Radius of Transducer Cable (r_{tc}):	0.006	m
Static Level:	4.25	m	Effective Casing Radius ($r_c = (r_{nc}$^2-r_{tc}^2)^0.5):	0.025	m
Initial Water Level			Modified Screen Radius (r_w*):	0.025	m
Change (H_0):	-0.425	m	Aspect Ratio (b/r_w*):	36.576	
Start Time for Test:	39	sec	Formation Thickness (B):	16.764	m
Type of Aquifer:	Thin till, therefore could be confined or unconfined				
Type:	Slug				

ET (min)	Celsius	PSI	time (s)	pressure head (m)	deviation from static (m)	time since tes	$H(t)/H_0$ normalized head
0	4.78	6.069	0	4.2483	0.00	-39.00	0.004
0.0167	4.78	6.072	1.002	4.2504	0.00	-38.00	-0.001
0.0333	4.8	6.074	1.998	4.2518	0.00	-37.00	-0.004
0.05	4.8	6.074	3	4.2518	0.00	-36.00	-0.004
0.0667	4.78	6.074	4.002	4.2518	0.00	-35.00	-0.004
0.0833	4.8	6.074	4.998	4.2518	0.00	-34.00	-0.004
0.1	4.78	6.074	6	4.2518	0.00	-33.00	-0.004
0.1167	4.8	6.074	7.002	4.2518	0.00	-32.00	-0.004
0.1333	4.78	6.074	7.998	4.2518	0.00	-31.00	-0.004
0.15	4.78	6.074	9	4.2518	0.00	-30.00	-0.004
0.1667	4.78	6.074	10.002	4.2518	0.00	-29.00	-0.004
0.1833	4.78	6.074	10.998	4.2518	0.00	-28.00	-0.004
0.2	4.78	6.074	12	4.2518	0.00	-27.00	-0.004
0.2167	4.78	6.074	13.002	4.2518	0.00	-26.00	-0.004
0.2333	4.78	6.074	13.998	4.2518	0.00	-25.00	-0.004
0.25	4.78	6.077	15	4.2539	0.00	-24.00	-0.009
0.2667	4.78	6.077	16.002	4.2539	0.00	-23.00	-0.009
0.2833	4.78	6.074	16.998	4.2518	0.00	-22.00	-0.004
0.3	4.78	6.074	18	4.2518	0.00	-21.00	-0.004
0.3167	4.78	6.074	19.002	4.2518	0.00	-20.00	-0.004
0.3333	4.78	6.077	19.998	4.2539	0.00	-19.00	-0.009
0.35	4.78	6.074	21	4.2518	0.00	-18.00	-0.004
0.3667	4.78	6.077	22.002	4.2539	0.00	-17.00	-0.009
0.3833	4.78	6.077	22.998	4.2539	0.00	-16.00	-0.009
0.4	4.78	6.074	24	4.2518	0.00	-15.00	-0.004
0.4167	4.78	6.077	25.002	4.2539	0.00	-14.00	-0.009
0.4333	4.78	6.077	25.998	4.2539	0.00	-13.00	-0.009
0.45	4.78	6.077	27	4.2539	0.00	-12.00	-0.009
0.4667	4.78	6.16	28.002	4.312	0.06	-11.00	-0.146
0.4833	4.78	6.153	28.998	4.3071	0.06	-10.00	-0.134
0.5	4.77	6.112	30	4.2784	0.03	-9.00	-0.067
0.5167	4.78	6.132	31.002	4.2924	0.04	-8.00	-0.100
0.5333	4.77	6.1	31.998	4.27	0.02	-7.00	-0.047
0.55	4.77	6.12	33	4.284	0.03	-6.00	-0.080
0.5667	4.77	6.107	34.002	4.2749	0.02	-5.00	-0.059
0.5833	4.77	6.1	34.998	4.27	0.02	-4.00	-0.047
0.6	4.77	6.089	36	4.2623	0.01	-3.00	-0.029
0.6167	4.77	6.049	37.002	4.2343	-0.02	-2.00	0.037
0.6333	4.77	6.115	37.998	4.2805	0.03	-1.00	-0.072
0.65	4.77	5.464	39	3.8248	-0.43	0.00	1.000
0.6667	4.77	5.53	40.002	3.871	-0.38	1.00	0.891
0.6833	4.77	5.639	40.998	3.9473	-0.30	2.00	0.712
0.7	4.77	5.717	42	4.0019	-0.25	3.00	0.583
0.7167	4.77	5.776	43.002	4.0432	-0.21	4.00	0.486
0.7333	4.77	5.824	43.998	4.0768	-0.17	5.00	0.407
0.75	4.77	5.862	45	4.1034	-0.15	6.00	0.345
0.7667	4.77	5.892	46.002	4.1244	-0.13	7.00	0.295
0.7833	4.77	5.917	46.998	4.1419	-0.11	8.00	0.254
0.8	4.77	5.94	48	4.158	-0.09	9.00	0.216
0.8167	4.77	5.958	49.002	4.1706	-0.08	10.00	0.187
0.8333	4.77	5.973	49.998	4.1811	-0.07	11.00	0.162
0.85	4.76	5.986	51	4.1902	-0.06	12.00	0.141
0.8667	4.76	5.996	52.002	4.1972	-0.05	13.00	0.124
0.8833	4.76	6.006	52.998	4.2042	-0.05	14.00	0.108
0.9	4.76	6.014	54	4.2098	-0.04	15.00	0.095
0.9167	4.76	6.021	55.002	4.2147	-0.04	16.00	0.083
0.9333	4.74	6.027	55.998	4.2189	-0.03	17.00	0.073

SP02-FLT2-08 1.273

Time	Date	Depth to water	Elasped Minutes	feet	Displacement (ft)	Elasped Minutes	Displacement (ft)
13:25:00	14-Oct	5.405	0	17.73294	4.132	0	4.132
13:25:30	14-Oct	5.395	0.5	this doesn't make	4.122	0.5	4.122
13:26:00	14-Oct	5.386	1	sense considering	4.113	1	4.113
13:27:00	14-Oct	5.375	2	well is only	4.102	2	4.102
13:28:00	14-Oct	5.363	3	14' deep	4.09	3	4.09
13:29:00	14-Oct	5.354	4	assuming the	4.081	4	4.081
13:30:00	14-Oct	5.344	5	measurements are	4.071	5	4.071
13:31:00	14-Oct	5.332	6	in feet	4.059	6	4.059
13:32:00	14-Oct	5.32	7		4.047	7	4.047
13:33:00	14-Oct	5.307	8		4.034	8	4.034
13:34:00	14-Oct	5.293	9		4.02	9	4.02
13:35:00	14-Oct	5.282	10		4.009	10	4.009
14:38:00	14-Oct	4.504	73		3.231	73	3.231
13:40:00	15-Oct	1.274	1455		0.001	1455	0.001

Appendix H

Groundwater Sampling Guidelines, Muskeg River Mine

H.1 Sampling Event Preparation

- Contact the laboratory performing the various chemical analyses so the sample bottles and preservatives (if required) can be shipped to the site.
- Since organic and inorganic desorbing agents are to be used, check with laboratories regarding potential analytical interferences or contamination potential.
- Organize shipment details with the Albian Sands warehouse to ship the samples daily.
- Order all necessary pumps, coolers, rock hammers, drill rods, filters and accessories from the supplier in advance of the sampling event.
- Arrange for a deionized water supply for decontamination.
- Service the generator that powers the heaters and pump.
- Arrange for living quarters, travel, truck rental, etc

H.2 Equipment

H.2.1 Water Supply

- Discuss with Noreen. Only water showing zero conductivity is allowed as rinse water (i.e. deionised water).

H.2.2 Maintenance and Storage

- store equipment in sealed containers or wrapped in aluminium foil/plastic wrap; and
- transport equipment to the sampling site in sealed containers.

H.2.3 Dissolved Oxygen Meter

Follow the manufacturer's recommendations for short-term (field) storage and for performance checks. Protect instruments and sensors from being jostled during transportation, from sudden impacts, sudden temperature changes, and extremes of heat and cold.

H.3 Water Sample Collection

H.3.1 General

A step-by-step checklist for sample collection is outlined in the following subsections. Always wear a fresh pair of disposable latex gloves throughout the sampling process.

H.3.2 Step 1 – Prepare for Sampling

H.3.2.1 Field sampling record

- location;
- date and time of sample collection;

- climatic conditions, including air temperature;
- field observations of sampling event;
- intake depth;
- pumping rate when driving downward;
- depth yield - high, medium or low;
- sample withdrawal procedure/equipment;
- collection method;
- sampling sequence;
- types of sample bottles used;
- parameters requested for analysis;
- field analysis data and method(s) used;
- name of sample collector; and
- field parameter calibration.

H.3.2.2 DO Meter (Radke et al., 1998)

Check the temperature-display thermistor in the DO sensor against a certified thermometer over the normal operating range of the instrument. If a thermistor reading is incorrect, apply a correction or return the instrument to the manufacturer for adjustment.

Check the instrument batteries and all electrical connections.

Test the instrument to ensure that it will read zero in a DO-free solution. If the instrument reading exceeds 0.2 mg/L, then the sensor membrane and electrolyte (if present) need to be replaced or the sensor needs to be repaired. Before repairing or replacing the sensor, check zero DO again with a freshly prepared zero DO solution.

H.3.3 Step 2 -Decontamination

The US:EPA Groundwater Monitoring Technical Guidance Report (1992) provides recommendations for cleaning sampling equipment used when organic and inorganic constituents are of interest. These procedures have been adapted below and are to be used at the start of the sampling program and with each change in location:

1. Calculate the volume needed for one rinse of the system. The profiler tip has a volume of 5 mL and the stainless steel tubing has around 3 mL per meter. At a depth of 10 m, this means that one tubing volume is 35 mL. Since I also want to rinse the bottle connectors, one rinse volume is 325 mL (35+40+250). Step 4 outlines a method that used only 100 mL of rinse solution.

2. Wash the equipment with a nonphosphate detergent (Sparkleen®) and scrub with an inert brush. For internal mechanisms and tubing, circulate 1L (3 rinse volumes) of the detergent solution through the equipment, after the entire profiling system has been assembled and bottles inserted in sampling manifold.

3. Rinse with 1.5 L DI water.

4. Rinse with 150 mL of dilute of 1% hydrochloric acid (low concentration due to stainless steel tubing of the profiler). Place the discharge end of the tubing into the cylinder, close the tubing to the bottles and blow 100 mL through the system to remove any sorbed metals. Open the stopcocks to the bottle, close the stopcock to the profiler and blow the 50 mL through the tubing. Remove the bottles, empty into waste container and replace bottles.

5. The hose is then flushed with 5 rinse volumes (1.5 L) of DI water to remove the acid wash solution.

6. Place equipment in an inert container or wrap in clean plastic or aluminium foil for storage and transport.

7. Groundwater may be poured out at some distance from the profile location. The 1% HCl solution may be further diluted and poured down a drain.

H.3.4 Step 3 – Preassembly and Test of the Waterloo Profiler

(University of Waterloo 2002)

Using a magnifying glass, check the screened ports in the drive tip for particulate matter, silicone, and distortion of the screens and insure the screens are held tight by the setscrews. The fitting in the drive tip should be smeared with silicone and threaded very tightly to survive the shock and vibration of installation. Remove and reinstall the Vinton o-ring in the sample bottle holder. Check the fit of a few sample bottles in the holder.

To insure not damaging the threads on the stainless steel three-way valve and to make coupling of the tubing easier, do not remove the 45 cm piece of tubing permanently attached to the bottom port. Couple a section of tubing between the drive tip and the short piece of tubing connected to the manifold. The peristaltic pump tubing is adapted to the 1/8 tubing by using a Swagelok to hose connector adapter (PT#B-4-HC-1-200). A small gear clamp is placed over the tubing in the barbed area. It is important to cut the peristaltic tubing so there is no excess (approximately 20 cm). Position the flowthrough cell for field parameters between the pump and the sample bottle manifold, placing these components as close to each other as possible. Couple the three components using two short pieces of flexible Teflon or poly tubing with the same dimensions as the stainless tubing. Thick walled tubing will reduce flow rate. To the other side of the pump, connect a piece of the same tubing, long enough to reach from the pump to the bottom of the 1L graduated cylinder if water is destined for waste container or to the bottom of the 100 mL graduated cylinder for measuring and timing purge water.

Perform a system leak test by placing the drive tip in a container of water. Switch on the pump to draw water through the manifold and pump into another vessel. Leaks down stream from the sample bottle will appear as air bubbles coming through the sample bottle. Leaks between the sample bottle and pump will cause air bubbles to exit the pump inlet and outlet tubing.

The peristaltic pump tubing maximum output pressure may be tested by running the pump in reverse or injection direction. With the system full of water and pump running at maximum RPM, close the three-way valve and record pressure. By knowing the maximum output pressure of the pump with the new tubing, the operator can do periodic tests in the field to check its integrity.

Operate the pump in the sampling direction. With the system full of water, close the three-way valve and record the maximum vacuum achieved by the new pump tubing. The maximum vacuum and output pressure provide the operator with some guidelines. Above ground system leaks can be easily found by dead heading the system in the injection cycle and watching for drops.

Run system in the sampling cycle at maximum RPM while timing and recording the flow rate for 100 mL. This free-flow rate also provided the operator a maximum flow guideline for the system. A good free flow rate should be approximately 35 to 50 seconds per mL. Not all groundwater will degas at the same rate under vacuum. An odd air bubble coming through the system undervacuum is probably not a leak but the degassing of the groundwater. Leaks usually have an even bubbling pattern and degassing is irregular.

Practice removing the sample bottle. Run the system in the sampling cycle, stop the pump, close the three-way valve and check the compound gauge. It should still show a vacuum. Zero and slightly pressurize system by turning the pump speed to slow and jogging the pump in reverse or injection cycle direction. While holding the sample bottle, loosen the bottom clamp and swing it far enough to lower sample bottle off of the inlet tube. The sample bottle should have a meniscus but if not, jog the pump on slow in the injection cycle direction while holding the bottle under the stem to catch the water from the storage loop. If preservatives are to be added, a perfect meniscus is not required and is done at this point.

With this preassembly and test, the manifold and pump should be leak checked and the maximum free flow rate, maximum output pressure and maximum vacuum recorded.

H.3.5 Step 4 – Sampling Station

We will be setting up sampling stations under two different conditions: fen and forest. In both cases, the sampling station needs to be up-wind of any source of exhaust and wind blown contamination.

In the fen, a scaffold will be needed to hold the sampling manifold, pump, graduated cylinders, stopwatch, clipboard, sample bottles and coolers out of the water. As well, the operator of the profiler will need to stand on the scaffolding in order to drive the profiler. If possible the scaffolding should be large enough to hold a small bottomless tent similar to the kind used by telephone and hydro workers.

In the forest, a small bottomless tent similar to the kind used by telephone and hydro workers will be set up with a heater to stop the water sample from freezer in the tubing. A TV table would provide a flat surface and a good piece of plywood would provide a stable floor.

H.3.6 Step 5 – Groundwater Sampling with Waterloo Profiler (UW, 2002).

Open a hole through the top soil or overburden far enough to avoid organic matter or roots. This can be accomplished by a hand auger or coring. If the ground is frozen, thaw it with a Tiger Torch.

The male thread of the drive casing should be smeared with silicone.

Connect the first piece of rise tubing, which should be 30 to 50 cm longer than the drive casing, to the drive tip.

Cap the opposite end.

Push the capped end of the riser tubing through the drive casing and tighten.

Attach the drive head adapter to the top of the drive casing.

Slip the slotted drive head over the adapter with the tubing through the slot.

Remove the cap on the riser tubing and couple another section of tubing between the sample bottle manifold and the tubing extending out of the drive head.

Switch on the peristaltic pump in the injection direction, at maximum RPM pumping the distilled water through the manifold, down the riser tubing about of the ports in the drive tip.

Hold the drive casing perpendicular, engage the hammering device and advance the drive casing slowly.

Stop periodically and check that the first piece of drive casing is straight.

As the drive tip is being advanced, monitor the pressure gauge and verify that water is being pumped down.

Stop the first casing while there is still enough room to tighten with a pipe wrench.

Stop the pump.

Disconnect the riser tubing from the sample manifold and cap.

Remove the drive head adapter.

Add the second piece of drive casing and replace the drive head adapter.

Add another section of riser tubing.

Start the pump, then advance the drive tip while watching the gauge and making sure that distilled/deionized water is being injected.

Pump 100 mL to purge the system.

The Bosch breaker hammer can drive the profiler in loose aquifers and remote areas and a floor jack can be used to retrieve the rods.

H.3.7 Step 6 – Measure Field Parameters

Two methods will be used to measure the field parameters: probes in a flow-through cell for dissolved oxygen, pH, temperature and electrical conductivity. Electrical conductivity greater than zero will confirm that the DI has been flushed out of the tubing.

H.3.7.1 Field Parameters Using Probes

Calibrate the probes in the standard solutions. The standard solutions should be comparable to the values expected in the field. Verify that any temperature adjustments have been done. Calibrate every 20 measurements.

Collect samples for analysis when the field parameters stabilize and the sensors have been allowed to equilibrate to the temperature of the water being monitored. According to the USGS, the criteria for stabilized field readings are defined operationally in table J.1, for a set of three or more sequential measurements. “ The natural variability inherent in surface water or ground water at the time of sampling generally falls within these stability criteria and reflects the accuracy that should be attainable with a calibrated instrument.” (Wilde and Radtke, 1997)

H.3.7.2 Dissolved Oxygen Calibration

Calibration and operation procedures differ among instrument types and makes–refer to manufacturer's instructions. Record all calibration information in instrument logbooks and copy calibration data onto field forms at the time of calibration. When measuring zero-DO water, results of 0.1 mg/L is normal and not to be worried about.

- Decontaminate the unit.
- Insert the probe into the flow-through cell, which permits continuous monitoring of the field parameters. Since this is a low-flow system, the three probes should be measuring the same water.
- Measure the field parameters at regular volume intervals and record the values on the sampling form next to the time and the volume purged. " Take instrument readings until the stabilization criteria in e) are met and the required number of well volumes of ground water have been purged." (Wilde and Radtke, 1997)
- "Record the median of the final five or more readings as the value to be reported for that site." (Wilde and Radtke, 1997)

H.3.8 Step 8 – Withdraw Sample

H.3.8.1 General

Refer to Table 1 in " Detailed Research Plan" for a list of parameters to be sampled. For QA/QC, 1) duplicate samples should be taken once for every ten samples submitted, 2) collect one sample of deionised water for analysis, 3) run one equipment blank through the profiler and one through the probe container before the first sample is taken and 4) run one total NA and one aromatic hydrocarbon field spike through the sampling equipment and transfer the other field spike to another bottle.

Even though sampling is usually done in order of volatility, in this case the sampling should be carried out in order of importance, then in order of volatility.

The sampling procedure is as follows:

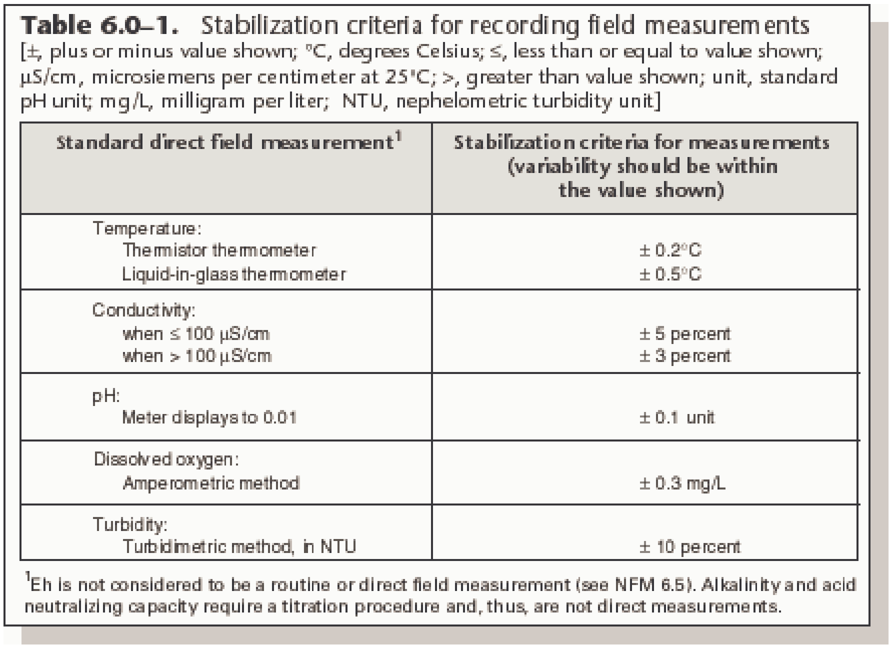

Table 6.0–1. Stabilization criteria for recording field measurements

[±, plus or minus value shown; °C, degrees Celsius; ≤, less than or equal to value shown; µS/cm, microsiemens per centimeter at 25°C; >, greater than value shown; unit, standard pH unit; mg/L, milligram per liter; NTU, nephelometric turbidity unit]

Standard direct field measurement[1]	Stabilization criteria for measurements (variability should be within the value shown)
Temperature:	
Thermistor thermometer	± 0.2°C
Liquid-in-glass thermometer	± 0.5°C
Conductivity:	
when ≤ 100 µS/cm	± 5 percent
when > 100 µS/cm	± 3 percent
pH:	
Meter displays to 0.01	± 0.1 unit
Dissolved oxygen:	
Amperometric method	± 0.3 mg/L
Turbidity:	
Turbidimetric method, in NTU	± 10 percent

[1] Eh is not considered to be a routine or direct field measurement (see NFM 6.5). Alkalinity and acid neutralizing capacity require a titration procedure and, thus, are not direct measurements.

Figure H.1: Stabilization criteria for recording field measurements.

- Complete the sample labels on the bottles, using durable labels and waterproof pens that will remain legible even when wet on every sample bottle. Include the following on the sample label:

a. name of collector;
b. sample identification number;
c. collection location and depth;
d. date and time of collection; and
e. parameters requested.

- Remove the bottle and cap the sample container quickly and tightly. Verify the presence of a meniscus to minimize the headspace.
- Store the sample in a cooler with ice packs. Seal the cooler with tape to keep dust out of the cooler. Store overnight in a warm building to make sure the water does not freeze.

H.3.9 Step 8 – Well Closure and Decomissioning

After all samples are collected from the well:

1. Pack all samples carefully into the coolers.
2. Turn off the generator.
3. Dismantle sampling equipment, decontaminate it and store in the clean storage bins selected, ready for the next site.
4. Slowly withdraw the profiler, verifying that the sand is collapsing by trying to reinsert the profiler.
5. Decontaminate and store drill rods and profiling tip.
6. Empty wastewater container with very dilute HCl, nonphosphate cleaner, rinse DI water and excess groundwater away from any sampling site and not in river.
7. Clean up the profiling site.

H.3.10 Step 9 – Ship Samples to Laboratory

H.3.10.1 Chain-of-Custody Record

Complete the chain-of-custody record provided by the laboratory and include it in every shipping container sent to the laboratory. Record the following data:

- sample number;
- sample type;
- date and time of collection;
- analysis requested;
- number of sample bottles;
- signature of collector;
- signature(s) of person(s) involved in the chain of possession; and
- inclusive dates of possession.

H.3.10.2 Packing Water Samples

- Seal and carefully pack the sample bottles in an upright position to ensure that they are not disturbed during shipping. Samples may be sealed in water tight plastic bags as added protection from leakage;
- Pack the cooler with packing material;
- Pack cooler with ice packs; and
- Seal the cooler with tape.

H.3.10.3 Packing Equipment

- Always keep an empty bottle in the sampling manifold when transporting

H.3.10.4 Addresses

UNIVERSITY OF WATERLOO
200 UNIVERSITY AVENUE WEST
WATERLOO ON N2L 3G1
ATTENTION:SHIRLEY CHATTEN, MARIANNE VANDERGRIENDT,
ORGANIC GEOCHEMISTRY LABORATORY (ESC – RM 222B)

UNIVERSITY OF WATERLOO
200 UNIVERSITY AVENUE WEST
WATERLOO ON N2L 3G1
Attention:Françoise Gervais BFG2125

Enviro-Test Laboratories
745 Logan Ave
Winnipeg MB R3E 3L5

Attention: Sample Reception

Maxxam Analytics Inc.
2021 - 41 Avenue NE
Calgary Alberta T2E 6P2

Maxxam Analytics Inc.
300A MacLennan Crescent
Fort McMurray, Alberta
P: (780) 791-9170

H.4 Field Quality Control

H.4.1 Introduction

If the QC program identifies a source of error, do not use the QC data to correct the groundwater data. Instead, identify and document the source of error, and take corrective action, including resampling. Annotate sampling forms with any unusual conditions. The QC steps can be divided into three categories:

- field parameters;
- blanks, spikes and duplicates;
- preliminary data review.

H.4.2 Field Parameters

Calibrate all field parameter meters prior to field use and recalibrate in the field often. Document the calibration to verify data quality.

H.4.3 Blanks, Spikes and Duplicates

H.4.3.1 Trip Blank

Have the laboratory fill one of each type of sample bottle with “ultra pure“ double-distilled water, transport it to the site, handle it like a sample (except for running it through the sampling equipment), and return it to the laboratory for analysis. A sampling record with a dummy sample number must be completed. Use one trip blank per sampling round.

H.4.3.2 Equipment Blank

To ensure that non-dedicated sampling devices have been effectively cleaned (in the laboratory and field), have the laboratory provide one equipment blank of deionized water (SDW). Follow all sampling and handling steps to ensure that procedures and equipment are tested by this blank. Complete a sampling record with a dummy sample number. Use one equipment blank per sampling round for each set of equipment.

H.4.3.3 DIW Blanks

Every day, collect a sample from the deionized water supply. A sampling record with a dummy sample number must be completed for each sample. Do not measure field parameters on DW samples.

H.4.3.4 Duplicate Samples

Duplicate samples should be taken at every sampling location or approximately once for every ten samples submitted for each sampling round, whichever is larger.

H.4.3.5 Field Spike

To ensure that the field and transportation procedures are not creating changes in water chemistry, have the laboratory provide two samples with known concentrations comparable to the expected field conditions (field spike). Two spikes are recommended so that the difference between natural sample degradation and sample degradation due to the sampling and handling procedures can be documented. Follow all sampling and handling steps with one of the spikes to ensure that procedures and equipment are tested. With the other spike, transfer the contents to another bottle. Complete sampling records with dummy sample numbers. The analytical chemist should retain a sample of the spike in the laboratory and analyze at the same time as the field spikes for comparison.

Appendix I

Suncor/Syncrude Profiling

I.1 Sampling Event Preparation

- Contact the laboratory performing the various chemical analyses so the sample bottles and preservatives (if required) can be shipped to the site.
- Since organic and inorganic desorbing agents are to be used, check with laboratories regarding potential analytical interferences or contamination potential.
- Organize shipment details with the warehouse to ship the samples daily.
- Order all necessary pumps, coolers, rock hammers, drill rods, filters and accessories from the supplier in advance of the sampling event.
- Arrange for a deionized water supply for decontamination.
- Arrange for living quarters, travel, truck rental, etc. . .

I.2 Equipment

I.2.1 Equipment Needed

- Extra batteries
- Large brush for cleaning pump

- Pail, Large for washing equipment, used HCl, DI water & groundwater
- Measuring tape, 100 ft or cord knotted every 5 ft
- Measuring tape, small
- Pail, Small or graduated cylinder to hold rinse solutions
- pH test strips
- Chain of custody forms
- Lock for wooden crate
- 125-mL plastic bottles
- Binder with field meter references
- Bottles of fresh zero DO calibration solution
- Conductivity/ temperature meter
- Dissolved oxygen meter
- Log sheets for recording all calibrations, maintenance and repairs.
- pH meters
- Replacement kit: membranes and filling solution
- Standard solution for pH meter: 4, 7 and 10
- standard solutions for EC meters
- 12" adjustable wrench
- Brunton compass
- Can fluorescent paint to mark locations
- Cooler packs
- Duct tape
- Electrical tape

- Flagging tape
- Small screwdriver
- Small vicegrip
- Tarps
- Twine
- 5' drill rods
- 8" $\frac{1}{2}$ round bastard file
- 8" smooth round file
- Allen key for putting legs back on manifold
- Allen key for switching to 25 mL bottle
- Coarse screened profiler tip
- Dentist pick
- extra 1/8" S.S. ferrules and fittings
- extra viton o-rings
- Fine screened profiler tip+extra tubing (45 mesh)
- Small pair of plyers
- Stainless steel Riser Tubing stored in PVC tube
- First aid kit
- 0.45 mm filters
- $\frac{1}{2}$" Waterra pump tips
- 1 L Graduated cylinder
- 1% HCl solution
- 100 mL graduated cylinder

- 250-mL amber glass bottles
- 40-mL bottles with screw-on septums
- 60 mL syringes
- 7/16 wrenches, modified for Profiler
- Box extra-large nitrile gloves for Bob
- Box Kimwipe paper towels
- Box large nitrile gloves for Barrett
- Box of sharpies
- Box small nitrile gloves for Françoise
- Carboys with handles and spout for deionised water, Sparkleen/DIW
- Clipboard
- Container Sparkleen detergent
- Deionised water (DIW)
- Extension cords
- Heavy duty paper towels
- Inline flow-through cell for field parameter measurement
- Location map
- Magnifying glass
- Nalgene squirt bottles for rinse water
- Pairs of orange waterproof work gloves
- Peristaltic pump tubing 6424-15
- Plastic wrap and aluminium foil
- Reversible, variable-speed peristaltic pump

- Sampling record sheets
- Silicone
- Silicone dispenser
- Stopwatch
- Teflon tape
- Tubing, $\frac{1}{4}$" tubing LDPE
- Tubing, $\frac{1}{4}$" tubing Teflon
- Tubing, $\frac{1}{2}$" tubing LDPE
- Tubing, 5/8" for Waterra pump, HDPE
- Water level tape
- Address labels for labs and ourselves
- Drive head adapter
- Sample bottle manifold adapted for 40 & 250 mL
- Slotted slip over drive head

I.2.2 Water Supply

Only water showing zero conductivity is allowed as rinse water (i.e. deionised water).

I.2.3 Maintenance and Storage

- store equipment in sealed containers or wrapped in aluminium foil/plastic wrap; and
- transport equipment to the sampling site in sealed containers;

I.2.3.1 Dissolved Oxygen Meter

Follow the manufacturer's recommendations for short-term (field) storage and for performance checks. Protect instruments and sensors from being jostled during transportation, from sudden impacts, sudden temperature changes, and extremes of heat and cold.

I.3 Water Sample Collection

I.3.1 General

A step-by-step checklist for sample collection is outlined in the following subsections. Always wear a fresh pair of disposable latex gloves throughout the sampling process.

I.3.2 Step 1 – Prepare for Sampling

I.3.2.1 Field sampling record

- location;
- date and time of sample collection;
- climatic conditions, including air temperature;
- field observations of sampling event;
- intake depth;
- pumping rate when driving downward;
- depth yield - high, medium or low;
- sample withdrawal procedure/equipment;
- collection method;
- sampling sequence;
- types of sample bottles used;

- parameters requested for analysis;
- field analysis data and method(s) used;
- name of sample collector; and
- field parameter calibration.

I.3.2.2 DO Meter (Radke et al., 1998)

Check the temperature-display thermistor in the DO sensor against a certified thermometer over the normal operating range of the instrument. If a thermistor reading is incorrect, apply a correction or return the instrument to the manufacturer for adjustment.

Check the instrument batteries and all electrical connections.

Test the instrument to ensure that it will read zero in a DO-free solution. If the instrument reading exceeds 0.2 mg/L, then the sensor membrane and electrolyte (if present) need to be replaced or the sensor needs to be repaired. Before repairing or replacing the sensor, check zero DO again with a freshly prepared zero DO solution.

I.3.3 Step 2 -Decontamination

The US:EPA Groundwater Monitoring Technical Guidance Report (1992) provides recommendations for cleaning sampling equipment used when organic and inorganic constituents are of interest. These procedures have been adapted below and are to be used at the start of the sampling program and with each change in location:

1. Calculate the volume needed for one rinse of the system. The profiler tip has a volume of 5 mL and the stainless steel tubing has around 3 mL per meter. At a depth of 10 m, this means that one tubing volume is 35 mL. Since I also want to rinse the bottle connectors, one rinse volume is 325 mL (35+40+250). Step 4 outlines a method that used only 100 mL of rinse solution.

2. Wash the equipment with a nonphosphate detergent (Sparkleen®) and scrub with an inert brush. For internal mechanisms and tubing, circulate 1L (3 rinse volumes) of the detergent solution through the equipment, after the entire profiling system has been assembled and bottles inserted in sampling manifold.

3. Rinse with 1.5 L DI water.

4. Rinse with 150 mL of dilute of 1% hydrochloric acid (low concentration due to stainless steel tubing of the profiler). Place the discharge end of the tubing into the cylinder, close the tubing to the bottles and blow 100 mL through the system to remove any sorbed metals. Open the stopcocks to the bottle, close the stopcock to the profiler and blow the 50 mL through the tubing. Remove the bottles, empty into waste container and replace bottles. However, if there is enough rinse water, use the high volume method.

5. The hose is then flushed with 5 rinse volumes (1.5 L) of DI water to remove the acid wash solution.

6. Place equipment in an inert container or wrap in clean plastic or aluminium foil for storage and transport.

7. Groundwater may be poured out at some distance from the profile location. The 1% HCl solution may be further diluted and poured down a drain.

I.3.4 Step 3 – Preassembly and Test of the Waterloo Profiler (University of Waterloo 2002)

Using a magnifying glass, check the screened ports in the drive tip for particulate matter, silicone, and distortion of the screens and insure the screens are held tight by the setscrews. The fitting in the drive tip should be smeared with silicone and threaded very tightly to survive the shock and vibration of installation. Remove and reinstall the Vinton o-ring in the sample bottle holder. Check the fit of a few sample bottles in the holder.

To insure not damaging the threads on the stainless steel three-way valve and to make coupling of the tubing easier, do not remove the 45 cm piece of tubing permanently attached to the bottom port. Couple a section of tubing between the drive tip and the short piece of tubing connected to the manifold. The peristaltic pump tubing is adapted to the 1/8 tubing by using a Swagelok to hose connector adapter (PT#B-4-HC-1-200). A small gear clamp is placed over the tubing in the barbed area. It is important to cut the peristaltic tubing so there is no excess (approximately 20 cm). Position the flowthrough cell for field parameters between the pump and the sample bottle manifold, placing these components as close to each other as possible. Couple the three components using two short pieces of flexible Teflon or poly tubing with the same dimensions as the stainless tubing. Thick walled tubing will reduce flow rate. To the other side of the pump, connect a piece of the same tubing, long enough to reach from the pump to the bottom of the 1L graduated cylinder if water is destined for waste container or to the bottom of the 100 mL graduated cylinder for measuring and timing purge water.

Perform a system leak test by placing the drive tip in a container of water. Switch on the pump to draw water through the manifold and pump into another vessel. Leaks down stream from the sample bottle will appear as air bubbles coming through the sample bottle. Leaks between the sample bottle and pump will cause air bubbles to exit the pump inlet and outlet tubing.

The peristaltic pump tubing maximum output pressure may be tested by running the pump in reverse or injection direction. With the system full of water and pump running at maximum RPM, close the three-way valve and record pressure. By knowing the maximum output pressure of the pump with the new tubing, the operator can do periodic tests in the field to check its integrity.

Operate the pump in the sampling direction. With the system full of water, close the three-way valve and record the maximum vacuum achieved by the new pump tubing. The maximum vacuum and output pressure provide the operator with some guidelines. Above ground system leaks can be easily found by dead heading the system in the injection cycle and watching for drops.

Run system in the sampling cycle at maximum RPM while timing and recording the flow rate for 100 mL. This free-flow rate also provided the operator a maximum flow guideline for the system. A good free flow rate should be approximately 35 to 50 seconds per mL. Not all groundwater will degas at the same rate under vacuum. An odd air bubble coming through the system undervacuum is probably not a leak but the degassing of the groundwater. Leaks usually have an even bubbling pattern and degassing is irregular.

Practice removing the sample bottle. Run the system in the sampling cycle, stop the pump, close the three-way valve and check the compound gauge. It should still show a vacuum. Zero and slightly pressurize system by turning the pump speed to slow and jogging the pump in reverse or injection cycle direction. While holding the sample bottle, loosen the bottom clamp and swing it far enough to lower sample bottle off of the inlet tube. The sample bottle should have a meniscus but if not, jog the pump on slow in the injection cycle direction while holding the bottle under the stem to catch the water from the storage loop. If preservatives are to be added, a perfect meniscus is not required and is done at this point.

With this preassembly and test, the manifold and pump should be leak checked and the maximum free flow rate, maximum output pressure and maximum vacuum recorded.

I.3.5 Step 4 – Sampling Station

The sampling station needs to be up-wind of any source of exhaust and wind blown contamination. The coolers used for transport would provide a flat surface.

I.3.6 Step 5 – Groundwater Sampling with Waterloo Profiler (UW, 2002).

- Open a hole through the topsoil or overburden far enough to avoid organic matter or roots.The male thread of the drive casing should be smeared with silicone.
- Connect the first piece of rise tubing, which should be 30 to 50 cm longer than the drive casing, to the drive tip.
- Cap the opposite end.
- Push the capped end of the riser tubing through the drive casing and tighten.
- Attach the drive head adapter to the top of the drive casing.
- Slip the slotted drive head over the adapter with the tubing through the slot.
- Remove the cap on the riser tubing and couple another section of tubing between the sample bottle manifold and the tubing extending out of the drive head.
- Switch on the peristaltic pump in the injection direction, at maximum RPM pumping the distilled water through the manifold, down the riser tubing about of the ports in the drive tip.

- Hold the drive casing perpendicular, engage the hammering device and advance the drive casing slowly.
- Stop periodically and check that the first piece of drive casing is straight.
- As the drive tip is being advanced, monitor the pressure gauge and verify that water is being pumped down.
- Stop the first casing while there is still enough room to tighten with a pipe wrench.
- Stop the pump.
- Disconnect the riser tubing from the sample manifold and cap.
- Remove the drive head adapter.
- Add the second piece of drive casing and replace the drive head adapter.
- Add another section of riser tubing.
- Start the pump, then advance the drive tip while watching the gauge and making sure that distilled/deionized water is being injected.
- Pump 100 mL to purge the system.

I.3.7 Step 6 – Measure Field Parameters

Field parameters will be measured by probes in a flow-through cell for dissolved oxygen, pH, temperature and electrical conductivity. Electrical conductivity greater than zero will confirm that the DI has been flushed out of the tubing. Collect samples for analysis when the field parameters stabilize and the sensors have been allowed to equilibrate to the temperature of the water being monitored. According to the USGS, the criteria for stabilized field readings are defined operationally in table J.1, for a set of three or more sequential measurements. “The natural variability inherent in surface water or ground water at the time of sampling generally falls within these stability criteria and reflects the accuracy that should be attainable with a calibrated instrument.” (Wilde and Radtke, 1997)

I.3.7.1 Field Parameters Using Probes

Calibrate the probes in the standard solutions. The standard solutions should be comparable to the values expected in the field. Verify that any temperature adjustments have been done. Calibrate every 20 measurements.

I.3.7.2 Dissolved Oxygen Calibration

Calibration and operation procedures differ among instrument types and makes–refer to manufacturer's instructions. Record all calibration information in instrument logbooks and copy calibration data onto field forms at the time of calibration. When measuring zero-DO water, results of 0.1 mg/L is normal and not to be worried about.

Decontaminate the unit.

Insert the probe into the flow-through cell, which permits continuous monitoring of the field parameters. Since this is a low-flow system, the three probes should be measuring the same water.

Measure the field parameters at regular volume intervals and record the values on the sampling form next to the time and the volume purged. “ Take instrument readings until the stabilization criteria in e) are met and the required number of well volumes of ground water have been purged.“ (Wilde and Radtke, 1997)

“ Record the median of the final five or more readings as the value to be reported for that site (see 6.0.3).” (Wilde and Radtke, 1997)

I.3.8 Step 7 – Withdraw Sample

I.3.8.1 General

Refer to Table above for a list of parameters to be sampled. For QA/QC, 1) duplicate samples should be taken once for every ten samples submitted, 2) collect one sample of deionised water for analysis, 3) run one equipment blank through the profiler and one through the probe container before the first sample is taken and 4) run one total NA and one aromatic hydrocarbon field spike through the sampling equipment and transfer the other field spike to another bottle.

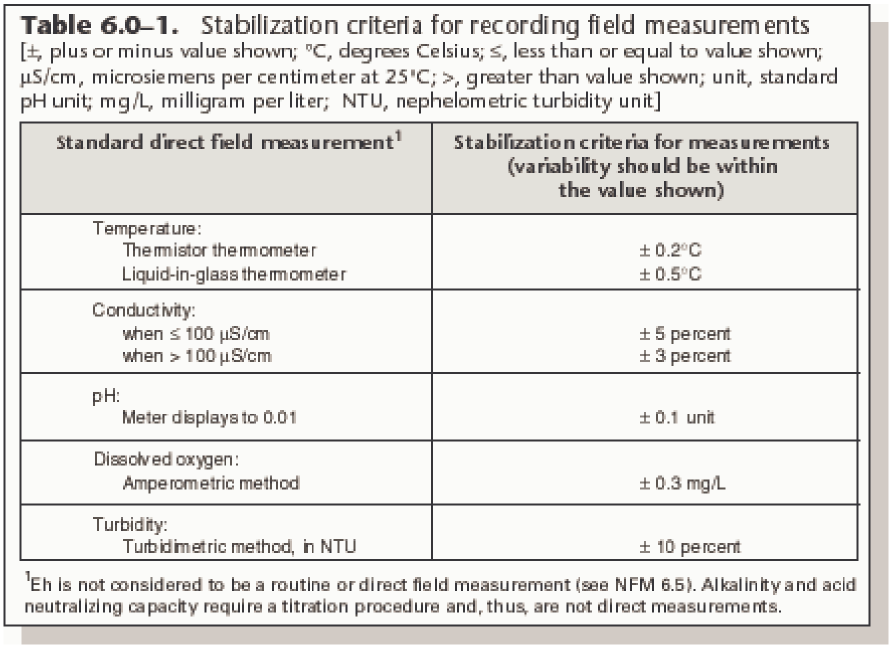

Table 6.0–1. Stabilization criteria for recording field measurements
[±, plus or minus value shown; °C, degrees Celsius; ≤, less than or equal to value shown; µS/cm, microsiemens per centimeter at 25°C; >, greater than value shown; unit, standard pH unit; mg/L, milligram per liter; NTU, nephelometric turbidity unit]

Standard direct field measurement[1]	Stabilization criteria for measurements (variability should be within the value shown)
Temperature:	
Thermistor thermometer	± 0.2°C
Liquid-in-glass thermometer	± 0.5°C
Conductivity:	
when ≤ 100 µS/cm	± 5 percent
when > 100 µS/cm	± 3 percent
pH:	
Meter displays to 0.01	± 0.1 unit
Dissolved oxygen:	
Amperometric method	± 0.3 mg/L
Turbidity:	
Turbidimetric method, in NTU	± 10 percent

[1] Eh is not considered to be a routine or direct field measurement (see NFM 6.5). Alkalinity and acid neutralizing capacity require a titration procedure and, thus, are not direct measurements.

FIGURE I.1: Stabilization criteria for recording field measurements

Even though sampling is usually done in order of volatility, in this case the sampling should be carried out in order of importance, then in order of volatility.

The sampling procedure is as follows:

- Complete the sample labels on the bottles, using durable labels and waterproof pens that will remain legible even when wet on every sample bottle. Include the following on the sample label:

a. name of collector;

b. sample identification number;

c. collection location and depth;

d. date and time of collection; and

e. parameters requested.

- Remove the bottle and cap the sample container quickly and tightly. Verify the presence of a meniscus to minimize the headspace.

- Store the sample in a cooler with ice packs. Seal the cooler with tape to keep dust out of the cooler. Store overnight in a warm building to make sure the water does not freeze.

I.3.9 Step 8 – Well Closure and Decomissioning

- After all samples are collected from the well:
- Pack all samples carefully into the coolers.
- Turn off the generator.
- Dismantle sampling equipment, decontaminate it and store in the clean storage bins selected, ready for the next site.
- Slowly withdraw the profiler, verifying that the sand is collapsing by trying to reinsert the profiler.
- Decontaminate and store drill rods and profiling tip.
- Empty wastewater container with very dilute HCl, nonphosphate cleaner, rinse DI water and excess groundwater away from any sampling site and not in river.
- Clean up the profiling site.

I.3.10 Step 9 – Ship Samples to Laboratory

I.3.10.1 Chain-of-Custody Record

Complete the chain-of-custody record provided by the laboratory and include it in every shipping container sent to the laboratory. Record the following data:

- sample number;
- sample type;
- date and time of collection;
- analysis requested;

- number of sample bottles;
- signature of collector;
- signature(s) of person(s) involved in the chain of possession; and
- inclusive dates of possession.

I.3.10.2 Packing Water Samples

- Seal and carefully pack the sample bottles in an upright position to ensure that they are not disturbed during shipping. Samples may be sealed in water tight plastic bags as added protection from leakage;
- Pack the cooler with packing material;
- Pack cooler with ice packs; and
- Seal the cooler with tape.

I.3.10.3 Packing Equipment

Always keep an empty bottle in the sampling manifold when transporting

I.4 Field Quality Control (QC)

I.4.1 Introduction

If the QC program identifies a source of error, do not use the QC data to correct the groundwater data. Instead, identify and document the source of error, and take corrective action, including resampling. Annotate sampling forms with any unusual conditions. The QC steps can be divided into three categories:

1. field parameters;
2. blanks, spikes and duplicates;
3. preliminary data review.

I.4.2 Field Parameters

Calibrate all field parameter meters prior to field use and recalibrate in the field often. Document the calibration to verify data quality.

I.4.3 Blanks, Spikes and Duplicates

I.4.3.1 Trip Blank:

Have the laboratory fill one of each type of sample bottle with “ultra pure“ double-distilled water, transport it to the site, handle it like a sample (except for running it through the sampling equipment), and return it to the laboratory for analysis. A sampling record with a dummy sample number must be completed. Use one trip blank per sampling round.

I.4.3.2 Equipment Blank:

To ensure that non-dedicated sampling devices have been effectively cleaned (in the laboratory and field), run deionised water through each piece of equipment (e.g. filter apparatus, field parameter sample container). Follow all sampling and handling steps to ensure that procedures and equipment are tested by this blank. Complete a sampling record with a dummy sample number. Use one equipment blank per sampling round for each set of equipment.

I.4.3.3 DIW Blanks:

Every day, collect a sample from the deionized water (DW) supply. A sampling record with a dummy sample number must be completed for each sample. Do not measure field parameters on DW samples.

I.4.3.4 Duplicate Samples:

Duplicate samples should be taken at every sampling location or approximately once for every ten samples submitted for each sampling round, whichever is larger.

I.4.3.5 Field Spike:

None taken

Appendix J

Piezometer Groundwater Sampling Guidelines

J.1 Equipment

J.1.1 Maintenance and Storage

- transport equipment to the sampling site in sealed containers; and
- clean non-dedicated equipment with deionized water between each well.

J.1.2 Equipment Inventories

J.1.2.1 Decontamination Equipment

- Large pail for decontaminating the water level probe, field parameter meters and Waterra pump;
- Large brush for cleaning pump;
- Sparkleen detergent;
- Kimwipe paper towels;
- Deionised water supply;

- Nalgene bottle for readily available rinse water; and
- Disposable nitrile gloves.

J.1.2.2 Purging Equipment

- Plastic coated water level probe;
- Inline flow-through cell for field parameter measurement;
- Conductivity meter, pH meter, dO meter;
- Small screwdriver and standard solutions for calibrating field parameter meters;
- Extra batteries;
- 20 L bucket for purge volume measurement;

J.1.2.3 Sampling Equipment

- Waterra pump;
- Clean length of tubing to siphon artesian wells;
- Appropriate sample bottles in a cooler with ice packs;
- 60 mL syringe and 0.45 μ m HT Tuffryn®membrane filter;
- Sample bottle labels, indelible markers, china pencils; and
- Laboratory return labels, fragile stickers.

J.1.2.4 Documentation

- Sampling record sheets for documenting purging and sampling details;
- Clipboard with elastic or clips;
- Well completion logs, previous sampling records, location map;
- Chain-of-custody forms; and
- Calculator, pencils, pens, eraser.

J.1.2.5 Miscellaneous Equipment

- Cellphone;
- 2 clean adjustable wrenches;
- Duct tape;
- Work gloves;
- Key for locked wells;
- tubing for measuring head in artesian wells; and
- Tape measure.

J.2 Water sample collection

Always wear a fresh pair of disposable latex gloves throughout the sampling process. Remove glow in the dark watch.

J.2.1 Step 1 – Prepare for Sampling

Prepare the standardised field sampling record:

- well number;
- date and time of sample collection;
- climatic conditions, including air temperature;
- field observations of sampling event;
- well depth;
- water level depth;
- pump intake depth;
- purge volume and pumping rate;

- well purging procedure/equipment;
- sample withdrawal procedure/equipment;
- collection method;
- sampling sequence;
- types of sample bottles used;
- parameters requested for analysis;
- filtration details and comments;
- field analysis data and method(s) used;
- name of sample collector; and
- field parameter calibration.

J.2.2 Step 2 -Decontamination

This procedure applies to both purging and sampling.

The exterior of the portable pump and tubing must be cleaned between each sampling well to minimize cross-contamination. As the pump is reeled in, the exterior of the hose and pump are washed by hand with soapy deionized water and a brush. The interior of the pump and hose is decontaminated between wells by pumping approximately 1 rinse volume of soapy deionized water (see Section 3.3) through the pump and hose, followed by 1 rinse volume of DI, repeat three time and then pump out water until water is no longer slimy. The pump and hose are then rinsed by pumping approximately 10 L of deionized water through the system. The exterior is then rinsed thoroughly with distilled water to remove any soapy water.

Similarly, the water level meter, field parameter meters, flow-through cell and any other portable support equipment must be decontaminated between wells to minimize cross-contamination. Wash each unit with soapy deionized water and rinse with deionized water.

J.2.3 Step 3 – Measure Static Water Level

Measure the static water level upon arrival at each well using the following procedures:

1. Ensure that the water level probe is operating and that the tape length is sufficient for the depth of water.
2. Decontaminate the water level probe by washing in a Sparkleen and water solution and rinsing with distilled water.
3. Measure the depth to water from the top of the PVC casing to within 0.01 m.
4. Determine the total depth of the well by measuring. Make sure to account for stick-up.
5. Calculate the volume of the water column in the well. For 2 inch PVC pipe,

$$\text{Volume in litres} = \Pi r^2 Hw \bullet 1000$$

$$\text{Volume in litres} = 2.026 \bullet Hw$$

$$\text{where } Hw = \text{ height of water column in metres}$$

$$\text{and } r = \text{radius of PVC pipe}$$

6. Record the measurements and calculations on the groundwater sampling record.

J.2.4 Step 4 – Purge Well

The stagnant water that is resident in the well prior to sampling is not representative of the in-situ groundwater quality and must be removed so that formation water can replace the stagnant water. The generally accepted purge is 3 well volumes. The well purge should continue past three well volumes, however, if field parameters have not stabilized to within 10% between successive readings. Since the contaminants of interested are expected be in aqueous phase, this is acceptable.

J.2.4.1 Purging with the Waterra Pump

1. Set the pump up at the well.
2. Lower the clean pump down the well.

3. Set the end of the tubing approximately five feet above the top of the screen. In wells where the water level intersects the screen, the end may be set to within one foot of the bottom.
4. Position the discharge tube above the 20 L bucket. This allows the purge volume to be calculated, and also facilitates the disposal of the purged water.
5. Once two well volumes have been purged, attach the flow cell with meters. Measure and record the field parameters regularly during purging to check for parameter stability.
6. Purge the required volume. The well purge should continue past three well volumes if field parameters have not stabilized to within 10% between successive readings.

J.2.4.2 Purging the Artesian Wells

1. Open the well cap to allow the water to overflow until it has produced the required volume.
2. Insert clean tubing into the well to a depth of approximately 5 ft and create a syphon. Do not collect samples from the stream coming from holes in the casing.
3. Collect field parameter samples through the tubing. Measure and record the field parameters regularly during purging to check for parameter stability.

J.2.5 Step 5 – Measure Field Parameters

1. Near the end of purging, measure the field parameters.
    - Calibrate the probes in the standard solutions according to the manuals. This can be done before going to the field.
    - The standard solutions should be comparable to the values expected in the field.
    - Verify that any temperature adjustments have been done.
    - Calibrate every 20 measurements.

- Record all calibration information in a logbook.
- For dissolved Oxygen calibration, test the instrument to ensure that it will read zero in a DO-free solution. If the instrument reading exceeds 0.2 mg/L, then the sensor membrane and electrolyte (if present) need to be replaced or the sensor needs to be repaired. Before repairing or replacing the sensor, check zero DO again with a freshly prepared zero DO solution.
- When measuring zero-DO water, results of 0.1 mg/L is normal and not to be worried about.

2. Rinse the probes with deionised water and blot dry with clean paper towels.
3. Attach the flow cell to the sample discharge line when purge volume equals about 2/3 to 3/4 of total volume required.
4. Measure the field parameters at regular volume intervals as purging progresses and record the values on the sampling form next to the time and the volume purged.
5. Turn off the meters to save the batteries.
6. Collect samples for analysis when the field parameters stabilize. Remove the flow cell from the sampling line before collecting the sample.

J.2.6 Step 6 – Withdraw Sample

J.2.6.1 General

Refer to groundwater sampling sheet for the list of parameters to be sampled from each well. The sampling should be carried out in the order they appear in the table.

The sampling procedure is as follows:

1. Complete the sample labels on the bottles prior to collecting the sample.
2. Prevent dirt and dust from contaminating the samples.
3. Precontaminate - triple rinse the sample bottles with well water (unless the preservative is already in the container). Do not precontaminate BTEX bottle!

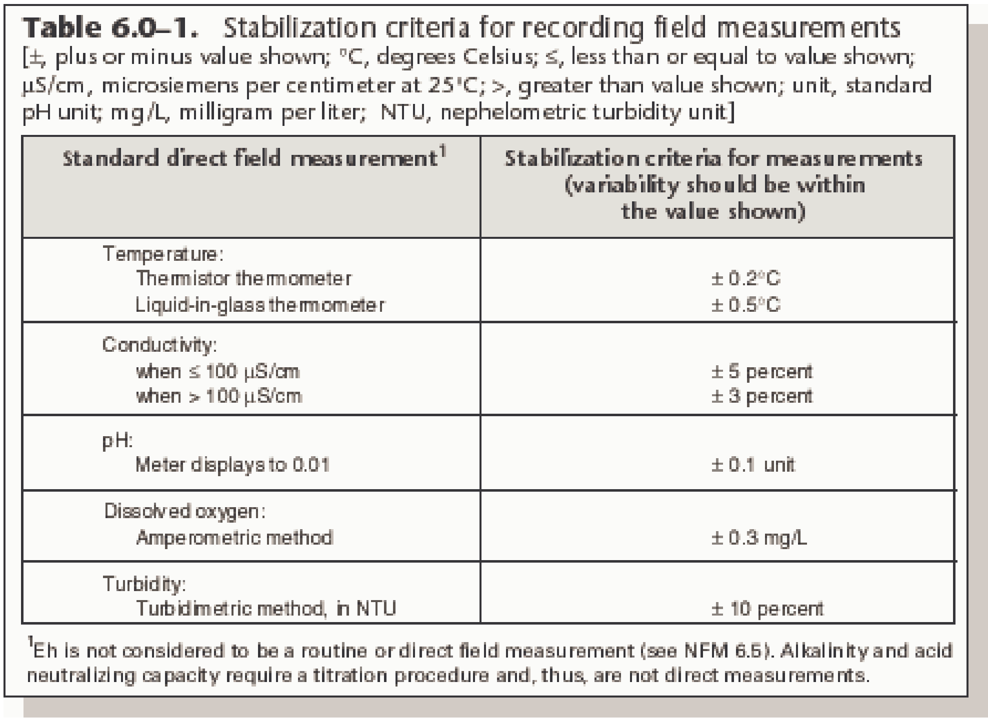

Table 6.0–1. Stabilization criteria for recording field measurements

[±, plus or minus value shown; °C, degrees Celsius; ≤, less than or equal to value shown; µS/cm, microsiemens per centimeter at 25°C; >, greater than value shown; unit, standard pH unit; mg/L, milligram per liter; NTU, nephelometric turbidity unit]

Standard direct field measurement[1]	Stabilization criteria for measurements (variability should be within the value shown)
Temperature:	
Thermistor thermometer	± 0.2°C
Liquid-in-glass thermometer	± 0.5°C
Conductivity:	
when ≤ 100 µS/cm	± 5 percent
when > 100 µS/cm	± 3 percent
pH:	
Meter displays to 0.01	± 0.1 unit
Dissolved oxygen:	
Amperometric method	± 0.3 mg/L
Turbidity:	
Turbidimetric method, in NTU	± 10 percent

[1] Eh is not considered to be a routine or direct field measurement (see NFM 6.5). Alkalinity and acid neutralizing capacity require a titration procedure and, thus, are not direct measurements.

FIGURE J.1: Stabilization criteria for recording field measurements.

4. For the BTEX and C6-C10, fill two bottles halfway, add HCl, fill it with a good meniscus and cap it. Inverse the bottle and tap it to see if a bubble appears. If so, add more water.
5. See isotope section below.
6. Add preservative to ammonia.
7. Filter the dissolved metal samples and add preservative. See section below.
8. Store the sample in a cooler with ice packs. Seal the cooler with tape to keep dust out of the cooler.

J.2.6.2 Metals Samples

Dissolved metals samples are to be filtered in the field, preserved with the required preservative, and then shipped to the laboratory. Indicate on the chain-of-custody the analytical parameter required is dissolved metals.

- Collect the filtered samples after all other samples have been collected from the well.
- Collect water in the 60 mL syringe and start filling 250 mL plastic bottle.
- Change to a new filter every time you refill the syringe.
- When the bottle is half full, add preservative and then continue filling to top.

J.2.6.3 Isotope Samples

- Collect samples in one 125-mL plastic.
- Fill the bottle completely and tightly seal to prevent evaporation.
- Avoid trapping air in the sample.
- Protect the sample against all sources of radiation, especially luminescent (glow in the dark) watches.

J.2.7 Step 7 – QA/QC

Take equipment blank at the beginning of sampling. Every 6 samples collect a duplicate. Collect a DIW sample at the same time.

J.2.8 Step 8 – Well Closure

After all samples are collected from the well:

- Decontaminate the portable pumps and hoses.
- Clean up the well site, and lock the well cap.

J.2.9 Step 9 – Ship Samples to Laboratory

J.2.9.1 Sample Labels

Use durable labels and waterproof pens that will remain legible even when wet on every sample bottle. Include the following on the sample label:

- name of collector;
- job number;
- sample identification number;
- place of collection;
- date and time of collection; and
- parameters requested.

Using the china pencil, write a shorthand label on the bottle in case the label is dissolved in transit. Record the shorthand label on the sampling sheet.

J.2.9.2 Chain-of-Custody Record

Complete a chain-of-custody record and include it in every shipping container sent to the laboratory. Chain-of-custody records are provided by the laboratory. Record the following data:

- sample number;
- well identification;
- sample type;
- date and time of collection;
- analysis requested;
- number of sample bottles;
- signature of collector;
- signature(s) of person(s) involved in the chain of possession; and
- inclusive dates of possession.

J.2.9.3 Packing

Careful packing is important for samples that are shipped to the laboratory off site.

- seal and carefully pack the sample bottles in an upright position to ensure that they are not disturbed during shipping. Samples may be sealed in water tight plastic bags as added protection from leakage;
- Pack the cooler with packing material;
- pack cooler with ice packs; and
- seal the cooler with tape.

J.3 Field Quality Control

J.3.1 Introduction

The field quality control (QC) program documents the condition of the monitoring well and verifies the adequacy of the sampling and handling program. If the QC program identifies a source of error, do not use the QC data to correct the groundwater data. Instead, identify and document the source of error, and take corrective action, including resampling. Annotate sampling forms with any unusual conditions. The QC steps can be divided into four categories:

- field parameters;
- blanks, spikes and duplicates;
- preliminary data review; and
- well tests.

J.3.2 Field Parameters

Calibrate all field parameter meters prior to field use and recalibrate in the field often as described in Section 4.6 Step 5. Document the calibration to verify data quality

J.3.3 Blanks, Spikes and Duplicates

J.3.3.1 Trip Blank

Have the laboratory fill one of each type of sample bottle with “ultra pure“ double-distilled water, transport it to the site, handle it like a sample (except for running it through the sampling equipment), and return it to the laboratory for analysis. A sampling record with a dummy sample number must be completed. Use one trip blank per sampling round. The samples should be analyzed for the same parameters as indicated in Table I-5 for DW-2.

J.3.3.2 Equipment Blank

To ensure that non-dedicated sampling devices have been effectively cleaned (in the laboratory and field), have the laboratory provide one equipment blank (“ultra pure“ double-distilled water) for each piece of equipment (e.g. filter apparatus, field parameter sample container). Follow all sampling and handling steps to ensure that procedures and equipment are tested by this blank. Complete a sampling record with a dummy sample number. Use one equipment blank per sampling round for each set of equipment. The samples should be analyzed for the same parameters as outlined in Table I-5 for DW-2.

J.3.3.3 DW Blanks

Every day, collect a sample from the deionized water (DW) supply. A sampling record with a dummy sample number must be completed for each sample. Do not measure field parameters on DW samples.

J.3.3.4 Duplicate Samples

Duplicate samples should be taken approximately once for every ten samples submitted for each sampling round.

J.3.3.5 Field Spike

Not done.

Appendix K

Chemical Data on all Field Samples

MR-02-GW-1A	**Sample Type:**	Quality Control		Equipment Blank
	Collection Method:	Waterloo Profiler		
	Date Collected:	29/11/2002		
	Easting:	471642.16	**Northing:**	6347363.06 **Elevation:**
	Collected By:	Françoise Gervais		University of Water
	Field Notes:	Sunny day, around -2C		

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Chloride, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.016**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**valid**	**0.003**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

MR-02-GW-1B	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	20/11/2002			
	Easting:	471642.16	**Northing:**	6347363.06	**Elevation:** -1.5
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:	Sunny, 0C, turbid water			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**379**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**462**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**106**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**10**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**2.1**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**693**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**774**	**uS/cm**	MDL=	
Ethane	**valid**	**2.3**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**20.1**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.153**	**mg/L**	MDL=	0.004
Methane	**valid**	**3470.2**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.096**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**<MDL**		**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**6.43**	**N/A**	MDL=	0
pH	**valid**	**6.94**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.3**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0

Sodium, dissolved	**valid**	**13.6**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Temperature	**valid**	**4.5**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

MR-02-GW-1C

Sample Type:	Field		Groundwater		
Collection Method:	Waterloo Profiler				
Date Collected:	21/11/2002				
Easting:	471642.16	**Northing:**	6347363.06	**Elevation:**	-1.9
Collected By:	Françoise Gervais		University of Water		
Field Notes:	1C, smoke from brushfire like fog, very turbid H2O				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**valid**	**398**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**485**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**111**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**9**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**1.3**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**700**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**718**	**uS/cm**	MDL=	
Ethane	**valid**	**3.8**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**21.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.127**	**mg/L**	MDL=	0.004
Methane	**valid**	**5148.1**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3

P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**6.9**	**N/A**	MDL=	0
pH	**valid**	**6.96**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.1**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**14.3**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Temperature	**valid**	**9.3**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**valid**	**1**	**mg/L**	MDL=	1

MR-02-GW-1D	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	21/11/2002			
	Easting:	471642.16	**Northing:**	6347363.06	**Elevation:** -2.9
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:	Sunny, 0C, very turbid to start; naph acid cracked			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Calcium, dissolved	**valid**	**112**	**mg/L**	MDL=	0.3
Chloride, dissolved	**valid**	**9.9**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**1.2**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**716**	**uS/cm**	MDL=	
Iron, dissolved	**valid**	**0.03**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**22.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.203**	**mg/L**	MDL=	0.004
Nitrate, dissolved	**valid**	**0.033**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**valid**	**6.87**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.3**	**mg/L**	MDL=	0.3
Sodium, dissolved	**valid**	**13.5**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Temperature	**valid**	**7.5**	**C**	MDL=	0
Total Naphthenic Acid	**valid**	**1**	**mg/L**	MDL=	1

MR-02-GW-2A	**Sample Type:**	Field		Groundwater		
	Collection Method:	Waterloo Profiler				
	Date Collected:	21/11/2002				
	Easting:	471680.66	**Northing:**	6347394.95	**Elevation:**	-1.6
	Collected By:	Françoise Gervais		University of Water		
	Field Notes:	Cloudy, 1C, grey turbid				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**valid**	**456**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**556**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**113**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**34.7**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**3**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**892**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**865**	**uS/cm**	MDL=	
Ethane	**valid**	**1.9**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.04**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**27.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.211**	**mg/L**	MDL=	0.004
Methane	**valid**	**1769.4**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.051**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**7.02**	**N/A**	MDL=	0
pH	**valid**	**7.88**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.4**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0

Sodium, dissolved	**valid**	**43.8**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**1**	**mg/L**	MDL=	0.1
Temperature	**valid**	**2.6**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**valid**	**2**	**mg/L**	MDL=	1

MR-02-GW-2B

Sample Type: Quality Control Equipment Blank
Collection Method: Waterloo Profiler
Date Collected: 22/11/2002
Easting: 471680.66 **Northing:** 6347394.95 **Elevation:**
Collected By: Françoise Gervais University of Water
Field Notes: Cloudy, -1C; NA bottle broken & sample not recover

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**2.61**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.27**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**4.61**	**N/A**	MDL=	0

Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**0.7**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22

MR-02-GW-3A

Sample Type:	Quality Control		Equipment Blank		
Collection Method:	Waterloo Profiler				
Date Collected:	29/11/2002				
Easting:	471730	**Northing:**	6347438	**Elevation:**	
Collected By:	Françoise Gervais		University of Water		
Field Notes:	Cloudy, 1C				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**valid**	**2.3**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**2.8**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**0.4**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**2**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.006**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.017**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76

pH	**valid**	**4.64**	**N/A**	MDL=	0
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**0.8**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

MR-02-GW-3B

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 29/11/2002
Easting: 471730 **Northing:** 6347438 **Elevation:** -1.4
Collected By: Françoise Gervais University of Water
Field Notes: Cloudy, 0C, sfc water under floating mat? NA broke

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**524**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**639**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**50.1**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**365**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**1.2**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1770**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**2020**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.66**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**25.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.021**	**mg/L**	MDL=	0.004
Methane	**valid**	**777.5**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.008**	**mg/L**	MDL=	0.003

Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**valid**	**0.033**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**7.34**	**N/A**	MDL=	0
pH	**valid**	**7.3**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.2**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**327**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**18.2**	**mg/L**	MDL=	0.1
Temperature	**valid**	**4**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**valid**	**5.5**	**mg/L**	MDL=	1

MR-02-GW-3C

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 29/11/2002

Easting: 471730 **Northing:** 6347438 **Elevation:** -1.9

Collected By: Françoise Gervais University of Water

Field Notes: Cloudy, 0C, turbid dark brown

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**valid**	**544**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**663**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**78.4**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**336**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.8**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1930**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1826**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5

Iron, dissolved	**valid**	**1.01**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**27.7**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.065**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.011**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**7.34**	**N/A**	MDL=	0
pH	**not taken**	**0**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3.7**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**333**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**20.2**	**mg/L**	MDL=	0.1
Temperature	**valid**	**3**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**valid**	**4**	**mg/L**	MDL=	1

MR-02-GW-4A

Sample Type: Quality Control Equipment Blank
Collection Method: Waterloo Profiler
Date Collected: 22/11/2002
Easting: **Northing:** **Elevation:**
Collected By: Françoise Gervais University of Water
Field Notes: Sunny OC

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

MR-02-GW-5A	**Sample Type:**	Field	Groundwater		
	Collection Method:	Waterloo Profiler			
	Date Collected:	23/11/2002			
	Easting:	471741	**Northing:** 6347475	**Elevation:**	-1.9
	Collected By:	Françoise Gervais	University of Water		
	Field Notes:	Cloudy, -5C, slightly brown turbid			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**678**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**827**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**147**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**400**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**9.7**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**2340**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**2160**	**uS/cm**	MDL=	
Ethane	**valid**	**0.6**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.11**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**29.9**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.15**	**mg/L**	MDL=	0.004
Methane	**valid**	**2398.6**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**7.07**	**N/A**	MDL=	0
pH	**valid**	**6.49**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.6**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**318**	**mg/L**	MDL=	0.5

Sulphate, dissolved	**valid**	**0.5**	**mg/L**	MDL=	0.1
Temperature	**valid**	**2.7**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**valid**	**9.8**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**6**	**mg/L**	MDL=	1

MR-02-GW-5B

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 23/11/2002
Easting: 471741 **Northing:** 6347475 **Elevation:** -2.5
Collected By: Françoise Gervais University of Water
Field Notes: Cloudy, -5C, brown to start

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**667**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**814**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**129**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**401**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**9.1**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**2320**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**2140**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.17**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**28.5**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.137**	**mg/L**	MDL=	0.004
Methane	**valid**	**94.5**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.034**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76

pH	**valid**	**7.16**	**N/A**	MDL=	0
pH	**valid**	**7**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.6**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**349**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**2**	**mg/L**	MDL=	0.1
Temperature	**valid**	**4.1**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**valid**	**7**	**mg/L**	MDL=	1

MR-02-GW-6A	**Sample Type:**	Quality Control		Equipment Blank	
	Collection Method:	Waterloo Profiler			
	Date Collected:	25/11/2002			
	Easting:	471722.57	**Northing:**	6347494.33	**Elevation:**
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:	Sunny, -15C; NA bottle broke			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**1.2**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**1.4**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**0.5**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**6.72**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.033**	**mg/L**	MDL=	0.003

Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**valid**	**0.004**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**4.63**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**0.6**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22

MR-02-GW-6C

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 26/11/2002

Easting: 471722.57 **Northing:** 6347494.33 **Elevation:** -2.5

Collected By: Françoise Gervais University of Water

Field Notes: Clear, 1C, slightly turbid; NA bottle broke

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**valid**	**734**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**896**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**123**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**297**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**1.3**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**2160**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1881**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.6**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**26.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.208**	**mg/L**	MDL=	0.004

Methane	**valid**	**2270**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.171**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**valid**	**0.084**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**6.6**	**N/A**	MDL=	0
pH	**valid**	**7.6**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**392**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**4.4**	**mg/L**	MDL=	0.1
Temperature	**valid**	**7**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22

MR-02-GW-6D

Sample Type:	Field		Groundwater		
Collection Method:	Waterloo Profiler				
Date Collected:	26/11/2002				
Easting:	471722.57	**Northing:**	6347494.33	**Elevation:**	-3
Collected By:	Françoise Gervais		University of Water		
Field Notes:	Cloudy, -1C, cloudy grey to start, degas or leak				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**valid**	**12.5**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**15.3**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**126**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**372**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.7**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**2470**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1920**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0

Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**1.71**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**24**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.179**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**valid**	**0.144**	**mg/L**	MDL=	0.003
pH	**valid**	**5.4**	**N/A**	MDL=	0
pH	**valid**	**6.68**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3.2**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**422**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**626**	**mg/L**	MDL=	0.1
Temperature	**valid**	**5.9**	**C**	MDL=	0
Total Naphthenic Acid	**valid**	**11**	**mg/L**	MDL=	1

MR-02-GW-6Ai

Sample Type: Quality Control Equipment Blank

Collection Method: Waterloo Profiler

Date Collected: 28/11/2002

Easting: 471722.57 **Northing:** 6347494.33 **Elevation:**

Collected By: Françoise Gervais University of Water

Field Notes: Sunny, 10C chinook replace broken NA bottle

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

MR-02-GW-6Bi	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	28/11/2002			
	Easting:	471722.57	**Northing:**	6347494.33	**Elevation:** -2
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:	Sunny, 10C chinook replace broken NA bottle			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Total Naphthenic Acid	**valid**	**7**	**mg/L**	MDL=	1

MR-02-GW-6Ci	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	28/11/2002			
	Easting:	471722.57	**Northing:**	6347494.33	**Elevation:** -2.5
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:	Sunny, 10C chinook replace broken NA bottle			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Total Naphthenic Acid	**valid**	**9**	**mg/L**	MDL=	1

MR-02-GW-6Di	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	28/11/2002			
	Easting:	471722.57	**Northing:**	6347494.33	**Elevation:** -3
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:	Sunny, 10C chinook replace broken NA bottle			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Total Naphthenic Acid	**valid**	**12**	**mg/L**	MDL=	1

MR-02-GW-8B	**Sample Type:**	Quality Control		Equipment Blank	
	Collection Method:	Waterloo Profiler			
	Date Collected:	27/11/2002			
	Easting:	471687.46	**Northing:**	6347529.92	**Elevation:**
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:	Sunny 4C			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Chloride, dissolved	**valid**	**0.3**	**mg/L**	MDL=	0.1
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.004

Methane	**valid**	**2.1**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**0.9**	**mg/L**	MDL=	0.5
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

MR-02-GW-8C

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 27/11/2002

Easting: 471687.46 **Northing:** 6347529.92 **Elevation:** -2.4

Collected By: Françoise Gervais University of Water

Field Notes: Sunny 5C cloudy brown/grey water to start

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**591**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**722**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**165**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**389**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.8**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**2180**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**2230**	**uS/cm**	MDL=	
Ethane	**valid**	**0.8**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.03**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**32.5**	**mg/L**	MDL=	0.2

Manganese, dissolved	**valid**	**0.084**	**mg/L**	MDL=	0.004
Methane	**valid**	**866.4**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**valid**	**0.014**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**7.21**	**N/A**	MDL=	0
pH	**valid**	**6.95**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3.2**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**329**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**53**	**mg/L**	MDL=	0.1
Temperature	**valid**	**9.2**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**valid**	**9.2**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**10**	**mg/L**	MDL=	1

MR-02-GW-8E

Sample Type:	Field		Groundwater		
Collection Method:	Waterloo Profiler				
Date Collected:	27/11/2002				
Easting:	471687.46	**Northing:**	6347529.92	**Elevation:**	-3.4
Collected By:	Françoise Gervais		University of Water		
Field Notes:	Clear, Sunset, 0C				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**532**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**649**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**195**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**371**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**2.5**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**2070**	**uS/cm**	MDL=	

Electrical Conductivity	**valid**	**2130**	**uS/cm**	MDL=	
Ethane	**valid**	**0.3**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**38.8**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.156**	**mg/L**	MDL=	0.004
Methane	**valid**	**65.2**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**7.6**	**N/A**	MDL=	0
pH	**valid**	**7.25**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**4.3**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**249**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**52.8**	**mg/L**	MDL=	0.1
Temperature	**valid**	**6.7**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**valid**	**9**	**mg/L**	MDL=	1

MR-02-GW-10A

Sample Type: Quality Control Equipment Blank
Collection Method: Waterloo Profiler
Date Collected: 30/11/2002
Easting: 471774 **Northing:** 6347473 **Elevation:**
Collected By: Françoise Gervais University of Water
Field Notes: Sunny -1C

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Chloride, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1

Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Iron, Total	**valid**	**0.08**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.008**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**0.8**	**mg/L**	MDL=	0.5
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

MR-02-GW-10B	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:				
	Easting:	471774	**Northing:**	6347473	**Elevation:** -2
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Calcium, dissolved	**valid**	**180**	**mg/L**	MDL=	0.3
Chloride, dissolved	**valid**	**389**	**mg/L**	MDL=	0.1
Iron, dissolved	**valid**	**0.06**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**35**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.273**	**mg/L**	MDL=	0.004
Potassium, dissolved	**valid**	**0.9**	**mg/L**	MDL=	0.3
Sodium, dissolved	**valid**	**193**	**mg/L**	MDL=	0.5
Total Naphthenic Acid	**valid**	**5**	**mg/L**	MDL=	1

MR-02-GW-11A	**Sample Type:**	Quality Control		Equipment Blank	
	Collection Method:	Waterloo Profiler			
	Date Collected:				
	Easting:	471774	**Northing:**	6347473	**Elevation:**
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

MR-02-MW-9808

Sample Type: Field Groundwater

Collection Method: Piezometer

Date Collected: 27/11/2002

Easting: 471700.9 **Northing:** 6347516.4 **Elevation:** -3.2

Collected By: Françoise Gervais University of Water

Field Notes: Sunny, -1C

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Calcium, dissolved	**valid**	**231**	**mg/L**	MDL=	0.3
Chloride, dissolved	**valid**	**377**	**mg/L**	MDL=	0.1
Ethane	**valid**	**2.1**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Iron, Total	**valid**	**23**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**46.1**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.655**	**mg/L**	MDL=	0.004
Methane	**valid**	**1628.8**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.007**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**valid**	**0.559**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Potassium, dissolved	**valid**	**3.8**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**303**	**mg/L**	MDL=	0.5
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**valid**	**1**	**mg/L**	MDL=	1

MR-02-MW-9811	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	27/11/2002			
	Easting:	471564.21	**Northing:**	6347654.96	**Elevation:** -0.7
	Collected By:	Trevor Scoular		Komex International Ltd.	
	Field Notes:				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Alkalinity	**valid**	**614**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Bicarbonate	**valid**	**749**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**110**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**316**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**2190**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.01**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**32.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**1.39**	**mg/L**	MDL=	0.004
Methane	**ND**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.095**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**7.1**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**345**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**79.2**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22

Total Naphthenic Acid	**valid**	**15**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**11.7**	**mg/L**	MDL=	1

MR-02-River	**Sample Type:**	Field	Surface Water
	Collection Method:	Surface Water	
	Date Collected:	27/11/2002	
	Easting:	**Northing:**	**Elevation:**
	Collected By:	Angela Scoular	H2O Environmental Monitoring Ltd.
	Field Notes:		

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Calcium, dissolved	**valid**	**47.1**	**mg/L**	MDL=	0.3
Chloride, dissolved	**valid**	**1.7**	**mg/L**	MDL=	0.1
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, Total	**valid**	**1.75**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**13.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.255**	**mg/L**	MDL=	0.004
Methane	**valid**	**64.5**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Nitrate, dissolved	**valid**	**0.089**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**valid**	**0.013**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Potassium, dissolved	**valid**	**1.3**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**12**	**mg/L**	MDL=	0.5
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22

MR-02-GW-11B	**Sample Type:**	Quality Control	Field Spike		Equipment
	Collection Method:	Waterloo Profiler			
	Date Collected:	30/11/2002			
	Easting:	0	**Northing:** 0	**Elevation:**	0
	Collected By:	Françoise Gervais	University of Water		
	Field Notes:	Sunny 0C			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**valid**	**1614**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**valid**	**1525**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**valid**	**1523**	**ug/L**	MDL=	2.43
Benzene	**valid**	**1447**	**ug/L**	MDL=	3.72
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
Naphthalene	**valid**	**1748**	**ug/L**	MDL=	4.34
O-Xylene	**valid**	**1562**	**ug/L**	MDL=	3
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**valid**	**3006**	**ug/L**	MDL=	5.76
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Toluene	**valid**	**1407**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

MR-02-GW-11C	**Sample Type:**	Quality Control	Field Spike	Equipment
	Collection Method:	Waterloo Profiler		
	Date Collected:	30/11/2002		
	Easting:	0 **Northing:**	0 **Elevation:**	0
	Collected By:	Françoise Gervais	University of Water	
	Field Notes:	Sunny 0C; [spike]=21 mg/L		

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Methane	**ND**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Naphthenic Acid	**valid**	**15**	**mg/L**	MDL=	1

MR-02-GW-6B						
	Sample Type:	Field		Groundwater		
	Collection Method:	Waterloo Profiler				
	Date Collected:	25/11/2002				
	Easting:	471722.57	**Northing:**	6347494.33	**Elevation:**	-2
	Collected By:	Françoise Gervais		University of Water		
	Field Notes:	Sunny -15C very turbid dark grey				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Calcium, dissolved	**valid**	**83.7**	**mg/L**	MDL=	0.3
Chloride, dissolved	**valid**	**259**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**7.1**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1672**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Iron, dissolved	**valid**	**2.35**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**20.3**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.174**	**mg/L**	MDL=	0.004
Methane	**valid**	**1698.1**	**ug/L**	MDL=	0
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**valid**	**6.88**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.3**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**288**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**10.4**	**mg/L**	MDL=	0.1
Temperature	**valid**	**3.7**	**C**	MDL=	0
Total Naphthenic Acid	**valid**	**8.2**	**mg/L**	MDL=	1

MR-02-GW-10C	**Sample Type:**	Quality Control		Trip Blank	
	Collection Method:	Waterloo Profiler			
	Date Collected:				
	Easting:	0	**Northing:**	0	**Elevation:** 0
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Calcium, dissolved	**valid**	**2**	**mg/L**	MDL=	0.3
Chloride, dissolved	**valid**	**1.1**	**mg/L**	MDL=	0.1
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**0.3**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.018**	**mg/L**	MDL=	0.004
Methane	**ND**	**0**	**ug/L**	MDL=	0
Nitrate, dissolved	**valid**	**0.008**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Orthophosphate	**<MDL**	**0**	**mg/L**	MDL=	0.003
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**1.3**	**mg/L**	MDL=	0.5

MR-02-GW-11D	**Sample Type:**	Quality Control		Field Spike		Trip
	Collection Method:	Waterloo Profiler				
	Date Collected:	30/11/2002				
	Easting:	0	**Northing:**	0	**Elevation:**	0
	Collected By:	Françoise Gervais		University of Water		
	Field Notes:	NA bottle frozen and cracked upon arrival; 21 mg/L				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Total Naphthenic Acid	**not valid**	**7**	**mg/L**	MDL=	1

MR-02-GW-11E	**Sample Type:**	Quality Control		Trip Blank		
	Collection Method:	Waterloo Profiler				
	Date Collected:	30/11/2002				
	Easting:	0	**Northing:**	0	**Elevation:**	0
	Collected By:	Françoise Gervais		University of Water		
	Field Notes:	bottle received frozen and cracked				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

MR-02-GW-9A	**Sample Type:**	Quality Control		Equipment Blank	
	Collection Method:	Waterloo Profiler			
	Date Collected:	28/11/2002			
	Easting:	0	**Northing:**	0	**Elevation:** 0
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Methane	**valid**	**3.1**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22

Trip Blank 1	**Sample Type:**	Quality Control		Trip Blank	
	Collection Method:	Waterloo Profiler			
	Date Collected:				
	Easting:	0	**Northing:**	0	**Elevation:** 0
	Collected By:	Françoise Gervais		University of Water	
	Field Notes:				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.49
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.45
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	2.43
Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.34
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22

MR-02- **River 2**	**Sample Type:**	Field		Surface Water	
	Collection Method:	Surface Water			
	Date Collected:	15/01/2003			
	Easting:	0	**Northing:**	0 **Elevation:**	0
	Collected By:	Angela Scoular		H2O Environmental Monitoring Ltd.	
	Field Notes:	Second set of samples			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**valid**	**254**	**mg/L**	MDL=	0.5
Bicarbonate	**valid**	**310**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**66.3**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**5**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**457**	**uS/cm**	MDL=	
Fluoride, dissolved	**valid**	**0.15**	**mg/L**	MDL=	0.05
Hardness (CaCO3)	**valid**	**240**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**1.57**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**18.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.46**	**mg/L**	MDL=	0.004
Nitrate, dissolved	**valid**	**0.06**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0.1**	**mg/L**	MDL=	0.003
pH	**not taken**	**0**	**N/A**	MDL=	0
pH	**valid**	**7.3**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**1.7**	**mg/L**	MDL=	0.3
Sodium, dissolved	**valid**	**14**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**9.8**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**valid**	**268**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**2**	**mg/L**	MDL=	1

WP-03-FLT2-1.01	**Sample Type:**	Field		Groundwater
	Collection Method:	Waterloo Profiler		
	Date Collected:	21/07/2003		
	Easting:	469052.22	**Northing:**	6315296.23 **Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo
	Field Notes:	showers; effervescing		

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**valid**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**3.74841424**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**279**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**340**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**141**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.88**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**16.8**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.14**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1540**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1133**	**uS/cm**	MDL=	
Ethane	**<MDL**	**1.89580388**	**ug/L**	MDL=	0
Ethene	**valid**	**0.34007417**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**550**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**80.5**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**48**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**21**	**mg/L**	MDL=	0.004
Methane	**valid**	**21.2041662**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**valid**	**4.36309914**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**valid**	**0.118**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.11**	**N/A**	MDL=	0
pH	**not taken**	**0**	**N/A**	MDL=	0

Potassium, dissolved	**valid**	**2.8**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.17337205**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.299416**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**81.8**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**507**	**mg/L**	MDL=	0.1
Temperature	**valid**	**28**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1070**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**20**	**mg/L**	MDL=	1

WP-03-FLT2-1.02

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 21/07/2003
Easting: 469052.22 **Northing:** 6315296.23 **Elevation:**
Collected By: Bob Ingleton University of Waterloo
Field Notes: showers; light green, effervescing

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**3.7576724**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**319**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**389**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**154**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.92**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**9.9**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.13**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**866**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1330**	**uS/cm**	MDL=	
Ethane	**valid**	**5.31659063**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**520**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**45.6**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**32.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**2.22**	**mg/L**	MDL=	0.004

Methane	**valid**	**20.2033912**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**2.01508166**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Nitrate, dissolved	**valid**	**0.031**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**valid**	**0.003**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**6.82**	**N/A**	MDL=	0
pH	**valid**	**7.32**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**1.9**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.19181338**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**71.4**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**384**	**mg/L**	MDL=	0.1
Temperature	**valid**	**32**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**893**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**22**	**mg/L**	MDL=	1

WP-03-FLT2-1.03

Sample Type:	Field		Groundwater	
Collection Method:	Waterloo Profiler			
Date Collected:	21/07/2003			
Easting:	469052.22	**Northing:**	6315296.23	**Elevation:**
Collected By:	Bob Ingleton		University of Waterloo	
Field Notes:	sunny; clear			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**3.01175131**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**598**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**729**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**201**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.92**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**9.6**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.07**	**mg/L**	MDL=	0

Electrical Conductivity	**valid**	**954**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1980**	**uS/cm**	MDL=	
Ethane	**valid**	**2.28449580**	**ug/L**	MDL=	0
Ethene	**valid**	**0.17743**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**650**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.22**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**36.4**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.504**	**mg/L**	MDL=	0.004
Methane	**valid**	**22.5830817**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**2.04236178**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Nitrate, dissolved	**valid**	**0.035**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.08**	**N/A**	MDL=	0
pH	**valid**	**7.91**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.15170054**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.35789569**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**146**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**432**	**mg/L**	MDL=	0.1
Temperature	**valid**	**25**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1190**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**23**	**mg/L**	MDL=	1

WP-03-FLT2-1.04

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 22/07/2003

Easting: 469052.22 **Northing:** 6315296.23 **Elevation:**

Collected By: Bob Ingleton University of Waterloo

Field Notes: sunny 25C

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55

1,3,5-Trimethylbenzene	**valid**	**5.4723197**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**545**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**665**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**173**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.9**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**10**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**1850**	**uS/cm**	MDL=	
Ethane	**valid**	**0.76546991**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0.14490117**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**560**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.07**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**30.1**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.417**	**mg/L**	MDL=	0.004
Methane	**valid**	**23.402255**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**1.50626111**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Nitrate, dissolved	**valid**	**0.006**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.85**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3.4**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.20154501**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.411697**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**146**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**402**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1090**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**32**	**mg/L**	MDL=	1

WP-03-FLT2-2.01	**Sample Type:**	Quality Control		Equipment Blank	
	Collection Method:	Tap or carboy or water truck			
	Date Collected:	22/07/2003			
	Easting:	468937.3	**Northing:**	6315267.3	**Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**7.5**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**9.2**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**2.9**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**18.9**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hydroxide		**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.26**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.024**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0.12481254**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH		**6.31**	**N/A**	MDL=	0
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.47443418**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**1.1**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**1.5**	**mg/L**	MDL=	0.1

Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-FLT2-2.02

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 22/07/2003

Easting: 468937.3 **Northing:** 6315267.3 **Elevation:**

Collected By: Bob Ingleton University of Waterloo

Field Notes: cloudy/sunny, 28C; clear, beige, sand in flow cell

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**1.3571659**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**6.78171658**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**406**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**496**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**48.7**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.98**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.5**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.12**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**924**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**	**0**	**uS/cm**	MDL=	
Ethane	**valid**	**1.91409263**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**200**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**2.02**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**17.9**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.666**	**mg/L**	MDL=	0.004
Methane	**valid**	**63.0611981**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**2.37812771**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**valid**	**0.005**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3

P- and M-Xylene	**valid**	**4.55574927**	**ug/L**	MDL=	3.13
pH	**valid**	**6.863**	**N/A**	MDL=	0
pH	**valid**	**7.8**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.7**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**135**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**79.8**	**mg/L**	MDL=	0.1
Temperature	**valid**	**22.5**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**539**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**44**	**mg/L**	MDL=	1

WP-03-FLT2-2.03

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 23/07/2003

Easting: 468937.3 **Northing:** 6315267.3 **Elevation:**

Collected By: Bob Ingleton University of Waterloo

Field Notes: cloudy/sunny 18C; bubbles in water

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.2**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**64.5**	**mg/L**	MDL=	0.1

Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**51**	**mg/L**	MDL=	1

WP-03-FLT2-2.04	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	23/07/2003			
	Easting:	468937.3	**Northing:**	6315267.3	**Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	sunny 20C; greenish tinge			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**1.20242444**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**7.15874082**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**467**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**570**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**73.4**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.3**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**959**	**uS/cm**	MDL=	
Ethane	**valid**	**0.44528308**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0.10793658**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**3.45679635**	**ug/L**	MDL=	1.49
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**28.4**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**22.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**1.47**	**mg/L**	MDL=	0.004
Methane	**valid**	**31.4501213**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**2.10698578**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**2.08558984**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**valid**	**0.056**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**valid**	**4.09122521**	**ug/L**	MDL=	3.13
pH	**valid**	**7.61**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**5**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0

Propene	**<MDL**	**0.187135**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**164**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**53.9**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Naphthenic Acid	**valid**	**48**	**mg/L**	MDL=	1

WP-03-FLT2-2.05

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 23/07/2003
Easting: 468937.3 **Northing:** 6315267.3 **Elevation:**
Collected By: Bob Ingleton University of Waterloo
Field Notes: sunny, 20C; clear, slightly green

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.1**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.1**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**	**0**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**		**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**		**mg/L**	MDL=	0.003
pH	**valid**	**6.903**	**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**50.5**	**mg/L**	MDL=	0.1
Temperature	**valid**	**28**	**C**	MDL=	0
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**40**	**mg/L**	MDL=	1

WP-03-FLT2-2.06	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	23/07/2003			
	Easting:	468937.3	**Northing:**	6315267.3	**Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	sunny, 23C			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**1.02988759**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**7.04418491**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**478**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**583**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**67.1**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.4**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.13**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**935**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**	**0**	**uS/cm**	MDL=	
Ethane	**valid**	**3.59651719**	**ug/L**	MDL=	0
Ethene	**valid**	**0.1508155**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**1.53295226**	**ug/L**	MDL=	1.49
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**14.4**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**12.4**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**1.12**	**mg/L**	MDL=	0.004
Methane	**valid**	**18.6027801**	**ug/L**	MDL=	0
Naphthalene	**valid**	**2.48957040**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**2.05707562**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**valid**	**3.48235591**	**ug/L**	MDL=	3.13
pH	**valid**	**6.961**	**N/A**	MDL=	0
pH	**valid**	**7.72**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3.2**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.67831814**	**ug/L**	MDL=	0

Propene	**<MDL**	**0.24561469**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**125**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**40.7**	**mg/L**	MDL=	0.1
Temperature	**valid**	**28**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Naphthenic Acid	**valid**	**34**	**mg/L**	MDL=	1

WP-03-FLT2-2.07

Sample Type: Quality Control Duplicate

Collection Method: Waterloo Profiler

Date Collected: 23/07/2003

Easting: 468937.3 **Northing:** 6315267.3 **Elevation:**

Collected By: Bob Ingleton University of Waterloo

Field Notes: sunny, 23C

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**7.07063962**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**482**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**588**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**67.6**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**7.5**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**942**	**uS/cm**	MDL=	
Ethane	**valid**	**3.40887281**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0.13011533**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**1.48128939**	**ug/L**	MDL=	1.49
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**11.8**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**12.8**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**1.14**	**mg/L**	MDL=	0.004
Methane	**valid**	**17.0548414**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**2.27449835**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3

P- and M-Xylene	**valid**	**3.27762220**	**ug/L**	MDL=	3.13
pH	**valid**	**7.73**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3.3**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.21671506**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.17777825**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**128**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**42.2**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Naphthenic Acid	**valid**	**39**	**mg/L**	MDL=	1

WP-03-FLT2-2.08

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 23/07/2003

Easting: 468937.3 **Northing:** 6315267.3 **Elevation:**

Collected By: Bob Ingleton University of Waterloo

Field Notes: slightly turbid and grey from fines

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**38**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**42.9**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**40**	**mg/L**	MDL=	1

WP-03-FLT2-2.09	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	23/07/2003			
	Easting:	468937.3	**Northing:**	6315267.3	**Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	grey, turbid, sunny breaks, 24C			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**7.06646855**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**510**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**622**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**74.9**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.19**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**	**0**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**985**	**uS/cm**	MDL=	
Ethane	**valid**	**3.36568482**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0.09019358**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0.95086521**	**ug/L**	MDL=	1.49
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**9.86**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**13.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**1.54**	**mg/L**	MDL=	0.004
Methane	**valid**	**23.5524105**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**1.73732775**	**ug/L**	MDL=	2.32
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**valid**	**4.09422423**	**ug/L**	MDL=	3.13
pH	**valid**	**7.027**	**N/A**	MDL=	0
pH	**valid**	**7.81**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3.4**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.55912485**	**ug/L**	MDL=	0

Propene	**<MDL**	**0.15204719**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**166**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**39.6**	**mg/L**	MDL=	0.1
Temperature	**valid**	**23.6**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Naphthenic Acid	**valid**	**44**	**mg/L**	MDL=	1

WP-03-FLT2-2.10	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	23/07/2003			
	Easting:	468937.3	**Northing:**	6315267.3	**Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	turbid, grey, bit more greenish			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.2**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**46.7**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**43**	**mg/L**	MDL=	1

WP-03-FLT2-2.11	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	23/07/2003			
	Easting:	468937.3	**Northing:**	6315267.3	**Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	light grey, turbid			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**6.74820118**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**511**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0.3868598**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**624**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**64.5**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.1**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.17**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**	**0**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1020**	**uS/cm**	MDL=	
Ethane	**valid**	**1.14845558**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0.09771033**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**9.46**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**11**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.457**	**mg/L**	MDL=	0.004
Methane	**valid**	**29.6308347**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**valid**	**5.03399867**	**ug/L**	MDL=	3.13
pH	**valid**	**7.9**	**N/A**	MDL=	0
pH	**valid**	**7.028**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.8**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.46236837**	**ug/L**	MDL=	0

Propene	**<MDL**	**0.20490188**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**157**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**55.8**	**mg/L**	MDL=	0.1
Temperature	**valid**	**31**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Naphthenic Acid	**valid**	**45**	**mg/L**	MDL=	1

WP-03-FLT2-2.12

Sample Type:	Quality Control		Trip Blank		
Collection Method:	Tap or carboy or water truck				
Date Collected:	23/07/2003				
Easting:	468937.3	**Northing:**	6315267.3	**Elevation:**	
Collected By:	Bob Ingleton		University of Waterloo		
Field Notes:					

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-FLT2-3.01

Sample Type:	Quality Control		Equipment Blank		
Collection Method:	Tap or carboy or water truck				
Date Collected:	24/07/2003				
Easting:	469114.21	**Northing:**	6315306.34	**Elevation:**	329.3
Collected By:	Bob Ingleton		University of Waterloo		
Field Notes:	grey till at 22.5 ft				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**9.6**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5

Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**11.7**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**2.1**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**3.46**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**2.2**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**8**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**12**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.13**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**1.7**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.03**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0.22968461**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**valid**	**0.02**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.44**	**N/A**	MDL=	0
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**14.9**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**27.4**	**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-FLT2-3.03	**Sample Type:**	Field	Groundwater		
	Collection Method:	Waterloo Profiler			
	Date Collected:	24/07/2003			
	Easting:	469114.21	**Northing:** 6315306.34	**Elevation:**	320.7
	Collected By:	Bob Ingleton	University of Waterloo		
	Field Notes:	grey fines; difficult to advance packed sands?			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**5.0296575**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**609**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**743**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**147**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.91**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.3**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.2**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1630**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**667**	**uS/cm**	MDL=	
Ethane	**valid**	**1.78560005**	**ug/L**	MDL=	0
Ethene	**valid**	**0.2040445**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**2.94830167**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**470**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**12.9**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**25**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.29**	**mg/L**	MDL=	0.004
Methane	**valid**	**15.9565832**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.59**	**N/A**	MDL=	0
pH	**valid**	**7.035**	**N/A**	MDL=	0

Potassium, dissolved	**valid**	**3.8**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.29906678**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.56374419**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**169**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**294**	**mg/L**	MDL=	0.1
Temperature	**not taken**	**0**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1030**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**39**	**mg/L**	MDL=	1

WP-03-FLT2-3.04

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 24/07/2003
Easting: 469114.21 **Northing:** 6315306.34 **Elevation:** 319.8
Collected By: Bob Ingleton University of Waterloo
Field Notes: sunny 22C

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**5.06682458**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**608**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**742**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**154**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.91**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.8**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.18**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**700**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1690**	**uS/cm**	MDL=	
Ethane	**valid**	**0.29903183**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**3.03172125**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**500**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**13**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**27.3**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.44**	**mg/L**	MDL=	0.004

Methane	**valid**	**1.07643148**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**6.976**	**N/A**	MDL=	0
pH	**valid**	**7.57**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**4.4**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.26060763**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.34377981**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**175**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**332**	**mg/L**	MDL=	0.1
Temperature	**valid**	**23.6**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1080**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**38**	**mg/L**	MDL=	1

WP-03-FLT2-3.05

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 24/07/2003

Easting: 469114.21 **Northing:** 6315306.34 **Elevation:** 318.7

Collected By: Bob Ingleton University of Waterloo

Field Notes:

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**4.40240595**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**558**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**681**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**4**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.03**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.5**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**1640**	**uS/cm**	MDL=	

Ethane	**valid**	**0.39613813**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**2.73460761**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**16**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.55**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**1.4**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.05**	**mg/L**	MDL=	0.004
Methane	**valid**	**1.84746369**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.52**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**0.7**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.19504355**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.29473763**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**8.2**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**613**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**972**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**32**	**mg/L**	MDL=	1

WP-03-FLT2-3.06

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 24/07/2003
Easting: 469114.21 **Northing:** 6315306.34 **Elevation:** 317.8
Collected By: Bob Ingleton University of Waterloo
Field Notes: turbid, greyish green; sunny 22C; very soft soil

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**2.17866138**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**641**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82

Bicarbonate	**valid**	**782**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**243**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.91**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.7**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.2**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**653**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1910**	**uS/cm**	MDL=	
Ethane	**valid**	**1.27330112**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**1.56376406**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**790**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**24.3**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**43.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.59**	**mg/L**	MDL=	0.004
Methane	**valid**	**9.08716289**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**1.89155204**	**ug/L**	MDL=	3.13
pH	**valid**	**6.839**	**N/A**	MDL=	0
pH	**valid**	**7.39**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**4.1**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.09535463**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.17777825**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**120**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**478**	**mg/L**	MDL=	0.1
Temperature	**valid**	**25**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1310**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**18**	**mg/L**	MDL=	1

WP-03-FLT2-3.07	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	24/07/2003			
	Easting:	469114.21	**Northing:**	6315306.34	**Elevation:** 316.9
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	refusal; sunny 22C; turbid, bit darker grey			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**2.13227105**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**610**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**744**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**204**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.9**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.24**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**586**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1810**	**uS/cm**	MDL=	
Ethane	**valid**	**0.86964813**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**1.52870738**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**690**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.07**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**44.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.52**	**mg/L**	MDL=	0.004
Methane	**valid**	**6.22988529**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**1.34227997**	**ug/L**	MDL=	3.13
pH	**valid**	**7.45**	**N/A**	MDL=	0
pH	**valid**	**6.877**	**N/A**	MDL=	0

Potassium, dissolved	**valid**	**4.3**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.2367755**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**113**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**414**	**mg/L**	MDL=	0.1
Temperature	**valid**	**23**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1150**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**17**	**mg/L**	MDL=	1

WP-03-FLT2-3.08

Sample Type: Quality Control Drilling Water

Collection Method: Tap or carboy or water truck

Date Collected: 24/07/2003

Easting: 469114.21 **Northing:** 6315306.34 **Elevation:**

Collected By: Bob Ingleton University of Waterloo

Field Notes:

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**8.9**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**10.9**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**0**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**<MDL**	**0**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**1.7**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**6**	**uS/cm**	MDL=	
Ethane	**valid**	**0.20299353**	**ug/L**	MDL=	0
Ethene	**valid**	**0.976675**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**<MDL**	**0**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.01**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0.11595011**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66

Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**6.61**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**0**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.29227275**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**0**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.4**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**7**	**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-FLT2-3.09	**Sample Type:**	Quality Control		Trip Blank
	Collection Method:	Tap or carboy or water truck		
	Date Collected:	24/07/2003		
	Easting:	469114.21	**Northing:**	6315306.34 **Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo
	Field Notes:			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-FLT2-4.01	**Sample Type:**	Quality Control		Equipment Blank	
	Collection Method:	Tap or carboy or water truck			
	Date Collected:	25/07/2003			
	Easting:	468826.87	**Northing:**	6315156.67	**Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	sheen on cuttings when auger pulled up			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**9**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**11**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**1**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**4**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.25**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.008**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0.11595011**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**6.56**	**N/A**	MDL=	0
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.4**	**mg/L**	MDL=	0.1

Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-FLT2-4.03	**Sample Type:**	Field	Groundwater	
	Collection Method:	Waterloo Profiler		
	Date Collected:	25/07/2003		
	Easting:	468826.87	**Northing:** 6315156.67	**Elevation:**
	Collected By:	Bob Ingleton	University of Waterloo	
	Field Notes:	cobbly		

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**61.9**	**mg/L**	MDL=	0.3
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**7**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**valid**	**2.81951009**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.3**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**14.3**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.506**	**mg/L**	MDL=	0.004
Methane	**valid**	**1102.63382**	**ug/L**	MDL=	0
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.7**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**60.8**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.3**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**11**	**mg/L**	MDL=	1

WP-03-FLT2-4.04	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	25/07/2003			
	Easting:	468826.87	**Northing:**	6315156.67	**Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	clear grey water			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**74.7**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**10.3**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**valid**	**0.9785688**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.27**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**23.3**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.33**	**mg/L**	MDL=	0.004
Methane	**valid**	**303.538179**	**ug/L**	MDL=	0
Nitrate, dissolved	**valid**	**0.007**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.36040708**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.13727963**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**114**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**20**	**mg/L**	MDL=	1

WP-03-FLT2-4.06	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	25/07/2003			
	Easting:	468826.87	**Northing:**	6315156.67	**Elevation:**
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	hard, slow drilling, prob clay			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**9.2**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.9**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**20**	**mg/L**	MDL=	1

WP-03-FLT2-3.02	**Sample Type:**	Field	Groundwater		
	Collection Method:	Waterloo Profiler			
	Date Collected:	24/07/2003			
	Easting:	469114.21	**Northing:** 6315306.34	**Elevation:**	321.6
	Collected By:	Bob Ingleton	University of Waterloo		
	Field Notes:	cloudy, 21C; slightly yellow, occasional black particles			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**4.98759809**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**571**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**697**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**145**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.98**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.7**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.27**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**	**0**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**744**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0.06701585**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**2.59204555**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**480**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.04**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**28.5**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.29**	**mg/L**	MDL=	0.004
Methane	**valid**	**2.49997214**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.52**	**N/A**	MDL=	0
pH	**valid**	**6.904**	**N/A**	MDL=	0

Potassium, dissolved	**valid**	**3.1**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.24922232**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.41871456**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**161**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**256**	**mg/L**	MDL=	0.1
Temperature	**not taken**	**0**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**945**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**36**	**mg/L**	MDL=	1

WP-03-FLT2-4.02

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 25/07/2003

Easting: 468826.87 **Northing:** 6315156.67 **Elevation:**

Collected By: Bob Ingleton University of Waterloo

Field Notes: Cloudy, 16C; degassing medium bubbles; slightly turbid, greyish red

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**25.6**	**mg/L**	MDL=	0.3
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**5.9**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.37**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**8.4**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.262**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.3**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**53**	**mg/L**	MDL=	0.5

Sulphate, dissolved	**valid**	**2.1**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**3**	**mg/L**	MDL=	1

WP-03-FLT2-4.05

Sample Type: Quality Control Duplicate
Collection Method: Waterloo Profiler
Date Collected: 25/07/2003
Easting: 468826.87 **Northing:** 6315156.67 **Elevation:**
Collected By: Bob Ingleton University of Waterloo
Field Notes: clear grey water; degassing in bottles, smaller bubbles like other site, s

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**74**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**9.8**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**valid**	**2.19290009**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.13**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**22.9**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.32**	**mg/L**	MDL=	0.004
Methane	**valid**	**552.700298**	**ug/L**	MDL=	0
Nitrate, dissolved	**valid**	**0.006**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.9**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.33836958**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.13204788**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**110**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**18**	**mg/L**	MDL=	1

WP-1 (Water Processing Plant)						
	Sample Type:	Quality Control		Drilling Water		
	Collection Method:	Tap or carboy or water truck				
	Date Collected:	15/10/2002				
	Easting:	0	**Northing:**	0	**Elevation:**	0
	Collected By:	Françoise Gervais		University of Water		
	Field Notes:	Water from the tap at the water processing plant.				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**valid**	**332**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Bicarbonate	**valid**	**405**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**81.9**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**534**	**mg/L**	MDL=	0.1
delta oxygen-18	**valid**	**-18.65**	**per mil**	MDL=	0
Deuterium	**valid**	**-144.59**	**per mil**	MDL=	0
Electrical Conductivity	**valid**	**2340**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.02**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**21.9**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.005**	**mg/L**	MDL=	0.004
Methane	**valid**	**9.6**	**ug/L**	MDL=	0
Nitrate, dissolved	**valid**	**0.103**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**valid**	**7.93**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**4.1**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**400**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**25.9**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**valid**	**1270**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**2**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**10.6**	**mg/L**	MDL=	0.2
Tritium	**valid**	**7**	**per mil**	MDL=	0

WP-2	**Sample Type:**	Quality Control	Sampling	DI water
	Collection Method:	Tap or carboy or water truck		
	Date Collected:	15/10/2002		
	Easting:	0	**Northing:** 0	**Elevation:** 0
	Collected By:	Françoise Gervais	University of Water	
	Field Notes:	The DI water used by MRRT for sampling		

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**5**	**mg/L**	MDL=	0.5
Bicarbonate	**valid**	**6**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1
delta oxygen-18	**valid**	**-18.38**	**per mil**	MDL=	0
Deuterium	**valid**	**-145.28**	**per mil**	MDL=	0
Electrical Conductivity	**valid**	**2.44**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.004
Methane	**ND**	**0**	**ug/L**	MDL=	0
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**valid**	**6.56**	**N/A**	MDL=	0
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**valid**	**3**	**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1
Total organic carbon	**<MDL**	**0**	**mg/L**	MDL=	0.2

ENV2000-2 Oct02	**Sample Type:**	Field		Groundwater	
	Collection Method:	Piezometer			
	Date Collected:	16/10/2002			
	Easting:	0	**Northing:**	0	**Elevation:** 0
	Collected By:	Illona		MRRT	
	Field Notes:				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
3-Methylcholanthrene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
7,12-Dimethylbenz(a)anthracene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Acenaphthene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Acenaphthylene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Alkalinity	**valid**	**514**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**valid**	**0.003**	**mg/L**	MDL=	0.001
Anthracene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Antimony, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Arsenic, dissolved	**valid**	**0.0006**	**mg/l**	MDL=	0.0002
Barium, dissolved	**valid**	**0.174**	**mg/l**	MDL=	0.0002
Benzo(a)anthracene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Benzo(a)pyrene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Benzo(b)fluoranthene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Benzo(c)phenanthrene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Benzo(g,h,i)perylene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Benzo(j)fluoranthene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Beryllium, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**627**	**mg/L**	MDL=	0.5
Biochemical Oxygen Demand	**valid**	**1**	**mg/L**	MDL=	0.1
Calcium, dissolved	**valid**	**82.5**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1
Chrysene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
delta oxygen-18	**valid**	**-20.81**	**per mil**	MDL=	0
Deuterium	**valid**	**-159.16**	**per mil**	MDL=	0
Dibenzo(a,h)anthracene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Electrical Conductivity	**valid**	**928**	**uS/cm**	MDL=	
Ethane	**valid**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Fluoranthene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Fluorene	**<MDL**	**0**	**mg/L**	MDL=	0.00001

Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Indeno(1,2,3-cd)pyrene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Iron, dissolved	**valid**	**0.02**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**31.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.108**	**mg/L**	MDL=	0.004
Methane	**valid**	**2.1**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	0.00001
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**valid**	**8.12**	**N/A**	MDL=	0
Phenanthrene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Phosphorus, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**5.2**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**valid**	**0**	**ug/L**	MDL=	0
Pyrene	**<MDL**	**0**	**mg/L**	MDL=	0.00001
Sodium, dissolved	**valid**	**71.3**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**27.1**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**valid**	**528**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**2**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**14.3**	**mg/L**	MDL=	0.2
Tritium	**valid**	**19**	**per mil**	MDL=	0

ENV91-7B Oct02

Sample Type: Field Groundwater

Collection Method: Piezometer

Date Collected: 15/10/2002

Easting: 0 **Northing:** 0 **Elevation:** 1080.2

Collected By: Françoise Gervais University of Water

Field Notes: Snowing

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**629**	**mg/L**	MDL=	0.5
Bicarbonate	**valid**	**768**	**mg/L**	MDL=	0.5
Biochemical Oxygen Demand	**valid**	**6.2**	**mg/L**	MDL=	0.1
Calcium, dissolved	**valid**	**216**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8.5**	**mg/L**	MDL=	0.1
delta oxygen-18	**valid**	**-17.3**	**per mil**	MDL=	0
Deuterium	**valid**	**-140.8**	**per mil**	MDL=	0

Electrical Conductivity	**valid**	**1900**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**1.62**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**35.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.241**	**mg/L**	MDL=	0.004
Methane	**valid**	**14.25**	**ug/L**	MDL=	0
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**valid**	**7.57**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**5.1**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**150**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**442**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**valid**	**1240**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**16**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**19.2**	**mg/L**	MDL=	0.2
Tritium	**valid**	**26**	**per mil**	MDL=	0

ENV91-7B Apr2003

Sample Type: Field Groundwater

Collection Method: Piezometer

Date Collected: 03/04/2003

Easting: 0 **Northing:** 0 **Elevation:** 1080.2

Collected By: Françoise Gervais University of Water

Field Notes: Collected 60 L for use in lab experiments, -3C

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
	<MDL	**0**	**%**	MDL=	100
	<MDL	**0**	**%**	MDL=	100
	<MDL	**0**	**%**	MDL=	100
	<MDL	**0**	**%**	MDL=	100
Alkalinity	**valid**	**625**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**1.15**	**mg/L**	MDL=	0.01
Antimony, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Arsenic, dissolved	**valid**	**0.0009**	**mg/l**	MDL=	0.0002
Barium, dissolved	**valid**	**0.0516**	**mg/l**	MDL=	0.0002

Benzene	**<MDL**	**0**	**ug/L**	MDL=	3.72
Beryllium, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**763**	**mg/L**	MDL=	0.5
Biochemical Oxygen Demand	**<MDL**	**0**	**mg/L**	MDL=	2
Boron, dissolved	**valid**	**0.9**	**mg/L**	MDL=	0.01
Cadmium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**229**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**7.8**	**mg/L**	MDL=	0.1
Chromium, dissolved	**valid**	**0.001**	**mg/L**	MDL=	0.001
Cobalt, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0003
Copper, dissolved	**valid**	**0.0005**	**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**17.7**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.28**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1663**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1710**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**valid**	**0.1**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	3.64
Fluoride, dissolved	**valid**	**0.25**	**mg/L**	MDL=	0.05
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.32**	**mg/L**	MDL=	0.01
Lead, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0003
Lithium, dissolved	**valid**	**0.098**	**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**40.9**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.232**	**mg/L**	MDL=	0.004
Methane	**valid**	**27.5**	**ug/L**	MDL=	0
Molybdenum, dissolved	**valid**	**0.0007**	**mg/L**	MDL=	0.0002
Nickel, dissolved	**valid**	**0.0009**	**mg/L**	MDL=	0.0005
Nitrate, dissolved	**valid**	**0.006**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**valid**	**0.008**	**mg/L**	MDL=	0.003
Oxydative-reductive potential	**valid**	**150**	**mV**	MDL=	0
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	5.76
pH	**valid**	**6.89**	**N/A**	MDL=	0
pH	**valid**	**7.24**	**N/A**	MDL=	0
Phosphorus, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**5.5**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**valid**	**0.2**	**ug/L**	MDL=	0
Selenium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.007
Silicon, dissolved	**valid**	**4.91**	**mg/L**	MDL=	0.04

Silver, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**161**	**mg/L**	MDL=	0.5
Strontium, dissolved	**valid**	**0.915**	**mg/L**	MDL=	0.004
Sulphate, dissolved	**valid**	**462**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**valid**	**157**	**mg/L**	MDL=	0.2
Temperature	**valid**	**5.14**	**C**	MDL=	0
Thallium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Tin, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Titanium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Toluene	**<MDL**	**0**	**ug/L**	MDL=	10.22
Total Dissolved Solids		**0**	**mg/L**	MDL=	1
Total Dissolved Solids	**valid**	**1.061**	**mg/L**	MDL=	0
Total Dissolved Solids	**valid**	**1280**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**15.8**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**18**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**18.1**	**mg/L**	MDL=	0.2
Total Suspended Solids	**valid**	**2**	**mg/L**	MDL=	0
Uranium, dissolved	**valid**	**0.0064**	**mg/L**	MDL=	0.0004
Vanadium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Xylenes, Total Purgeable	**<MDL**	**0**	**mg/L**	MDL=	0.0008
Zinc, dissolved	**valid**	**0.0097**	**mg/L**	MDL=	0.0006
Zirconium, dissolved	**valid**	**0.0044**	**mg/L**	MDL=	0.0002

SP-03-FLT2-20

Sample Type: Quality Control Drilling Water

Collection Method: Tap or carboy or water truck

Date Collected: 29/03/2003

Easting: 0 **Northing:** 0 **Elevation:** 0

Collected By: Françoise Gervais University of Water

Field Notes: From well near water processing plant; sampled from truck

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**409**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**valid**	**0.002**	**mg/L**	MDL=	0.001
Antimony, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Antimony, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Arsenic, dissolved	**valid**	**0.0004**	**mg/l**	MDL=	0.0002
Barium, dissolved	**valid**	**0.361**	**mg/l**	MDL=	0.0002
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0004
Beryllium, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002

Bicarbonate	**valid**	**499**	**mg/L**	MDL=	0.5
Boron, dissolved	**valid**	**0.32**	**mg/L**	MDL=	0.01
Boron, dissolved	**valid**	**0.32**	**mg/L**	MDL=	0.01
Boron, dissolved		**0**	**mg/L**	MDL=	0.01
Cadmium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**74.5**	**mg/L**	MDL=	0.3
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**409**	**mg/L**	MDL=	0.1
Chromium, dissolved	**valid**	**0.001**	**mg/L**	MDL=	0.001
Cobalt, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0003
Copper, dissolved	**valid**	**0.002**	**mg/L**	MDL=	0.0002
Dibenzo(a,h)anthracene		**0**	**mg/L**	MDL=	0.00001
Dissolved organic carbon	**valid**	**17.3**	**mg/L**	MDL=	0.2
Electrical Conductivity	**valid**	**1980**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**2250**	**uS/cm**	MDL=	
Ethane	**ND**	**0**	**ug/L**	MDL=	0
Ethene	**ND**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0004
Fluoride, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.05
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.09**	**mg/L**	MDL=	0.01
Lead, dissolved	**<MDL**	**0.0003**	**mg/L**	MDL=	0.0003
Lithium, dissolved	**valid**	**0.043**	**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**23.9**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.115**	**mg/L**	MDL=	0.004
Molybdenum, dissolved	**valid**	**0.0002**	**mg/L**	MDL=	0.0002
Nickel, dissolved	**valid**	**0.0026**	**mg/L**	MDL=	0.0005
Nitrate, dissolved	**valid**	**0.225**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**valid**	**0.005**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0004
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0008
pH	**valid**	**8.03**	**N/A**	MDL=	0
Phosphorus, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**3.3**	**mg/L**	MDL=	0.3
Propane	**ND**	**0**	**ug/L**	MDL=	0
Propene	**ND**	**0**	**ug/L**	MDL=	0
Selenium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.007
Silicon, dissolved	**valid**	**5.42**	**mg/L**	MDL=	0.04
Silver, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**328**	**mg/L**	MDL=	0.5
Strontium, dissolved	**valid**	**0.572**	**mg/L**	MDL=	0.004
Sulphate, dissolved	**valid**	**0.4**	**mg/L**	MDL=	0.1

Sulphur, dissolved	**valid**	**0.6**	**mg/L**	MDL=	0.2
Temperature	**valid**	**31.5**	**C**	MDL=	0
Thallium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Tin, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Titanium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Toluene	**valid**	**0.0006**	**ug/L**	MDL=	0.0004
Total Dissolved Solids	**valid**	**1090**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**2.6**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**1**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**18.3**	**mg/L**	MDL=	0.2
Total organic carbon	**valid**	**15**	**mg/L**	MDL=	0.2
Uranium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0004
Vanadium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Xylenes, Total Purgeable	**<MDL**	**0**	**mg/L**	MDL=	0.0008
Zinc, dissolved	**valid**	**0.0349**	**mg/L**	MDL=	0.0006
Zirconium, dissolved	**valid**	**0.0094**	**mg/L**	MDL=	0.0002

SP-02-FLT2-01

Sample Type:	Field		Groundwater	
Collection Method:	Piezometer			
Date Collected:	23/07/2003			
Easting:	469000	**Northing:**	6315266	**Elevation:**
Collected By:	Barrett Elliott		University of Waterloo	
Field Notes:	elevation=top of screen; foam			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**3.04175502**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**552**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**valid**	**0.005**	**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**0.59**	**mg/L**	MDL=	0.01
Antimony, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Arsenic, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Barium, dissolved	**valid**	**0.0934**	**mg/l**	MDL=	0.0002
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Beryllium, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**674**	**mg/L**	MDL=	0.5
Boron, dissolved	**valid**	**0.36**	**mg/L**	MDL=	0.01

Cadmium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**247**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.95**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**11.9**	**mg/L**	MDL=	0.1
Chromium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Cobalt, dissolved	**valid**	**0.0046**	**mg/L**	MDL=	0.0003
Copper, dissolved	**valid**	**0.001**	**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**19.8**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.08**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1670**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**valid**	**3.68736089**	**ug/L**	MDL=	0
Ethene	**valid**	**0.29423808**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Ethylbenzene	**valid**	**1.82359569**	**ug/L**	MDL=	1.49
Fluoride, dissolved	**valid**	**0.18**	**mg/L**	MDL=	0.05
Hardness (CaCO3)	**valid**	**840**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.38**	**mg/L**	MDL=	0.01
Lead, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0003
Lithium, dissolved	**valid**	**0.054**	**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**53.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**2.45**	**mg/L**	MDL=	0.004
Methane	**valid**	**15.9982494**	**ug/L**	MDL=	0
Molybdenum, dissolved	**valid**	**0.0028**	**mg/L**	MDL=	0.0002
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**nd**	**0**	**ug/L**	MDL=	4.66
Nickel, dissolved	**valid**	**0.0019**	**mg/L**	MDL=	0.0005
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**nd**	**0**	**ug/L**	MDL=	3
O-Xylene	**not taken**		**ug/L**	MDL=	0.0005
P- and M-Xylene	**nd**	**0**	**ug/L**	MDL=	3.13
P- and M-Xylene	**not taken**		**ug/L**	MDL=	0.0005
pH	**valid**	**7.23**	**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Phosphorus, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**4**	**mg/L**	MDL=	0.3
Propane	**valid**	**0.23188511**	**ug/L**	MDL=	0
Propene	**valid**	**0.57544013**	**ug/L**	MDL=	0

Selenium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.007
Silicon, dissolved	**valid**	**7.29**	**mg/L**	MDL=	0.04
Silver, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**107**	**mg/L**	MDL=	0.5
Strontium, dissolved	**valid**	**0.89**	**mg/L**	MDL=	0.004
Sulphate, dissolved	**valid**	**544**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**valid**	**161**	**mg/L**	MDL=	0.2
Temperature	**valid**	**7.5**	**C**	MDL=	0
Thallium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Tin, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Titanium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Toluene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Toluene	**nd**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1300**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**10**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**20.1**	**mg/L**	MDL=	0.2
Total volatiles	**not taken**		**mg/L**	MDL=	0.1
Total Xylenes	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0004
Vanadium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Zinc, dissolved	**valid**	**0.0154**	**mg/L**	MDL=	0.0006
Zirconium, dissolved	**valid**	**0.0024**	**mg/L**	MDL=	0.0002

SP-02-FLT2-04

Sample Type: Field Groundwater
Collection Method: Piezometer
Date Collected: 25/07/2003
Easting: 468816 **Northing:** 6315151 **Elevation:**
Collected By: Barrett Elliott University of Waterloo
Field Notes: elevation=top of screen; turbid; brown

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**281**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**0.16**	**mg/L**	MDL=	0.01
Antimony, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Arsenic, dissolved	**not taken**		**mg/l**	MDL=	0.0002

Barium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Beryllium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**343**	**mg/L**	MDL=	0.5
Boron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Cadmium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**35.1**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.01**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**11**	**mg/L**	MDL=	0.1
Chromium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Cobalt, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Copper, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**18.3**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.1**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**603**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**valid**	**11.6406288**	**ug/L**	MDL=	0
Ethene	**valid**	**0.161849**	**ug/L**	MDL=	0
Ethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.49
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Fluoride, dissolved	**valid**	**0.62**	**mg/L**	MDL=	0.05
Hardness (CaCO3)	**valid**	**130**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.07**	**mg/L**	MDL=	0.01
Lead, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Lithium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**11.1**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.536**	**mg/L**	MDL=	0.004
Methane	**valid**	**10314.3898**	**ug/L**	MDL=	0
Molybdenum, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Naphthalene	**nd**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**valid**	**2.05223162**	**ug/L**	MDL=	2.69
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.32
Nickel, dissolved	**not taken**		**mg/L**	MDL=	0.0005
Nitrate, dissolved	**valid**	**0.012**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
O-Xylene	**nd**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**nd**	**0**	**ug/L**	MDL=	3.13
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005

pH	**not taken**		**N/A**	MDL=	0
pH	**valid**	**7.86**	**N/A**	MDL=	0
Phosphorus, dissolved	**not taken**		**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**1.8**	**mg/L**	MDL=	0.3
Propane	**valid**	**1.77149245**	**ug/L**	MDL=	0
Propene	**valid**	**1.48129144**	**ug/L**	MDL=	0
Selenium, dissolved	**not taken**		**mg/L**	MDL=	0.007
Silicon, dissolved	**not taken**		**mg/L**	MDL=	0.04
Silver, dissolved	**not taken**		**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**90**	**mg/L**	MDL=	0.5
Strontium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Sulphate, dissolved	**valid**	**30.2**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**not taken**		**mg/L**	MDL=	0.2
Temperature	**valid**	**6.2**	**C**	MDL=	0
Thallium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Tin, dissolved	**not taken**		**mg/L**	MDL=	0.001
Titanium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Toluene	**nd**	**0**	**ug/L**	MDL=	1.76
Toluene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Total Dissolved Solids	**valid**	**349**	**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**18.3**	**mg/L**	MDL=	0.2
Total volatiles	**<MDL**	**0**	**mg/L**	MDL=	0.1
Total Xylenes	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**not taken**		**mg/L**	MDL=	0.0004
Vanadium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Zinc, dissolved	**not taken**		**mg/L**	MDL=	0.0006
Zirconium, dissolved	**not taken**		**mg/L**	MDL=	0.0002

SP-03-FLT2-06

Sample Type: Field Groundwater
Collection Method: Piezometer
Date Collected: 26/07/2003
Easting: 468919 **Northing:** 6315213 **Elevation:**
Collected By: Barrett Elliott University of Waterloo
Field Notes: elevation=top of screen; brown; turbid

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**4.74196326**	**ug/L**	MDL=	1.63

Alkalinity	**valid**	**287**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**0.32**	**mg/L**	MDL=	0.01
Antimony, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Arsenic, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Barium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Beryllium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**351**	**mg/L**	MDL=	0.5
Boron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Cadmium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**51.3**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.03**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**7.7**	**mg/L**	MDL=	0.1
Chromium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Cobalt, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Copper, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**28.1**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.35**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**538**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**valid**	**11.0605934**	**ug/L**	MDL=	0
Ethene	**valid**	**0.124201**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Ethylbenzene	**valid**	**2.97993654**	**ug/L**	MDL=	1.49
Fluoride, dissolved	**valid**	**0.28**	**mg/L**	MDL=	0.05
Hardness (CaCO3)	**valid**	**180**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.26**	**mg/L**	MDL=	0.01
Lead, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Lithium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**11.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**1.26**	**mg/L**	MDL=	0.004
Methane	**valid**	**1922.14839**	**ug/L**	MDL=	0
Molybdenum, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**nd**	**0**	**ug/L**	MDL=	4.66
Nickel, dissolved	**not taken**		**mg/L**	MDL=	0.0005

Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
O-Xylene	**nd**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**nd**	**0**	**ug/L**	MDL=	3.13
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
pH	**not taken**		**N/A**	MDL=	0
pH	**valid**	**7.72**	**N/A**	MDL=	0
Phosphorus, dissolved	**not taken**		**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**1.9**	**mg/L**	MDL=	0.3
Propane	**valid**	**0.26222522**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Selenium, dissolved	**not taken**		**mg/L**	MDL=	0.007
Silicon, dissolved	**not taken**		**mg/L**	MDL=	0.04
Silver, dissolved	**not taken**		**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**58.9**	**mg/L**	MDL=	0.5
Strontium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Sulphate, dissolved	**<MDL**	**0.1**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**not taken**		**mg/L**	MDL=	0.2
Temperature	**valid**	**4.9**	**C**	MDL=	0
Thallium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Tin, dissolved	**not taken**		**mg/L**	MDL=	0.001
Titanium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Toluene	**nd**	**0**	**ug/L**	MDL=	1.76
Toluene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Total Dissolved Solids	**valid**	**306**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**17**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**29.3**	**mg/L**	MDL=	0.2
Total volatiles	**<MDL**	**0**	**mg/L**	MDL=	0.1
Total Xylenes	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**not taken**		**mg/L**	MDL=	0.0004
Vanadium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Zinc, dissolved	**not taken**		**mg/L**	MDL=	0.0006
Zirconium, dissolved	**not taken**		**mg/L**	MDL=	0.0002

SP-03-FLT2-July27TB	**Sample Type:**	Quality Control	Trip Blank
	Collection Method:	Tap or carboy or water truck	
	Date Collected:	27/07/2003	
	Easting:	**Northing:**	**Elevation:**
	Collected By:	Barrett Elliott	University of Waterloo
	Field Notes:		

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

SP-03-FLT2-July25TB	**Sample Type:**	Quality Control	Trip Blank
	Collection Method:	Tap or carboy or water truck	
	Date Collected:	25/07/2003	
	Easting:	**Northing:**	**Elevation:**
	Collected By:	Barrett Elliott	University of Waterloo
	Field Notes:		

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

SP-02-FLT2-02

Sample Type: Field Groundwater
Collection Method: Piezometer
Date Collected: 24/07/2003
Easting: 469000 **Northing:** 6315266 **Elevation:**
Collected By: Barrett Elliott University of Waterloo
Field Notes: elevation=top of screen; much degassing; greenish water

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**4.03314256**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**532**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**valid**	**0.003**	**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**0.55**	**mg/L**	MDL=	0.01
Antimony, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Arsenic, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Barium, dissolved	**valid**	**0.003**	**mg/l**	MDL=	0.0002
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Beryllium, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**650**	**mg/L**	MDL=	0.5
Boron, dissolved	**valid**	**0.38**	**mg/L**	MDL=	0.01
Cadmium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**195**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.01**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**14.3**	**mg/L**	MDL=	0.1
Chromium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Cobalt, dissolved	**valid**	**0.0016**	**mg/L**	MDL=	0.0003
Copper, dissolved	**valid**	**0.0005**	**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**22.7**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.1**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1430**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**valid**	**13.0844721**	**ug/L**	MDL=	0
Ethene	**valid**	**0.49976117**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**2.34863878**	**ug/L**	MDL=	1.49
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Fluoride, dissolved	**valid**	**0.19**	**mg/L**	MDL=	0.05

Hardness (CaCO3)	valid	670		MDL=	0
Hydroxide	<MDL	0	mg/L	MDL=	0.5
Iron, dissolved	valid	0.03	mg/L	MDL=	0.01
Lead, dissolved	<MDL	0	mg/L	MDL=	0.0003
Lithium, dissolved	valid	0.03	mg/L	MDL=	0.004
Magnesium, dissolved	valid	44.8	mg/L	MDL=	0.2
Manganese, dissolved	valid	1.13	mg/L	MDL=	0.004
Methane	valid	16.1546942	ug/L	MDL=	0
Molybdenum, dissolved	valid	0.0015	mg/L	MDL=	0.0002
Naphthalene	nd	0	ug/L	MDL=	4.66
Naphthalene	nd	0	ug/L	MDL=	2.32
Naphthalene	nd	0	ug/L	MDL=	2.69
Nickel, dissolved	valid	0.0016	mg/L	MDL=	0.0005
Nitrate, dissolved	<MDL	0	mg/L	MDL=	0.003
Nitrite, dissolved	<MDL	0	mg/L	MDL=	0.003
O-Xylene	not taken		ug/L	MDL=	0.0005
O-Xylene	nd	0	ug/L	MDL=	3
P- and M-Xylene	nd	0	ug/L	MDL=	3.13
P- and M-Xylene	not taken		ug/L	MDL=	0.0005
pH	valid	7.3	N/A	MDL=	0
pH	valid	7.38	N/A	MDL=	0
Phosphorus, dissolved	<MDL	0	mg/L	MDL=	0.1
Potassium, dissolved	valid	3.5	mg/L	MDL=	0.3
Propane	valid	0.32073829	ug/L	MDL=	0
Propene	valid	0.823394	ug/L	MDL=	0
Selenium, dissolved	<MDL	0	mg/L	MDL=	0.007
Silicon, dissolved	valid	7.43	mg/L	MDL=	0.04
Silver, dissolved	<MDL	0	mg/L	MDL=	0.0001
Sodium, dissolved	valid	113	mg/L	MDL=	0.5
Strontium, dissolved	valid	0.63	mg/L	MDL=	0.004
Sulphate, dissolved	valid	349	mg/L	MDL=	0.1
Sulphur, dissolved	valid	114	mg/L	MDL=	0.2
Temperature	valid	7	C	MDL=	0
Thallium, dissolved	<MDL	0	mg/L	MDL=	0.0002
Tin, dissolved	<MDL	0	mg/L	MDL=	0.001
Titanium, dissolved	<MDL	0	mg/L	MDL=	0.001
Toluene	nd	0	ug/L	MDL=	1.76
Toluene	<MDL	0	ug/L	MDL=	0.0005
Total Dissolved Solids	valid	1040	mg/L	MDL=	1
Total Naphthenic Acid	valid	19	mg/L	MDL=	1
Total organic carbon	valid	22.9	mg/L	MDL=	0.2
Total volatiles	not taken		mg/L	MDL=	0.1

Total Xylenes	**valid**	**0.0006**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0004
Vanadium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Zinc, dissolved	**valid**	**0.0107**	**mg/L**	MDL=	0.0006
Zirconium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002

SP-02-FLT2-05

Sample Type: Field Groundwater

Collection Method: Piezometer

Date Collected: 25/07/2003

Easting: 468816 **Northing:** 6315151 **Elevation:**

Collected By: Barrett Elliott University of Waterloo

Field Notes: elevation=top of screen; much degassing; smells like hydrogen compo

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**1.75229412**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**valid**	**1.64397963**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**8.25550181**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**563**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**valid**	**0.03**	**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**0.72**	**mg/L**	MDL=	0.01
Antimony, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Arsenic, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Barium, dissolved	**valid**	**0.3**	**mg/l**	MDL=	0.0002
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Beryllium, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**686**	**mg/L**	MDL=	0.5
Boron, dissolved	**valid**	**1.39**	**mg/L**	MDL=	0.01
Cadmium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**90.5**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.97**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**14.7**	**mg/L**	MDL=	0.1
Chromium, dissolved	**valid**	**0.002**	**mg/L**	MDL=	0.001
Cobalt, dissolved	**valid**	**0.0006**	**mg/L**	MDL=	0.0003
Copper, dissolved	**valid**	**0.0009**	**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**29.5**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.5**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1340**	**uS/cm**	MDL=	

Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**valid**	**0.41996598**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**4.72658424**	**ug/L**	MDL=	1.49
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Fluoride, dissolved	**valid**	**0.62**	**mg/L**	MDL=	0.05
Hardness (CaCO3)	**valid**	**330**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**4.72**	**mg/L**	MDL=	0.01
Lead, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0003
Lithium, dissolved	**valid**	**0.044**	**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**26.9**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.29**	**mg/L**	MDL=	0.004
Methane	**valid**	**0.10220012**	**ug/L**	MDL=	0
Molybdenum, dissolved	**valid**	**0.0012**	**mg/L**	MDL=	0.0002
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**3.48980433**	**ug/L**	MDL=	4.66
Naphthalene	**valid**	**2.97188994**	**ug/L**	MDL=	2.32
Nickel, dissolved	**valid**	**0.0147**	**mg/L**	MDL=	0.0005
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**valid**	**0.016**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
O-Xylene	**nd**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
P- and M-Xylene	**valid**	**3.25636819**	**ug/L**	MDL=	3.13
pH	**not taken**		**N/A**	MDL=	0
pH	**valid**	**7.91**	**N/A**	MDL=	0
Phosphorus, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**2.1**	**mg/L**	MDL=	0.3
Propane	**valid**	**0.16903775**	**ug/L**	MDL=	0
Propene	**valid**	**0.14035125**	**ug/L**	MDL=	0
Selenium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.007
Silicon, dissolved	**valid**	**7.76**	**mg/L**	MDL=	0.04
Silver, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**216**	**mg/L**	MDL=	0.5
Strontium, dissolved	**valid**	**0.33**	**mg/L**	MDL=	0.004
Sulphate, dissolved	**valid**	**203**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**valid**	**66.9**	**mg/L**	MDL=	0.2
Temperature	**valid**	**5.1**	**C**	MDL=	0
Thallium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Tin, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Titanium, dissolved	**valid**	**0.004**	**mg/L**	MDL=	0.001

Toluene	**nd**	**0**	**ug/L**	MDL=	1.76
Toluene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Total Dissolved Solids	**valid**	**873**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**29**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**29.5**	**mg/L**	MDL=	0.2
Total volatiles	**<MDL**	**0**	**mg/L**	MDL=	0.1
Total Xylenes	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0004
Vanadium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Zinc, dissolved	**valid**	**0.0038**	**mg/L**	MDL=	0.0006
Zirconium, dissolved	**valid**	**0.0018**	**mg/L**	MDL=	0.0002

SP-02-FLT2-09

Sample Type: Field Groundwater
Collection Method: Piezometer
Date Collected: 26/07/2003
Easting: 468595 **Northing:** 6315257 **Elevation:**
Collected By: Barrett Elliott University of Waterloo
Field Notes: elevation=top of screen; slightly green; moderate degassing;

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**valid**	**2.68958881**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**11.0669918**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**567**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**valid**	**0.003**	**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**0.93**	**mg/L**	MDL=	0.01
Antimony, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Arsenic, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Barium, dissolved	**valid**	**0.497**	**mg/l**	MDL=	0.0002
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Benzene	**valid**	**0.0006**	**ug/L**	MDL=	0.0005
Beryllium, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**691**	**mg/L**	MDL=	0.5
Boron, dissolved	**valid**	**1.09**	**mg/L**	MDL=	0.01
Cadmium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**66.8**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.06**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**46.4**	**mg/L**	MDL=	0.1

Chromium, dissolved	**valid**	**0.002**	**mg/L**	MDL=	0.001
Cobalt, dissolved	**valid**	**0.0011**	**mg/L**	MDL=	0.0003
Copper, dissolved	**valid**	**0.0005**	**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**26.6**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.1**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1140**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**1.01848188**	**ug/L**	MDL=	1.49
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Fluoride, dissolved	**valid**	**0.17**	**mg/L**	MDL=	0.05
Hardness (CaCO3)	**valid**	**240**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.26**	**mg/L**	MDL=	0.01
Lead, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0003
Lithium, dissolved	**valid**	**0.074**	**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**16.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.339**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Molybdenum, dissolved	**valid**	**0.027**	**mg/L**	MDL=	0.0002
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**3.63957872**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**2.07931487**	**ug/L**	MDL=	2.32
Nickel, dissolved	**valid**	**0.0118**	**mg/L**	MDL=	0.0005
Nitrate, dissolved	**not taken**		**mg/L**	MDL=	0.003
Nitrite, dissolved	**not taken**		**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
O-Xylene	**nd**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
P- and M-Xylene	**nd**	**0**	**ug/L**	MDL=	3.13
pH	**not taken**		**N/A**	MDL=	0
pH	**valid**	**7.9**	**N/A**	MDL=	0
Phosphorus, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**4.9**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Selenium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.007
Silicon, dissolved	**valid**	**11.2**	**mg/L**	MDL=	0.04
Silver, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**205**	**mg/L**	MDL=	0.5
Strontium, dissolved	**valid**	**0.58**	**mg/L**	MDL=	0.004

Sulphate, dissolved	**valid**	**19.8**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**valid**	**9.1**	**mg/L**	MDL=	0.2
Temperature	**valid**	**8.3**	**C**	MDL=	0
Thallium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Tin, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Titanium, dissolved	**valid**	**0.004**	**mg/L**	MDL=	0.001
Toluene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Toluene	**nd**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**701**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**34**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**27.7**	**mg/L**	MDL=	0.2
Total volatiles	**<MDL**	**0**	**mg/L**	MDL=	0.1
Total Xylenes	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0004
Vanadium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Zinc, dissolved	**valid**	**0.0069**	**mg/L**	MDL=	0.0006
Zirconium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002

SP-03-FLT2-01

Sample Type: Field Groundwater
Collection Method: Piezometer
Date Collected: 30/07/2003
Easting: 468597 **Northing:** 6314875 **Elevation:**
Collected By: Barrett Elliott University of Waterloo
Field Notes: elevation=top of screen; clear water but slightly grey; bituminous smell,

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**244**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**0.92**	**mg/L**	MDL=	0.01
Antimony, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Arsenic, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Barium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Beryllium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**298**	**mg/L**	MDL=	0.5

Boron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Cadmium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**55.3**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.03**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**3.8**	**mg/L**	MDL=	0.1
Chromium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Cobalt, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Copper, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**5.5**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.03**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**345**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.49
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Fluoride, dissolved	**valid**	**0.24**	**mg/L**	MDL=	0.05
Hardness (CaCO3)	**valid**	**190**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.04**	**mg/L**	MDL=	0.01
Lead, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Lithium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**11.8**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.217**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Molybdenum, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**nd**	**0**	**ug/L**	MDL=	4.66
Nickel, dissolved	**not taken**		**mg/L**	MDL=	0.0005
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**nd**	**0**	**ug/L**	MDL=	3
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
P- and M-Xylene	**nd**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.9**	**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Phosphorus, dissolved	**not taken**		**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**2.5**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0

Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Selenium, dissolved	**not taken**		**mg/L**	MDL=	0.007
Silicon, dissolved	**not taken**		**mg/L**	MDL=	0.04
Silver, dissolved	**not taken**		**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**32.8**	**mg/L**	MDL=	0.5
Strontium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Sulphate, dissolved	**valid**	**6.9**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**not taken**		**mg/L**	MDL=	0.2
Temperature	**valid**	**5.6**	**C**	MDL=	0
Thallium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Tin, dissolved	**not taken**		**mg/L**	MDL=	0.001
Titanium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Toluene	**nd**	**0**	**ug/L**	MDL=	1.76
Toluene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Total Dissolved Solids	**valid**	**261**	**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**6.8**	**mg/L**	MDL=	0.2
Total volatiles	**<MDL**	**0**	**mg/L**	MDL=	0.1
Total Xylenes	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**not taken**		**mg/L**	MDL=	0.0004
Vanadium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Zinc, dissolved	**not taken**		**mg/L**	MDL=	0.0006
Zirconium, dissolved	**not taken**		**mg/L**	MDL=	0.0002

SP-03-FLT2-02

Sample Type: Field Groundwater
Collection Method: Piezometer
Date Collected: 25/07/2003
Easting: 468597 **Northing:** 6314875 **Elevation:**
Collected By: Barrett Elliott University of Waterloo
Field Notes: elevation=top of screen; no degassing visible in bucket

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**198**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**0.2**	**mg/L**	MDL=	0.01
Antimony, dissolved	**not taken**		**mg/L**	MDL=	0.0002

Arsenic, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Barium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Beryllium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**242**	**mg/L**	MDL=	0.5
Boron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Cadmium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**48.1**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.99**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**<MDL**	**0.9**	**mg/L**	MDL=	0.1
Chromium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Cobalt, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Copper, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**6**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.2**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**337**	**uS/cm**	MDL=	
Ethane	**valid**	**0.43538612**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.49
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Fluoride, dissolved	**valid**	**0.18**	**mg/L**	MDL=	0.05
Hardness (CaCO3)	**valid**	**160**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Lead, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Lithium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**9.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.098**	**mg/L**	MDL=	0.004
Methane	**valid**	**1624.04004**	**ug/L**	MDL=	0
Molybdenum, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Naphthalene	**nd**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**valid**	**4.64219769**	**ug/L**	MDL=	2.69
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.32
Nickel, dissolved	**not taken**		**mg/L**	MDL=	0.0005
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
O-Xylene	**nd**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**nd**	**0**	**ug/L**	MDL=	3.13

P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
pH	**not taken**		**N/A**	MDL=	0
pH	**valid**	**7.95**	**N/A**	MDL=	0
Phosphorus, dissolved	**not taken**		**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**1.5**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Selenium, dissolved	**not taken**		**mg/L**	MDL=	0.007
Silicon, dissolved	**not taken**		**mg/L**	MDL=	0.04
Silver, dissolved	**not taken**		**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**16.9**	**mg/L**	MDL=	0.5
Strontium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Sulphate, dissolved	**valid**	**1.5**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**not taken**		**mg/L**	MDL=	0.2
Temperature	**valid**	**8.3**	**C**	MDL=	0
Thallium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Tin, dissolved	**not taken**		**mg/L**	MDL=	0.001
Titanium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Toluene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Toluene	**nd**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**198**	**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**8.1**	**mg/L**	MDL=	0.2
Total volatiles	**<MDL**	**0**	**mg/L**	MDL=	0.1
Total Xylenes	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**not taken**		**mg/L**	MDL=	0.0004
Vanadium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Zinc, dissolved	**not taken**		**mg/L**	MDL=	0.0006
Zirconium, dissolved	**not taken**		**mg/L**	MDL=	0.0002

SP-03-FLT2-04

Sample Type: Field Groundwater
Collection Method: Piezometer
Date Collected: 27/07/2003
Easting: 468919 **Northing:** 6315213 **Elevation:**
Collected By: Barrett Elliott University of Waterloo
Field Notes: elevation=top of screen; brown; turbid; some degassing; bituminous sm

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**1.04146272**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**valid**	**1.59265812**	**ug/L**	MDL=	1.55

1,3,5-Trimethylbenzene	**valid**	**6.34077042**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**481**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**valid**	**0.013**	**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**0.55**	**mg/L**	MDL=	0.01
Antimony, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Arsenic, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Barium, dissolved	**valid**	**0.41**	**mg/l**	MDL=	0.0002
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Beryllium, dissolved	**<MDL**	**0**	**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**587**	**mg/L**	MDL=	0.5
Boron, dissolved	**valid**	**0.66**	**mg/L**	MDL=	0.01
Cadmium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**86**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.99**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**8**	**mg/L**	MDL=	0.1
Chromium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Cobalt, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0003
Copper, dissolved	**valid**	**0.0006**	**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**28**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.1**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**940**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Ethylbenzene	**valid**	**1.79146401**	**ug/L**	MDL=	1.49
Fluoride, dissolved	**valid**	**0.13**	**mg/L**	MDL=	0.05
Hardness (CaCO3)	**valid**	**290**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**26.7**	**mg/L**	MDL=	0.01
Lead, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0003
Lithium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**18**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.502**	**mg/L**	MDL=	0.004
Methane	**valid**	**1.46696479**	**ug/L**	MDL=	0
Molybdenum, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**2.38864958**	**ug/L**	MDL=	4.66
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.69

Nickel, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**nd**	**0**	**ug/L**	MDL=	3
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
P- and M-Xylene	**valid**	**3.37654187**	**ug/L**	MDL=	3.13
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
pH	**valid**	**7.4**	**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Phosphorus, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**2.8**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Selenium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.007
Silicon, dissolved	**valid**	**8.4**	**mg/L**	MDL=	0.04
Silver, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**114**	**mg/L**	MDL=	0.5
Strontium, dissolved	**valid**	**0.37**	**mg/L**	MDL=	0.004
Sulphate, dissolved	**valid**	**53**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**valid**	**17.9**	**mg/L**	MDL=	0.2
Temperature	**valid**	**6.9**	**C**	MDL=	0
Thallium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0002
Tin, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.001
Titanium, dissolved	**valid**	**0.002**	**mg/L**	MDL=	0.001
Toluene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Toluene	**nd**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**599**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**27**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**34.4**	**mg/L**	MDL=	0.2
Total volatiles	**<MDL**	**0**	**mg/L**	MDL=	0.1
Total Xylenes	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.0004
Vanadium, dissolved	**valid**	**0.002**	**mg/L**	MDL=	0.001
Zinc, dissolved	**valid**	**0.0184**	**mg/L**	MDL=	0.0006
Zirconium, dissolved	**valid**	**0.0058**	**mg/L**	MDL=	0.0002

SP-03-FLT2-05	**Sample Type:**	Field		Groundwater	
	Collection Method:	Piezometer			
	Date Collected:	27/07/2003			
	Easting:	468919	**Northing:**	6315213	**Elevation:**
	Collected By:	Barrett Elliott		University of Waterloo	
	Field Notes:	elevation=top of screen; grey; turbid; bituminous smell;			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**1.73016121**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**valid**	**6.72459069**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**527**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Ammonia, Total	**valid**	**0.6**	**mg/L**	MDL=	0.01
Antimony, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Arsenic, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Barium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Beryllium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**644**	**mg/L**	MDL=	0.5
Boron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Cadmium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**114**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.02**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**9.1**	**mg/L**	MDL=	0.1
Chromium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Cobalt, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Copper, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**29**	**mg/L**	MDL=	0.2
Dissolved oxygen	**valid**	**0.1**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1140**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**valid**	**10.7249164**	**ug/L**	MDL=	0
Ethene	**valid**	**0.35421825**	**ug/L**	MDL=	0
Ethylbenzene	**valid**	**2.43921358**	**ug/L**	MDL=	1.49
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Fluoride, dissolved	**valid**	**0.14**	**mg/L**	MDL=	0.05

Hardness (CaCO3)	**valid**	**380**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.03**	**mg/L**	MDL=	0.01
Lead, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Lithium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**24.1**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.247**	**mg/L**	MDL=	0.004
Methane	**valid**	**7.89634182**	**ug/L**	MDL=	0
Molybdenum, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Naphthalene	**<MDL**	**2.21187708**	**ug/L**	MDL=	4.66
Naphthalene	**valid**	**2.70558606**	**ug/L**	MDL=	2.32
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.69
Nickel, dissolved	**not taken**		**mg/L**	MDL=	0.0005
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**valid**	**0.006**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
O-Xylene	**<MDL**	**1.32276038**	**ug/L**	MDL=	3
P- and M-Xylene	**valid**	**3.47677542**	**ug/L**	MDL=	3.13
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
pH	**not taken**		**N/A**	MDL=	0
pH	**valid**	**7.47**	**N/A**	MDL=	0
Phosphorus, dissolved	**not taken**		**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**3.2**	**mg/L**	MDL=	0.3
Propane	**valid**	**0.44652536**	**ug/L**	MDL=	0
Propene	**valid**	**0.41549194**	**ug/L**	MDL=	0
Selenium, dissolved	**not taken**		**mg/L**	MDL=	0.007
Silicon, dissolved	**not taken**		**mg/L**	MDL=	0.04
Silver, dissolved	**not taken**		**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**139**	**mg/L**	MDL=	0.5
Strontium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Sulphate, dissolved	**valid**	**133**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**not taken**		**mg/L**	MDL=	0.2
Temperature	**valid**	**5.9**	**C**	MDL=	0
Thallium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Tin, dissolved	**not taken**		**mg/L**	MDL=	0.001
Titanium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Toluene	**nd**	**0**	**ug/L**	MDL=	1.76
Toluene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Total Dissolved Solids	**valid**	**739**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**26**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**32.3**	**mg/L**	MDL=	0.2
Total volatiles	**<MDL**	**0**	**mg/L**	MDL=	0.1

Total Xylenes	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**not taken**		**mg/L**	MDL=	0.0004
Vanadium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Zinc, dissolved	**not taken**		**mg/L**	MDL=	0.0006
Zirconium, dissolved	**not taken**		**mg/L**	MDL=	0.0002

SP-02-FLT2-02A

Sample Type: Quality Control Duplicate
Collection Method: Tap or carboy or water truck
Date Collected: 24/07/2003
Easting: **Northing:** **Elevation:**
Collected By: Barrett Elliott University of Waterloo
Field Notes:

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

SP-03-FLT2-02D

Sample Type: Quality Control Duplicate
Collection Method: Piezometer
Date Collected: 29/07/2003
Easting: 468597 **Northing:** 6314875 **Elevation:**
Collected By: Barrett Elliott University of Waterloo
Field Notes: elevation=top of screen; much degassing; greenish water

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**197**	**mg/L**	MDL=	0.5
Aluminium, dissolved	**not taken**		**mg/L**	MDL=	0.001

Ammonia, Total	**valid**	**0.2**	**mg/L**	MDL=	0.01
Antimony, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Arsenic, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Barium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Benzene	**nd**	**0**	**ug/L**	MDL=	1.82
Benzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Beryllium, dissolved	**not taken**		**mg/l**	MDL=	0.0002
Bicarbonate	**valid**	**241**	**mg/L**	MDL=	0.5
Boron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Cadmium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Calcium, dissolved	**valid**	**47.3**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.97**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**2**	**mg/L**	MDL=	0.1
Chromium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Cobalt, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Copper, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Dissolved organic carbon	**valid**	**4.7**	**mg/L**	MDL=	0.2
Electrical Conductivity	**valid**	**338**	**uS/cm**	MDL=	
Ethane	**valid**	**0.45078563**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**nd**	**0**	**ug/L**	MDL=	1.49
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Fluoride, dissolved	**valid**	**0.18**	**mg/L**	MDL=	0.05
Hardness (CaCO3)	**valid**	**160**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Lead, dissolved	**not taken**		**mg/L**	MDL=	0.0003
Lithium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Magnesium, dissolved	**valid**	**9.4**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.096**	**mg/L**	MDL=	0.004
Methane	**valid**	**1735.55893**	**ug/L**	MDL=	0
Molybdenum, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Naphthalene	**<MDL**	**2.05404068**	**ug/L**	MDL=	2.69
Naphthalene	**nd**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**nd**	**0**	**ug/L**	MDL=	2.32
Nickel, dissolved	**not taken**		**mg/L**	MDL=	0.0005
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**nd**	**0**	**ug/L**	MDL=	3
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
P- and M-Xylene	**nd**	**0**	**ug/L**	MDL=	3.13

P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
pH	**not taken**	**0**	**N/A**	MDL=	0
pH	**valid**	**7.93**	**N/A**	MDL=	0
Phosphorus, dissolved	**not taken**		**mg/L**	MDL=	0.1
Potassium, dissolved	**valid**	**1.5**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Selenium, dissolved	**not taken**		**mg/L**	MDL=	0.007
Silicon, dissolved	**not taken**		**mg/L**	MDL=	0.04
Silver, dissolved	**not taken**		**mg/L**	MDL=	0.0001
Sodium, dissolved	**valid**	**16.7**	**mg/L**	MDL=	0.5
Strontium, dissolved	**not taken**		**mg/L**	MDL=	0.004
Sulphate, dissolved	**valid**	**1**	**mg/L**	MDL=	0.1
Sulphur, dissolved	**not taken**		**mg/L**	MDL=	0.2
Thallium, dissolved	**not taken**		**mg/L**	MDL=	0.0002
Tin, dissolved	**not taken**		**mg/L**	MDL=	0.001
Titanium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Toluene	**<MDL**	**0**	**ug/L**	MDL=	0.0005
Toluene	**nd**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**197**	**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1
Total organic carbon	**valid**	**6.8**	**mg/L**	MDL=	0.2
Total volatiles	**<MDL**	**0**	**mg/L**	MDL=	0.1
Total Xylenes	**<MDL**	**0**	**mg/L**	MDL=	0.0005
Uranium, dissolved	**not taken**		**mg/L**	MDL=	0.0004
Vanadium, dissolved	**not taken**		**mg/L**	MDL=	0.001
Zinc, dissolved	**not taken**		**mg/L**	MDL=	0.0006
Zirconium, dissolved	**not taken**		**mg/L**	MDL=	0.0002

WP-03-MLSB-1.01

Sample Type: Quality Control Equipment Blank
Collection Method: Tap or carboy or water truck
Date Collected: 26/07/2003
Easting: 463574.23 **Northing:** 6325493.49 **Elevation:** 317.8859
Collected By: Bob Ingleton University of Waterloo
Field Notes: Sunny; 20C

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63

Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.94**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**6.3**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**50.8**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**valid**	**0.98**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**<MDL**	**0**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.28**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.026**	**mg/L**	MDL=	0.004
Methane	**valid**	**0.79**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**4.14**	**N/A**	MDL=	0
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.25**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**2.1**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.3**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-1.02

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 26/07/2003

Easting: 463574.23 **Northing:** 6325493.49 **Elevation:** 312.0947

Collected By: Bob Ingleton University of Waterloo

Field Notes: Sunny; 20C; turbid, reddish brown

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results	MDL

Chloride, dissolved	**valid**	**158**	**mg/L**	MDL=	0.1
Total Naphthenic Acid	**valid**	**100**	**mg/L**	MDL=	1

WP-03-MLSB-1.03	**Sample Type:**	Field	Groundwater		
	Collection Method:	Waterloo Profiler			
	Date Collected:	26/07/2003			
	Easting:	463574.23	**Northing:** 6325493.49	**Elevation:**	310.2659
	Collected By:	Bob Ingleton	University of Waterloo		
	Field Notes:	Sunny; 20C; turbid, reddish brown			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Chloride, dissolved	**valid**	**153**	**mg/L**	MDL=	0.1
Total Naphthenic Acid	**valid**	**100**	**mg/L**	MDL=	1

WP-03-MLSB-2.01	**Sample Type:**	Quality Control	Equipment Blank		
	Collection Method:	Tap or carboy or water truck			
	Date Collected:	26/07/2003			
	Easting:	463664.41	**Northing:** 6325524.36	**Elevation:**	315.4774
	Collected By:	Bob Ingleton	University of Waterloo		
	Field Notes:	Sunny; 30C			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**3.2**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**3.9**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3

Calculated Ion Balanced	**valid**	**0.63**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**<MDL**	**0.9**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**9**	**uS/cm**	MDL=	
Ethane	**valid**	**0.3513888**	**ug/L**	MDL=	0
Ethene	**valid**	**1.417574**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**<MDL**	**0**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.03**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.024**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0.14696861**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**4.89**	**N/A**	MDL=	0
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.10995470**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.56461781**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**1.1**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.3**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-2.02

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 26/07/2003
Easting: 463664.41 **Northing:** 6325524.36 **Elevation:** 312.4294
Collected By: Bob Ingleton University of Waterloo
Field Notes: Sunny; 30C; clear, slightly beige

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**323**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5

Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**394**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**81.3**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.07**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**57.8**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**2.95**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**720**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1020**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**290**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**22.2**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**11.5**	**mg/L**	MDL=	0.004
Methane	**valid**	**4.32338807**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**not taken**		**N/A**	MDL=	0
pH	**valid**	**7.59**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**4.6**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**124**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**123**	**mg/L**	MDL=	0.1
Temperature	**valid**	**31.6**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Naphthenic Acid	**valid**	**8**	**mg/L**	MDL=	1

WP-03- MLSB-2.03	**Sample Type:**	Field		Groundwater		
	Collection Method:	Waterloo Profiler				
	Date Collected:	26/07/2003				
	Easting:	463664.41	**Northing:**	6325524.36	**Elevation:**	310.6006
	Collected By:	Bob Ingleton		University of Waterloo		
	Field Notes:	Sunny; 30C; rusty water				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**743**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**906**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**55.1**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.04**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**120**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**1950**	**uS/cm**	MDL=	
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**190**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.14**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**12.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**3.1**	**mg/L**	MDL=	0.004
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**valid**	**0.008**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.92**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3.4**	**mg/L**	MDL=	0.3
Sodium, dissolved	**valid**	**439**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**190**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1270**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**85**	**mg/L**	MDL=	1

WP-03-MLSB-2.04	**Sample Type:**	Field		Groundwater		
	Collection Method:	Waterloo Profiler				
	Date Collected:	27/07/2003				
	Easting:	463664.41	**Northing:**	6325524.36	**Elevation:**	309.229
	Collected By:	Bob Ingleton		University of Waterloo		
	Field Notes:	Sunny; 20C; rusty water; 23 ft muddier water				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**722**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**881**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**46.5**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.06**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**113**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**1880**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**150**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.11**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**9.5**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.367**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**valid**	**0.01**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**8.06**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.4**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.63529384**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0

Sodium, dissolved	**valid**	**451**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**181**	**mg/L**	MDL=	0.1
Toluene	**valid**	**2.6**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1240**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**76**	**mg/L**	MDL=	1

WP-03-MLSB-2.05

Sample Type:	Field		Groundwater		
Collection Method:	Waterloo Profiler				
Date Collected:	27/07/2003				
Easting:	463664.41	**Northing:**	6325524.36	**Elevation:**	307.4002
Collected By:	Bob Ingleton		University of Waterloo		
Field Notes:	Sunny; 20C; grey water, becomes clear; foaming				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**822**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**1000**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**98.2**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.02**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**150**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**2.16**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1275**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1890**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**320**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.14**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**18**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.184**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**1.54**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32

Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.87**	**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.8**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.24799758**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**376**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**80.4**	**mg/L**	MDL=	0.1
Temperature	**valid**	**29.9**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1220**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**80**	**mg/L**	MDL=	1

WP-03-MLSB-3.02

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 27/07/2003

Easting: 463747.62 **Northing:** 6325534.09 **Elevation:** 311.7891

Collected By: Bob Ingleton University of Waterloo

Field Notes: start: turbid, dark brown

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**206**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**251**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**48.4**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.07**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**19.3**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**2.08**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**635**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**529**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0

Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**160**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.12**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**10.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**1.24**	**mg/L**	MDL=	0.004
Methane	**valid**	**2.77541721**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.64**	**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.1**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**75.1**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**73.2**	**mg/L**	MDL=	0.1
Temperature	**valid**	**25**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**354**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**9**	**mg/L**	MDL=	1

WP-03-MLSB-3.04

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 27/07/2003

Easting: 463747.62 **Northing:** 6325534.09 **Elevation:** 309.9603

Collected By: Bob Ingleton University of Waterloo

Field Notes: rusty brown, turbid

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**71.3**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5

Chloride, dissolved	**valid**	**153**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.04**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**19**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**2.65**	**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**1.6**	**mg/L**	MDL=	0.3
Sodium, dissolved	**valid**	**411**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**187**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**29**	**mg/L**	MDL=	1

WP-03-MLSB-3.06

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 27/07/2003

Easting: 463747.62 **Northing:** 6325534.09 **Elevation:** 308.1315

Collected By: Bob Ingleton University of Waterloo

Field Notes: clear; slightly milky or grey; slow flow

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**170**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0

Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**16.7**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**56**	**mg/L**	MDL=	1

WP-03-MLSB-3.09

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 28/07/2003

Easting: 463747.62 **Northing:** 6325534.09 **Elevation:** 307.2171

Collected By: Bob Ingleton University of Waterloo

Field Notes: light grey fines; cleaned up quickly

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**736**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**898**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**119**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**130**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**1590**	**uS/cm**	MDL=	
Ethane	**valid**	**1.48360237**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0.0948365**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**380**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.23**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**19.3**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.314**	**mg/L**	MDL=	0.004
Methane	**valid**	**459.694179**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**1.02**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003

O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.82**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**3.5**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.20596409**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.13660125**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**253**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**11.7**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**979**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**42**	**mg/L**	MDL=	1

WP-03-MLSB-3.10

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 28/07/2003
Easting: 463747.62 **Northing:** 6325534.09 **Elevation:** 306.3027
Collected By: Bob Ingleton University of Waterloo
Field Notes: slightly darker grey than 3.9; degassing slightly

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**619**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**15.9**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**172**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.04**		MDL=	0
Carbonate	**valid**	**755**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**109**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**2.77**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1370**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**759**	**uS/cm**	MDL=	
Ethane	**valid**	**0.99256835**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0.15487275**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**550**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.12**	**mg/L**	MDL=	0.01

Magnesium, dissolved	**valid**	**29.3**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.517**	**mg/L**	MDL=	0.004
Methane	**valid**	**108.56475**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**7.76**	**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**4.2**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.10588231**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.17049244**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**126**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**23.6**	**mg/L**	MDL=	0.1
Temperature	**valid**	**28**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**836**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**23**	**mg/L**	MDL=	1

WP-03-MLSB-3.11

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 28/07/2003

Easting: 463747.62 **Northing:** 6325534.09 **Elevation:** 305.6904

Collected By: Bob Ingleton University of Waterloo

Field Notes: dark grey fines in waer

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**101**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**14.7**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5

Iron, dissolved	**valid**	**0.03**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**18.3**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.271**	**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0.03**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**4.3**	**mg/L**	MDL=	0.3
Sodium, dissolved	**valid**	**10**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**22**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1

WP-03-MLSB-4.01

Sample Type: Quality Control Equipment Blank

Collection Method: Tap or carboy or water truck

Date Collected: 28/07/2003

Easting: 463811.57 **Northing:** 6325565.97 **Elevation:** 316.9056

Collected By: Bob Ingleton University of Waterloo

Field Notes: sunny 27C

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**5.9**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**7.2**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0.5**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.15**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**1.1**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**7**	**uS/cm**	MDL=	
Ethane	**valid**	**1.12534201**	**ug/L**	MDL=	0
Ethene	**valid**	**2.92125158**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**1.2**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.12**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.33**	**mg/L**	MDL=	0.004
Methane	**valid**	**0.53821574**	**ug/L**	MDL=	0

Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**8.38**	**N/A**	MDL=	0
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.28582772**	**ug/L**	MDL=	0
Propene	**valid**	**1.40926956**	**ug/L**	MDL=	0
Sodium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**6**	**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-4.02

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 28/07/2003

Easting: 463811.57 **Northing:** 6325565.97 **Elevation:** 311.1144

Collected By: Bob Ingleton University of Waterloo

Field Notes: rusty brown fines

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**730**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**891**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**128**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.99**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**134**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.084**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1099**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1790**	**uS/cm**	MDL=	
Ethane	**valid**	**0.61662134**	**ug/L**	MDL=	0

Ethene	**valid**	**0.35117775**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**430**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.1**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**27.6**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**5.85**	**mg/L**	MDL=	0.004
Methane	**valid**	**48.148327**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Nitrate, dissolved	**valid**	**0.036**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**valid**	**2.17**	**ug/L**	MDL=	3
P- and M-Xylene	**valid**	**4.36**	**ug/L**	MDL=	3.13
pH	**valid**	**7.6**	**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.4**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.57880669**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**280**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**137**	**mg/L**	MDL=	0.1
Temperature	**valid**	**31**	**C**	MDL=	0
Toluene	**valid**	**4.78**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1150**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**66**	**mg/L**	MDL=	1

WP-03-MLSB-4.03

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 28/07/2003
Easting: 463811.57 **Northing:** 6325565.97 **Elevation:** 310.2
Collected By: Bob Ingleton University of Waterloo
Field Notes: 27' sandy clay; soft; bituminous; dark grey

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0

Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**148**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0.005**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**9**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**52**	**mg/L**	MDL=	1

WP-03-MLSB-4.04

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 28/07/2003

Easting: 463811.57 **Northing:** 6325565.97 **Elevation:** 309.1027

Collected By: Bob Ingleton University of Waterloo

Field Notes:

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**154**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**3.12**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1120**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**valid**		**mg/L**	MDL=	0.01

Magnesium, dissolved	**valid**		**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**		**mg/L**	MDL=	0.004
Methane	**valid**	**2.86260637**	**ug/L**	MDL=	0
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**70.9**	**mg/L**	MDL=	0.1
Temperature	**valid**	**26**	**C**	MDL=	0
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**77**	**mg/L**	MDL=	1

WP-03-MLSB-5.01

Sample Type: Quality Control Equipment Blank
Collection Method: Tap or carboy or water truck
Date Collected: 29/07/2003
Easting: 463904.34 **Northing:** 6325600.81 **Elevation:** 318.1456
Collected By: Bob Ingleton University of Waterloo
Field Notes: sunny; 15C

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**5.3**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**6.4**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0.3**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.32**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**1.2**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**6**	**uS/cm**	MDL=	
Ethane	**valid**	**1.25715991**	**ug/L**	MDL=	0
Ethene	**valid**	**2.91746775**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**<MDL**	**0.7**		MDL=	0

Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.03**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.026**	**mg/L**	MDL=	0.004
Methane	**valid**	**0.46749311**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**6.87**	**N/A**	MDL=	0
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.31153833**	**ug/L**	MDL=	0
Propene	**valid**	**1.53221775**	**ug/L**	MDL=	0
Sodium, dissolved	**<MDL**	**0.7**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.2**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**6**	**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-5.02

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 29/07/2003

Easting: 463904.34 **Northing:** 6325600.81 **Elevation:** 311.1352

Collected By: Bob Ingleton University of Waterloo

Field Notes: rusty brown

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**valid**	**4.98**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**47.5**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5

Chloride, dissolved	**valid**	**130**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0.145106**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**10.1**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**3.62**	**mg/L**	MDL=	0.004
Methane	**valid**	**2.78058696**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**1.17**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0.01**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**valid**	**2.29**	**ug/L**	MDL=	3
P- and M-Xylene	**valid**	**5.45**	**ug/L**	MDL=	3.13
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**1.9**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.21920456**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**448**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**128**	**mg/L**	MDL=	0.1
Toluene	**valid**	**5.6**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**44**	**mg/L**	MDL=	1

WP-03-MLSB-5.03

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 29/07/2003
Easting: 463904.34 **Northing:** 6325600.81 **Elevation:** 309.6112
Collected By: Bob Ingleton University of Waterloo
Field Notes:

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**not taken**		**mg/L**	MDL=	0.5

Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**75.8**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**120**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**3.83**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1169**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Ethane	**valid**	**1.23756054**	**ug/L**	MDL=	0
Ethene	**valid**	**0.56786675**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.05**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**13.9**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.508**	**mg/L**	MDL=	0.004
Methane	**valid**	**100.440857**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**2.13**	**ug/L**	MDL=	3.13
pH	**not taken**		**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**valid**	**2.6**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.44796361**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.48269288**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**273**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**52.7**	**mg/L**	MDL=	0.1
Temperature	**valid**	**36**	**C**	MDL=	0
Toluene	**valid**	**2.83**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**28**	**mg/L**	MDL=	1

WP-03-MLSB-6.01	**Sample Type:**	Quality Control		Equipment Blank	
	Collection Method:	Tap or carboy or water truck			
	Date Collected:	29/07/2003			
	Easting:	464194.46	**Northing:**	6324929.43	**Elevation:** 317.29
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	sunny; 28C			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**<MDL**	**0.6**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**<MDL**	**0.1**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-6.02	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	29/07/2003			
	Easting:	464194.46	**Northing:**	6324929.43	**Elevation:** 311.4988
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	wt@17'; rusty brown fines			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**5.5**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**1.62**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**420**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**valid**	**18.8**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**50.2**	**mg/L**	MDL=	0.1
Temperature	**valid**	**35**	**C**	MDL=	0
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-6.03	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	29/07/2003			
	Easting:	464194.46	**Northing:**	6324929.43	**Elevation:** 309.67
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	light grey fines			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**4.1**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**1.34**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**383**	**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**valid**	**0.009**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**42.5**	**mg/L**	MDL=	0.1
Temperature	**valid**	**35**	**C**	MDL=	0
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-7.01	**Sample Type:**	Quality Control		Equipment Blank	
	Collection Method:	Tap or carboy or water truck			
	Date Collected:	30/07/2003			
	Easting:	464144.53	**Northing:**	6325037.79	**Elevation:** 316.96
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	sunny; 16C			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**2**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.3**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1

WP-03-MLSB-7.02	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	30/07/2003			
	Easting:	464144.53	**Northing:**	6325037.79	**Elevation:** 310.864
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	wt@19'; rusty brown			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**21.3**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**4.25**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**399**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**valid**	**0.461**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**29.4**	**mg/L**	MDL=	0.1
Temperature	**valid**	**29**	**C**	MDL=	0
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-7.03	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	30/07/2003			
	Easting:	464144.53	**Northing:**	6325037.79	**Elevation:** 309.34
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	almost clear brown from start; still bubbles			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**13.7**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**2.27**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**554**	**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**31.2**	**mg/L**	MDL=	0.1
Temperature	**valid**	**28.7**	**C**	MDL=	0
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-8.01	**Sample Type:**	Quality Control		Equipment Blank		
	Collection Method:	Tap or carboy or water truck				
	Date Collected:	30/07/2003				
	Easting:	464048.22	**Northing:**	6324993.73	**Elevation:**	317.61
	Collected By:	Bob Ingleton		University of Waterloo		
	Field Notes:	wt@14'				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**2.8**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.3**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1

WP-03-MLSB-1.04

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 26/07/2003
Easting: 463574.23 **Northing:** 6325493.49 **Elevation:** 308.4371
Collected By: Bob Ingleton University of Waterloo
Field Notes: Sunny; 20C; light grey, see picture; harder driving, out of tailings?

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Chloride, dissolved	**valid**	**258**	**mg/L**	MDL=	0.1
Total Naphthenic Acid	**valid**	**82**	**mg/L**	MDL=	1

WP-03-MLSB-2.06

Sample Type: Field Groundwater
Collection Method: Waterloo Profiler
Date Collected: 27/07/2003
Easting: 463664.41 **Northing:** 6325524.36 **Elevation:** 306.6382
Collected By: Bob Ingleton University of Waterloo
Field Notes: Sunny; 20C; dark grey initially, becomes clear; no foam

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**123**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.79**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0

Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**6.5**	**mg/L**	MDL=	0.1
Temperature	**valid**	**35.8**	**C**	MDL=	0
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**24**	**mg/L**	MDL=	1

WP-03-MLSB-3.01

Sample Type: Quality Control Equipment Blank

Collection Method: Tap or carboy or water truck

Date Collected: 27/07/2003

Easting: 463747.62 **Northing:** 6325534.09 **Elevation:** 313.9227

Collected By: Bob Ingleton University of Waterloo

Field Notes: near OW99-17; wt@5', no sheen on water; middle of forest stand; chan

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**4.8**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**5.9**	**mg/L**	MDL=	0.5
Calcium, dissolved	**<MDL**	**0.4**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**0.15**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**<MDL**	**0.6**	**mg/L**	MDL=	0.1
Electrical Conductivity	**valid**	**6**	**uS/cm**	MDL=	
Ethane	**valid**	**0.21139326**	**ug/L**	MDL=	0
Ethene	**valid**	**0.8176165**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**<MDL**	**0.9**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5

Iron, dissolved	**valid**	**0.14**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.025**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0.15656957**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**valid**	**6.73**	**N/A**	MDL=	0
Potassium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0**	**ug/L**	MDL=	0
Propene	**<MDL**	**0.35648419**	**ug/L**	MDL=	0
Sodium, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**0.3**	**mg/L**	MDL=	0.1
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**4**	**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-3.03

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 27/07/2003

Easting: 463747.62 **Northing:** 6325534.09 **Elevation:** 310.8747

Collected By: Bob Ingleton University of Waterloo

Field Notes: bit of foam; start rusty brown, ended up clear no colour

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results		MDL	
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**82.5**	**mg/L**	MDL=	0.1
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01

Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**171**	**mg/L**	MDL=	0.1
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**13**	**mg/L**	MDL=	1

WP-03-MLSB-3.05

Sample Type: Field Groundwater

Collection Method: Waterloo Profiler

Date Collected: 27/07/2003

Easting: 463747.62 **Northing:** 6325534.09 **Elevation:** 309.0459

Collected By: Bob Ingleton University of Waterloo

Field Notes: started off rusty brown turbid, ended up clear, slightly grey

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Alkalinity	**valid**	**783**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**955**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**29.6**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.04**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**142**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.79**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**2030**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**1773**	**uS/cm**	MDL=	
Ethane	**<MDL**	**0**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**100**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.06**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**6.3**	**mg/L**	MDL=	0.2

Manganese, dissolved	**valid**	**0.732**	**mg/L**	MDL=	0.004
Methane	**<MDL**	**0.11078036**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.69
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Nitrate, dissolved	**valid**	**0.011**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**valid**	**2.92**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**2.21**	**ug/L**	MDL=	3.13
pH	**not taken**		**N/A**	MDL=	0
pH	**valid**	**8.07**	**N/A**	MDL=	0
Potassium, dissolved	**valid**	**1.3**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.39502245**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**491**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**133**	**mg/L**	MDL=	0.1
Temperature	**valid**	**27**	**C**	MDL=	0
Toluene	**valid**	**2.07**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1270**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**80**	**mg/L**	MDL=	1

WP-03-MLSB-3.07

Sample Type: Quality Control Trip Blank
Collection Method: Waterloo Profiler
Date Collected: 27/07/2003
Easting: 463747.62 **Northing:** 6325534.09 **Elevation:** 309.0459
Collected By: Bob Ingleton University of Waterloo
Field Notes: pulled back up to 16' to take DNA while I could; TNA is trip blank

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-8.02	**Sample Type:**	Field		Groundwater	
	Collection Method:	Waterloo Profiler			
	Date Collected:	30/07/2003			
	Easting:	464048.22	**Northing:**	6324993.73	**Elevation:** 313.038
	Collected By:	Bob Ingleton		University of Waterloo	
	Field Notes:	bubbles in bottle; rusty brown, cleared, slightly brown			

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**14.9**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**3.72**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**363**	**uS/cm**	MDL=	
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**2.19**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**14.3**	**mg/L**	MDL=	0.1
Temperature	**valid**	**33**	**C**	MDL=	0
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-8.03	**Sample Type:**	Field		Groundwater		
	Collection Method:	Waterloo Profiler				
	Date Collected:	30/07/2003				
	Easting:	464048.22	**Northing:**	6324993.73	**Elevation:**	310.9044
	Collected By:	Bob Ingleton		University of Waterloo		
	Field Notes:	bubbles in bottle; rusty brown, cleared, slightly brown				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Alkalinity	**not taken**		**mg/L**	MDL=	0.5
Bicarbonate	**not taken**		**mg/L**	MDL=	0.5
Calcium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Calculated Ion Balanced	**not taken**			MDL=	0
Carbonate	**not taken**		**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**65.2**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**0.9**	**mg/L**	MDL=	0
Electrical Conductivity	**not taken**		**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**449**	**uS/cm**	MDL=	
Hardness (CaCO3)	**not taken**			MDL=	0
Hydroxide	**not taken**		**mg/L**	MDL=	0.5
Iron, dissolved	**not taken**		**mg/L**	MDL=	0.01
Magnesium, dissolved	**not taken**		**mg/L**	MDL=	0.2
Manganese, dissolved	**not taken**		**mg/L**	MDL=	0.004
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
pH	**not taken**		**N/A**	MDL=	0
pH	**not taken**		**N/A**	MDL=	0
Potassium, dissolved	**not taken**		**mg/L**	MDL=	0.3
Sodium, dissolved	**not taken**		**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**25.8**	**mg/L**	MDL=	0.1
Temperature	**valid**	**35**	**C**	MDL=	0
Total Dissolved Solids	**not taken**		**mg/L**	MDL=	1
Total Naphthenic Acid	**<MDL**	**0**	**mg/L**	MDL=	1

WP-03-MLSB-3.08	**Sample Type:**	Quality Control		Duplicate		
	Collection Method:	Waterloo Profiler				
	Date Collected:	28/07/2003				
	Easting:	463747.62	**Northing:**	6325534.09	**Elevation:**	308.1315
	Collected By:	Bob Ingleton		University of Waterloo		
	Field Notes:	light grey fines				

Note: MDL=method detection limit; ND=non detect; valid=field sample taken; not taken=no field sample taken

Description	Comment	Results			MDL
1,2,3-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.81
1,2,4-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.55
1,3,5-Trimethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.63
Alkalinity	**valid**	**973**	**mg/L**	MDL=	0.5
Alkalinity	**<MDL**	**0**	**mg/L**	MDL=	0.5
Benzene	**<MDL**	**0**	**ug/L**	MDL=	1.82
Bicarbonate	**valid**	**1190**	**mg/L**	MDL=	0.5
Calcium, dissolved	**valid**	**54.7**	**mg/L**	MDL=	0.3
Calculated Ion Balanced	**valid**	**1.04**		MDL=	0
Carbonate	**<MDL**	**0**	**mg/L**	MDL=	0.5
Chloride, dissolved	**valid**	**183**	**mg/L**	MDL=	0.1
Dissolved oxygen	**valid**	**1.53**	**mg/L**	MDL=	0
Electrical Conductivity	**valid**	**1460**	**uS/cm**	MDL=	
Electrical Conductivity	**valid**	**2150**	**uS/cm**	MDL=	
Ethane	**valid**	**2.22343692**	**ug/L**	MDL=	0
Ethene	**<MDL**	**0**	**ug/L**	MDL=	0
Ethylbenzene	**<MDL**	**0**	**ug/L**	MDL=	1.49
Hardness (CaCO3)	**valid**	**180**		MDL=	0
Hydroxide	**<MDL**	**0**	**mg/L**	MDL=	0.5
Iron, dissolved	**valid**	**0.19**	**mg/L**	MDL=	0.01
Magnesium, dissolved	**valid**	**9.8**	**mg/L**	MDL=	0.2
Manganese, dissolved	**valid**	**0.039**	**mg/L**	MDL=	0.004
Methane	**valid**	**677.665405**	**ug/L**	MDL=	0
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	4.66
Naphthalene	**<MDL**	**0**	**ug/L**	MDL=	2.32
Naphthalene	**<MDL**	**1.86**	**ug/L**	MDL=	2.69
Nitrate, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
Nitrite, dissolved	**<MDL**	**0**	**mg/L**	MDL=	0.003
O-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3
P- and M-Xylene	**<MDL**	**0**	**ug/L**	MDL=	3.13
pH	**not taken**		**N/A**	MDL=	0
pH	**valid**	**8.01**	**N/A**	MDL=	0

Potassium, dissolved	**valid**	**3.4**	**mg/L**	MDL=	0.3
Propane	**<MDL**	**0.51794899**	**ug/L**	MDL=	0
Propene	**<MDL**	**0**	**ug/L**	MDL=	0
Sodium, dissolved	**valid**	**516**	**mg/L**	MDL=	0.5
Sulphate, dissolved	**valid**	**19.8**	**mg/L**	MDL=	0.1
Temperature	**valid**	**20**	**C**	MDL=	0
Toluene	**<MDL**	**0**	**ug/L**	MDL=	1.76
Total Dissolved Solids	**valid**	**1370**	**mg/L**	MDL=	1
Total Naphthenic Acid	**valid**	**26**	**mg/L**	MDL=	1

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