FINAL REPORT

BEAVER CREEK PROFILING PROGRAM
2008 FIELD STUDY

Submitted to:

Syncrude Canada Ltd.
Fort McMurray, Alberta

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February 2009 **08-1337-0003**

EXECUTIVE SUMMARY

The year 2007 marked the culmination of a three year monitoring program of Beaver Creek, which was carried out to ensure that risk management conclusions remained the same as those presented in the Beaver Creek Ecological Risk Assessment (ERA) (Golder 2004). The conclusions of the ERA were that there was some evidence for risk to the benthic invertebrate community immediately downstream of the lower seepage dam, but no risks to wildlife populations, fish or amphibians that use Beaver Creek.

Overall, the results of the three year monitoring program indicated that conditions have improved in Beaver Creek and the wastewater control system is working effectively to limit seepage water from the Mildred Lake Settling Basin (MLSB) from entering the creek. No unacceptable ecological risks to Beaver Creek due to the seepage of process water were identified, which supported the overall goal of the original ERA. Consequently the conclusions of the ERA remained valid and additional field studies were deemed not warranted (Golder 2007). However, as part of Syncrude Canada's (Syncrude's) commitment to environmental sustainability, additional monitoring of Beaver Creek was conducted in 2008 to continue to assess and document surface water quality and toxicity within the creek.

The 2008 Beaver Creek Profiling Program was a scaled-down version of the three year ERA monitoring program (2005 to 2007) and was designed to compliment data gathered during that time. Water samples were collected and analyzed for chemistry and toxicity. Sediment samples were analyzed for toxicity.

The objectives of the 2008 study were as follows:

- Objective 1: To confirm that seasonal/annual/spatial trends observed in 2008 were consistent with trends observed during previous years of study.
- Objective 2: To ensure that the conclusions from the three year ERA monitoring program remained valid, i.e., there are no unacceptable ecological risks to Beaver Creek due to the seepage of process water from the MLSB.

Results for Objective 1

Based on the results of the surface water testing, the conclusions for the first study objective were:

1. Surface water concentrations of most parameters were highest in March and decreased by fall. This trend is evident through 2005 to 2008 suggesting that perhaps contributions from spring thaw and surface water runoff are the main

source(s) of inorganic parameters in Beaver Creek, not seepage from the wastewater control system.

2. Surface water COC concentrations were generally highest immediately below the seepage dam at site BC-3 and decreased in a downstream direction toward BC-8.

3. The wastewater control system is operating effectively as surface water concentrations of naphthenic acids, a tracer of process-affected water, have decreased in samples from sites BC-3 and BC-6 since modifications were made to the pumping system below the dam.

Results for Objective 2

Based on the results of the toxicity testing, the conclusions for the second objective were:

1. Water collected from site BC-3 has a statistically significant effect on mortality and malformations in *Xenopus* larvae. This effect does not occur at the sites downstream of BC-3. A growth effect of less than 10% of the control mean growth is observable at all sites downstream of the seepage dam but this does not necessarily confer biological effect.

2. Water collected from BC-5 is not acutely toxic to rainbow trout or fathead minnows. This result has been consistently demonstrated from 2004 to 2008.

3. Significant differences in *Chironomus tentans* survival and growth were detected in sediment from Site BC-6 from Beaver Creek in 2008. This is similar to the 2007 *C. tentans* toxicity test results, when survival and growth were significantly different from controls at site BC-6. However, no differences were detected in growth and survival at Site BC-3 located immediately downstream of the seepage dam. This suggests that the effects detected in sediment samples are unlikely to be related to the toxicity of substances released from the seepage dam. Rather, a localized effect in the vicinity of Site BC-6 may account for the sediment effects observed at this location.

Overall, the results of the 2008 Beaver Creek Profiling Program indicate that conditions have remained stable in Beaver Creek since the culmination of the three year ERA field program and the wastewater control system is working effectively to limit seepage water from entering the creek. There were no substantial changes to COC concentrations in 2008, when compared to the ERA study from 2005 and 2007, indicating that conditions in Beaver Creek are relatively stable. There are no unacceptable ecological risks to Beaver Creek due to seepage of process water, which supports the overall goal of the original ERA.

TABLE OF CONTENTS

SECTION **PAGE**

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

LIST OF APPENDICES

1 INTRODUCTION

The year 2007 marked the culmination of a three year monitoring program of Beaver Creek, which was carried out to ensure that risk management conclusions remained similar to those presented in the Beaver Creek Ecological Risk Assessment (ERA) (Golder 2004). The conclusions of the ERA were that there was some evidence for risk to the benthic invertebrate community immediately downstream of the lower seepage dam, but no risks to wildlife populations, fish or amphibians that use Beaver Creek.

Overall, the results of the three year monitoring program indicated that conditions have improved in Beaver Creek and the wastewater control system is working effectively to limit seepage water from the Mildred Lake Settling Basin (MLSB) from entering the creek. No unacceptable ecological risks to Beaver Creek due to the seepage of process water were identified, which supported the overall goal of the original ERA. Consequently the conclusions of the ERA remained valid and additional field studies were deemed not warranted (Golder 2007).

However, as part of Syncrude Canada's (Syncrude's) commitment to environmental sustainability, it was decided to conduct additional monitoring of Beaver Creek in 2008 to continue to assess and document surface water quality and toxicity within the creek. This report outlines the results of the 2008 Beaver Creek Profiling Program and provides comparison to previous years' data.

1.1 BACKGROUND

1.1.1 Mine Operation and Site Characterization

The Syncrude Mildred Lake site is located in north-eastern Alberta, 40 kilometres (km) north of the city of Fort McMurray. At Syncrude, oil sand is mined and bitumen is extracted and upgraded to synthetic crude oil. The three main by-products of the operation include tailings, sulphur and coke.

The Syncrude site can be divided into three general areas: the mine, the tailings areas, and the plant site. There are two open pit mines, Base Mine and North Mine; and three tailings areas, MLSB, Southwest Sand Storage (SWSS) and In-pit areas which are comprised of the West In-pit (WIP), the Southeast Pond (SEP) and the Northeast Pond (NEP). Other significant features include coke storage cells, overburden dumps, sulphur blocks, sand and gravel pits, sewage treatment facilities, and the Beaver Creek diversion.

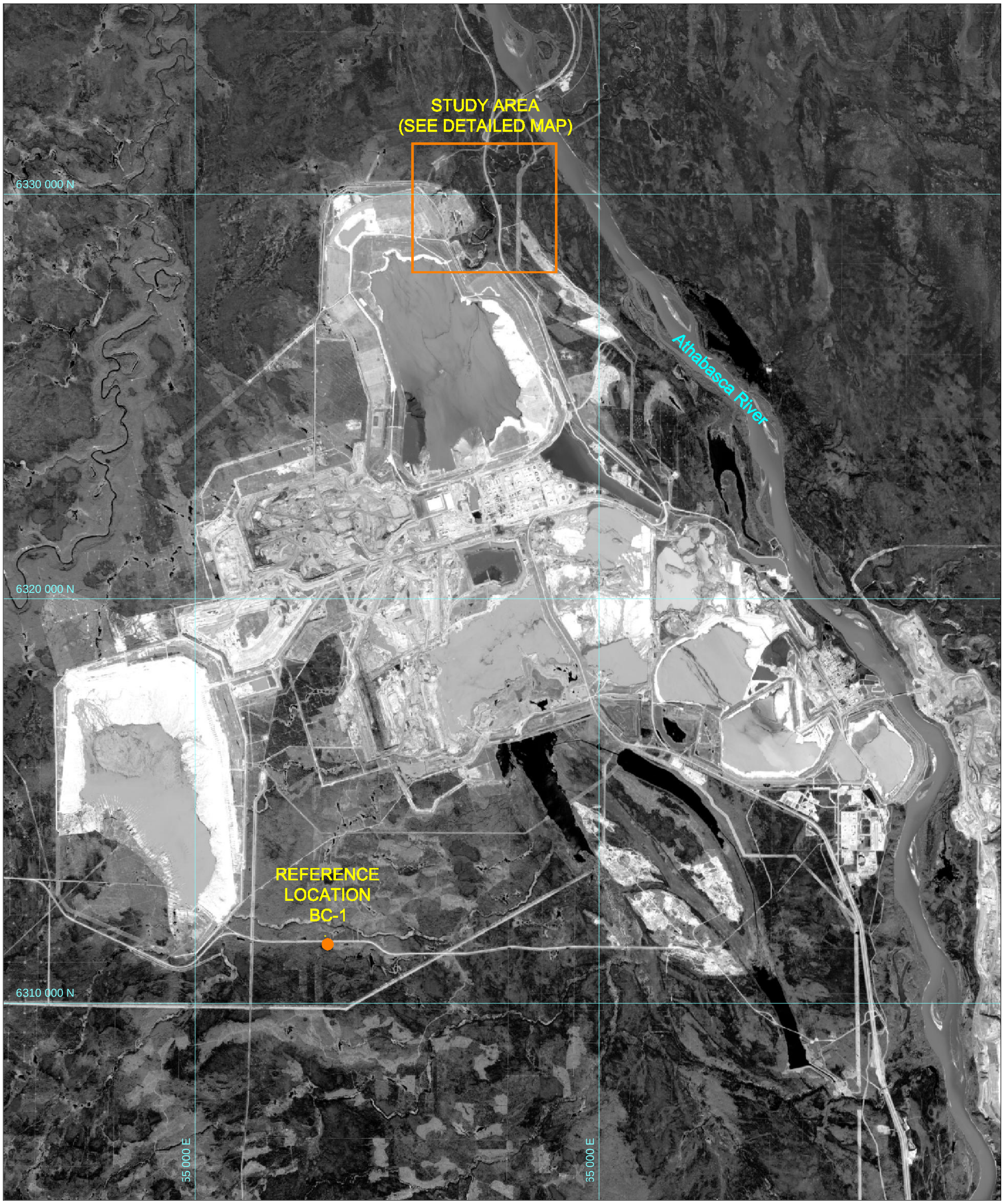
The surface mineable area is associated with the topographic low along the Athabasca River valley. The ore deposit is a bitumen-saturated sedimentary deposit of the Lower Cretaceous McMurray Formation. At the Mildred Lake Site, the open pit excavation reaches an average depth of 65 m and covers an area of approximately 39 square kilometres (km^2). A satellite photograph of the Syncrude Mildred Lake site is shown in Figure 1.1.

Beaver Creek is in a deeply incised valley northeast of the MLSB. During construction of the Mildred Lake Project, the headwaters of Beaver Creek were diverted into Poplar Creek. Therefore, flow within the creek below the MLSB is minimal. In addition, beaver activity in the creek has been extensive, which has changed the morphology of the creek into a series of beaver ponds rather than a free-flowing creek. There is abundant vegetation in the valley which provides habitat for deer, beaver, waterfowl and other birds and amphibians. Due to the low flow and abundant beaver activity, fish habitat is marginal and begins approximately 2 km downstream of the MLSB.

1.1.2 Process Water Seepage

Process water potentially seeping from the Mildred Lake oil sands lease is collected by a series of ditches and returned (by pump) to the MLSB via the seepage control pond. Two dams were constructed in 1999-2000 to retain water and prevent release of process-affected seepage water into Beaver Creek. The lower dam was constructed to increase the capacity of the control pond; ensuring process-affected water is not released to the surrounding environment during flood events. However, there have been contributions of process-affected water detected in Beaver Creek below the dam.

In 2003, work was undertaken to minimize the potential for process-affected water to seep through the lower dam into Beaver Creek. Modifications were made to the pumping system at the lower seepage dam to minimize the gradient across the dam. The modifications included the excavation of a deeper sump and ditching, and periodic operation of a pump to remove ponded water on the upstream side of the dam. Overall, there was less ponding of water in this area in 2004 and 2005. Groundwater monitoring carried out in Beaver Creek and the surrounding area in 2005 indicated that concentrations of major ions had decreased in 2004 and 2005, and remained steady through 2007 as a result of this mitigation.



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SCALE KILOMETRES

PROJECT
Syncrude

TITLE

REFERENCE AND STUDY AREA LOCATIONS

Golder Associates
Calgary, Alberta

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CADD	YAW	05/01/08
CHECK	TD	02/02/09
REVIEW	RR	02/02/09

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FIGURE: 1.1

REFERENCES
AIRPHOTO OBTAINED FROM SYNCRUDE CANADA LTD.

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1.2 OBJECTIVES

The 2008 Beaver Creek Profiling Program was a scaled-down version of the three year ERA monitoring program (2005 to 2007) and was designed to compliment data gathered during that time. Sample locations remained the same as in previous years, so that results across years were comparable. Previous reports provided results of the 2004 to 2007 sampling programs (Golder 2005; 2006; 2007; 2008).

The objectives of the 2008 study were as follows:

- Objective 1: To confirm that seasonal/annual/spatial trends observed in 2008 were consistent with trends observed during previous years of study.
- Objective 2: To ensure that the conclusions from the three year ERA monitoring program remained valid, i.e., there are no unacceptable ecological risks to Beaver Creek due to the seepage of process water from the MLSB.

To answer the above stated objectives, the following evaluations were completed:

- 2008 water quality, FETAX and chironomid assay data were compared among sites;
- 2008 water quality was compared to water quality measured during previous studies (2004 - 2007); and
- results of the fathead minnow, rainbow trout, chironomid, and FETAX toxicity tests were compared among years (2004 - 2008).

2 METHODS FOR 2008 PROFILING PROGRAM

This section describes the sampling locations and methods for the 2008 Beaver Creek Profiling Program. Fieldwork was completed during two separate field sampling events in 2008, March 17th to 19th and September 8th to 10th. Samples were collected for water quality analysis and toxicity testing on both sampling dates, while sediment samples for the chironomid toxicity assay were collected during the September sampling period only.

2.1 SAMPLE LOCATIONS

The 2008 Beaver Creek Profiling Program utilized the same sampling sites as those studied in the 2004 to 2007 Beaver Creek ERA monitoring program. The original 2004 sampling regime was designed to evaluate effects along a gradient of exposure in Beaver Creek from immediately downstream of the lower seepage dam (BC-3), to the confluence with the Athabasca River (BC-8). Thus, data were grouped into general geographical areas: upstream reference area (BC-1); immediately downstream of the lower seepage dam (BC-3, BC-6, and BC-7); midway between the dam and Highway 63 (BC-4); at Highway 63 (BC-5) and a downstream reference site at the confluence with the Athabasca River (BC-8). The location of the upstream reference area (BC-1) is shown in Figure 1. Detailed sample site locations are presented in Table 2.1 and Figure 2.1.

Table 2.1 Sampling Dates and Locations for the 2008 Beaver Creek Profiling Program

Sample Site	March 2008			September 2008		
	UTM Coordinate (WGS 84)		Sampling Date	UTM Coordinate (WGS 84)		Sampling Date
	Easting	Northing		Easting	Northing	
BC-1	458223	6311656	17-Mar	458220	6311657	08-Sep
BC-3	461970	6328770	18-Mar	461961	6328762	09-Sep
BC-6	461829	6328934	18-Mar	461869	6329010	09-Sep
BC-7	462194	6329502	19-Mar	462142	632920	10-Sep
BC-4	462091	6329568	19-Mar	462224	6329353	10-Sep
BC-5	462016	6330239	19-Mar	462022	6330241	08-Sep
BC-8	463136	6330688	17-Mar	463140	6330682	08-Sep

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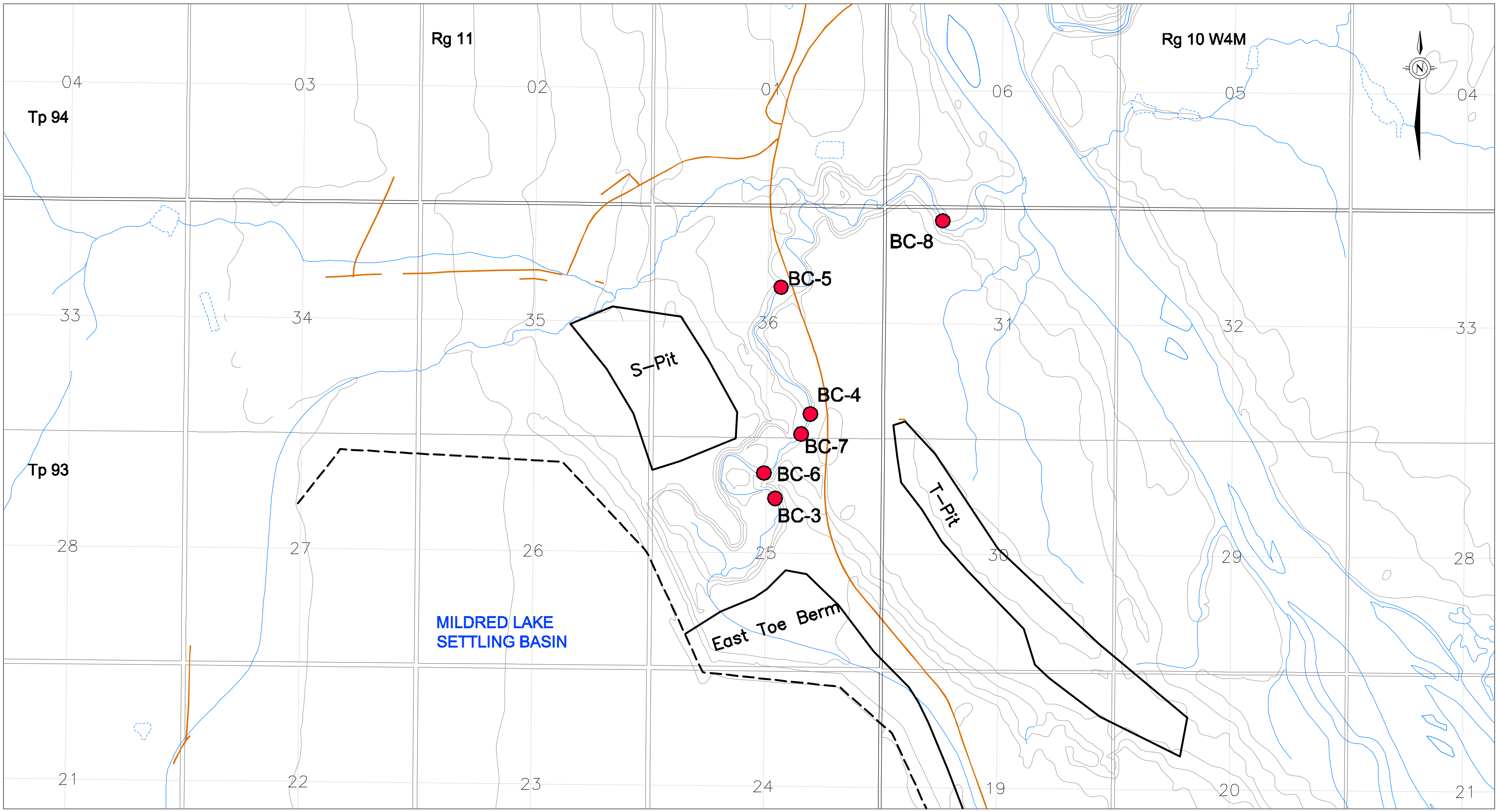

LEGEND

BC-3 2008 SAMPLE LOCATIONS

SCALE 1 0 1 KILOMETRES

REFERENCE

Alberta Digital Data Obtained From AltaLIS Ltd. (September 2004.) used under license.
Projection: Transverse Mercator Datum: Nad 83 Coordinate System: Utm Zone 12

PROJECT

Syncrude

TITLE

SAMPLING LOCATIONS IN BEAVER CREEK

Golder Associates
Calgary, Alberta

PROJECT 08.1337.0003.4000			FILE No. Sampling Locations	
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CHECK	TD	02/02/09	FIGURE: 2.1	
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2.1.1 Site Descriptions

2.1.1.1 BC-1

The Beaver Creek reference site (BC-1) is located about five kilometres south of the Syncrude site (Photo 1). The sample site is located in a lowland area (i.e., grassland and wetland characteristics) with a generally flat topography. The sample site is ephemeral; water flows through the channel during flood events only. Fisher Marten (*Martes pennanti*) tracks, boreal chorus frogs (*Pseudacris maculate)* and moose (*Alces alces*) scat have been observed at this site during previous sampling events.

2.1.1.2 BC-3

Site BC-3 is located approximately 200 m downstream of the Lower Seepage Dam (Photo 2). This area was cleared during construction of the dam and many pioneer species (i.e., shrubs) are present. In this location, the creek has cut through the surrounding topography to form a river valley. Downstream of the sample site, the forest changes from a successional forest to a mature stand of poplar (*Populus spp.*) and spruce (*Picea spp.*). The water is stagnant at this pooled site. In July 2007, boreal chorus frogs and tadpoles (*Pseudacris maculate*) were observed at this site; in September 2007 a wolf (*Canis lupus*) was observed at this site.

Photo 1 BC-1 (September 2008)

Photo 2 BC-3 (September 2008)

2.1.1.3 BC-6

BC-6 is located approximately 1 km downstream of the Lower Seepage Dam in a pooled area between two old beaver dams with little or no water flow (Photo 3). The topography of the surrounding area is generally flat, with a forest composed of a mixture of mature poplar and spruce. A steep cliff rises to the east of the creek at this location. Due to the gentle topography, this area of the creek is composed of either pools, or a slow moving channel. In addition to birds, BC-6 also contains suitable habitat for amphibians and moose; weasel and rabbit activity is evident. Approximately 20% of the water surface is covered by aquatic vegetation. In July 2007, boreal chorus frogs and tadpoles were observed at this site.

2.1.1.4 BC-7

BC-7 is located approximately 1.5 km downstream of the Lower Seepage Dam (Photo 4). The site is the start of the river valley topography which continues throughout the remainder of the downstream sample locations. A steep limestone bank is situated to the east of the site, which has resulted in a landslide of sand into the creek. Water flow is minimal at this site; spruce trees are prevalent along the banks. Approximately 95% of the watercourse is covered with milfoil (*Myriophyllum spp.*) and bladderwort (*Ultricularia spp.*). In July 2007, numerous tadpoles were observed at this site; moose scat was observed at this site in March 2008.

2.1.1.5 BC-4

BC-4 is located 1.7 km downstream of the Lower Seepage Dam (Photo 5). The steep river valley topography continues through this stretch of the creek. BC-4 is a beaver pond, positioned between two beaver dams. The water at this site is clear and flows at a very slow rate. Shrub (willow, *Salix spp.*), grass species, and spruce trees dominate the surrounding riparian vegetation. A shale deposit exists along the banks of the creek. A variety of small bird species have been observed at this site.

2.1.1.6 BC-5

BC-5 is located in a pooled area (i.e., a beaver pond) approximately 3 km downstream of the Lower Seepage Dam (Photo 6). A beaver dam exists to the east side of the pond. The steep river valley topography continues through this stretch of the creek with the rock changing from shale to limestone. The sample site is approximately 100 m west of Highway 63. The area has shallow, slow-moving water with a maximum depth of 40 cm. The banks are composed of grass species and approximately 95% of the water surface is covered with aquatic vegetation. Brook stickleback (*Culaea inconstans*) are commonly observed at this site; Western tanagers (*Piranga ludoviciana)*, spotted sandpipers (*Actitis macularius)* and evening grosbeaks (*Coccothraustes vespertinus)* have been observed at this site.

Photo 3 BC-6 (September 2008)

Photo 4 BC-7 (September 2007)

Photo 5 BC-4 (September 2008)

Photo 6 BC-5 (September 2008)

2.1.1.7 BC-8

BC-8 is located approximately 1 km upstream of the confluence of Beaver Creek with the Athabasca River (Photo 7). Site BC-8 was added to the field study in 2004 since: (1) there were habitat differences between the upstream reference site (BC-1) and the other sites located downstream of the seepage dam (BC-1), and (2) Alberta Environment (AENV) were concerned about potential impacts on the Athabasca River. This area was subjected to a forest fire approximately 10 years ago. The river valley topography noted at BC-4 and BC-5 continues at this site. A pipeline is present in this area and recent construction close to the sample site has resulted in the re-establishment of willow species along the banks of the creek. Water flow in the channel is slow, with abundant woody debris. A maximum water depth to 20 cm was recorded at this site and rust-coloured algae and iron deposits are evident within the creek channel. A variety of small bird species were observed at this site.

Photo 7 BC-8 (September 2008)

2.1.2 Sample Descriptions

Water and sediment samples were collected during the 2008 Profiling Program. The types of samples, analyses and sample locations are presented in Table 2.2.

Table 2.2 Types of Samples, Analyses and Sample Locations for the 2008 Beaver Creek Profiling Program

Media	Type of Analysis	Upstream Reference Location	Downstream Locations					Downstream Reference Location
		BC-1	BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
water	Routine Parameters and Ammonia Total Metals Naphthenic Acids Polycyclic Aromatic Hydrocarbons (PAHs) and Alkylated PAHs	x	x	x	x	x	x	x
water	Fathead Minnow and Rainbow Trout toxicity tests						x	
water	Frog Embryo Teratogenicity Assay – *Xenopus* (FETAX)		x[a]	x	x	x	x	x
sediment[b]	Chironomid Assay		x	x	x	x	x	x

[a] Definitive toxicity test. Screening-level FETAX tests at the remaining sample sites.
[b] Chironomid assays in September only.

2.2 WATER SAMPLING METHODS

Prior to sampling at each location, temperature, conductivity, dissolved oxygen and pH were recorded using a Quanta Multiline P4 water quality meter. Samples were collected in appropriate pre-cleaned containers provided by the analytical laboratory. Bottles for metals analyses were triple-rinsed using creek water prior to sampling. Bottles for other types of samples were not rinsed. Grab samples of water were collected by submerging sample bottles approximately 0.15 m under the water surface. Water samples collected for analysis of total metals were preserved according to instructions from the analytical laboratory. Samples were placed on ice, in coolers, and shipped to the laboratory (ALS Laboratory Group, Edmonton, AB) at the end of each sampling day.

Water samples were also collected for conducting toxicity tests on rainbow trout (*Oncorhynchus mykiss*), fathead minnow (*Pimephales promelas*) and frog embryos (*Xenopus laevis*) (FETAX). Water samples for conducting the rainbow trout and fathead minnow toxicity tests were placed on ice, in coolers, and shipped to HydroQual Laboratories (Calgary, AB) at the end of the sampling day. Water samples for conducting FETAX were placed on ice, in coolers, and shipped to Fort Environmental Laboratories Ltd., (Stillwater, Oklahoma, USA) at the end of each sampling day.

2.3 SEDIMENT SAMPLING METHODS

Sediment samples were collected using an Ekman grab. Sediment samples were placed in 5 litre (l) containers provided by HydroQual. Sufficient grabs were taken at each site to fill the containers. Samples were placed on ice, in coolers, and shipped to HydroQual at the end of each day.

2.4 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

2.4.1 Field Protocol

Water QA samples were collected for the 2008 Profiling Program. These samples were submitted blind (unique sample ID) to the analytical laboratory (ALS) as part of the field quality control procedures. QA/QC samples consisted of field blanks and field duplicates, collected at site BC-3, on both sampling dates.

Field blanks were water samples that consisted of distilled water provided by the analytical laboratory. The water was transferred into sample bottles in the field and treated in the same way as the actual water samples (i.e., preserved, stored and transported). The purpose of the field blanks was to assess potential contamination from sample bottles, field procedures or laboratory error. Field blanks should have values well below the quantified levels in the actual samples and should not have concentrations that are greater than five times the detection limit (US EPA, 1985).

Duplicate samples provide an indication of heterogeneity among samples. The acceptable Relative Percent Difference (RPD) between duplicate samples should be no more than 20% (US EPA, 1985).

2.4.2 Data Analysis

Several QC measures were taken in order to ensure the integrity of data management. Macros were used to organize the data once it was received from the analytical laboratory. This reduced the possibility of transcription errors and highlighted any naming irregularities and redundancies in the original data set.

Ten percent of the water and sediment data in the final database was then cross-checked back to the original data sets in order to capture any possible transcription errors in reported units or values.

2.5 TOXICITY TESTS

Toxicity testing was conducted in 2008 using frog embryos (FETAX), rainbow trout, fathead minnow, and chironomid (*Chironomus tentans*) larvae. All toxicity tests were conducted in accordance with established protocols (Environment Canada 1990, 1992, 1997; ASTM E1439-98). The methodology for each of the above mentioned toxicity tests are outlined in the subsequent sections.

2.5.1 Frog Embryo Toxicity Assay - *Xenopus* (FETAX) Methodology

Xenopus Assay

The 96-hour whole embryo assays (FETAX) were performed by Fort Environmental Laboratories, Stillwater, Oklahoma, using test method ASTM E1439-98, with a modification for increased replicates. Two separate assays were conducted, a screen assay and a definitive assay. For the screen assay, water samples from BC-3, BC-4, BC-5, BC-6, BC-7 and BC-8 were tested at 100% strength. For the definitive assay, a water sample from BC-3 was tested using five concentrations (50%, 75%, 90%, 95% and 100%). All treatments were tested in replicates of four, using test vessels containing 25 *Xenopus laevis* embryos and 200 mL of each test concentration per replicate. Frog embryos were cultured at 24 °C ±2 °C. Dead embryo removal and water changes were performed daily throughout the testing period.

At the end of the 96-hour test period, the number of live larvae in each test concentration was determined. Larvae were then preserved in 3% formalin and the number of malformed larvae was determined using a dissecting microscope. FETAX solution water was used as the laboratory negative control and dilution water, where appropriate, for the assays. Two concentrations (2,500 mg/L and 5.5 mg/L) of the chemical 6-aminonicotinamide (6-AN) were used as positive reference controls to induce embryo-lethality and effect (malformation) in the test culture. The FETAX screen and definitive tests were conducted side by side, with both the negative and positive laboratory controls being shared by both assays. The FETAX data endpoints included mortality, malformation and growth measurements.

Data Analysis

Mortality and malformation frequencies were determined for each test treatment. Head-to-tail lengths of the surviving larvae were measured (cm) as an index of growth (mean sample growth divided by mean control growth, expressed as a percent). Trimmed Spearman-Karber 1.5 (USEPA, Cincinnati, OH) analysis was used to determine the 4-day LC50 and EC50 concentrations. To determine if statistically significant differences existed between the FETAX control solution and the site water treatments, an ANOVA with a Bonferroni t-test ($p<0.05$) and Kruskal Wallace (KW) ANOVA with Dunn's Method ($p<0.05$) were perfomed. Descriptive and ANOVA statistical calculations were performed by Fort Environmental Labs using SigmaStat ® 2.03 statistical software (SPSS ® Inc., Chicago IL).

2.5.2 Rainbow Trout and Fathead Minnow Methodology

Rainbow trout and fathead minnow toxicity tests were performed by HydroQual Laboratories, Calgary, Alberta, on water samples collected from site BC-5. Site BC-5 was chosen as this is the singular site were fish presence has been confirmed (Golder 2004).

Rainbow Trout Assay

96-hour rainbow trout static acute toxicity tests were performed on water collected from site BC-5. One replicate of each treatment was analyzed; treatments consisted of five dilution concentrations (6.25, 12.5, 25, 50, 100% v/v), a positive control (phenol), a whole water sample, and a control treatment (de-chlorinated City of Calgary water). Experimental protocol was followed as outlined in Test method EPS 1/RM/13, with 1996 and 2000 amendments (Environment Canada 1990).

Fathead Minnow Assay

Seven-day fathead minnow larval growth and survival static renewal tests were performed on water collected from site BC-5 in September 2008. Tests were not performed in March as a result of fish supply issues at HydroQual. Four replicates within each treatment were analyzed; treatments consisted of five dilution concentrations (6.25, 12.5, 25, 50, 100% v/v), a positive control (phenol), a whole water sample, and a control treatment (de-chlorinated City of Calgary water). Experimental protocol was followed as outlined in Test method EPS 1/RM/22, amended 1997 (Environment Canada 1992).

Data Analysis

Endpoints for survival (LC_{50}, LC_{25}) and growth (IC_{25}, IC_{50}) were determined by HydroQual for both the rainbow trout and fathead minnow assays.

2.5.3 *Chironomus* Toxicity Methodology

Chironomus Assay

Chironomus sediment toxicity tests were conducted on sediments collected from all sample locations downstream of the MLSB in September. The test species was *Chironomus tentans,* a sediment-dwelling benthic invertebrate that is a common member of the benthic invertebrate community in Beaver Creek.

The chironomid laboratory assay consisted of a 10-day static chironomid survival and growth test. Tests were run on whole sediment samples, each with five laboratory replicates. Treatments also included a laboratory control (silica sand #30 grit and de-chlorinated City of Calgary water) and a positive control (KCl-water only). Test method EPS 1/RM/22, amended 1997 (Environment Canada 1997) was followed for toxicity testing.

An initial assay, set up by HydroQual within the permitted sampling window, failed the testing protocol due to elevated mortality in the control treatments. The test assay was therefore reset with a protocol deviation; samples were outside of the six week holding time by 3 days. Mortality in the control treatments for this test fell within the acceptable limits.

Data Analysis

Chironomid survival and growth data were tested for significant differences from laboratory controls by Golder using a one-way analysis of variance (ANOVA) and Dunnett's test.

3 RESULTS OF 2008 PROFILING PROGRAM

The results of the 2008 Beaver Creek Profiling Program are presented in the following section. Comparison of the 2008 results to previous sample programs, and interpretation of the 2008 results are presented in Section 4.

3.1 WATER QUALITY

3.1.1 Conventional Parameters

Water quality information on conventional parameters, recorded during the two sampling periods in 2008, is presented in Table 3.1. Information is not provided for site BC-1 in March because no water was present at this site at the time of sampling.

The lowest field measured dissolved oxygen (DO) concentrations were recorded in March at sites BC-6 and BC-5. DO concentrations at these two sites were below the Canadian Council of Ministers (CCME) DO guideline of 5.5 mg/L (CCME 1999). DO concentrations increased at these sites during the subsequent sampling event in September and were above the CCME guideline. DO concentrations at all other sites were above the CCME DO guideline on both sampling events.

For sampling periods in both March and September, 2008, specific conductance and alkalinity values were highest at site BC-3 and tended to decrease with distance downstream from the seepage dam (Table 3.1). Water pH values were within the CCME guideline range of 6.5 to 9 for all sites and sampling periods.

Bicarbonate concentrations were highest immediately downstream of the seepage dam (i.e., BC-3) and decreased with distance downstream. Total dissolved solids (TDS) showed a similar trend.

Table 3.1 Conventional Water Quality Parameters at Sites Sampled in Beaver Creek, March and September, 2008

Variable	March							September						
	BC-1	BC-3	BC-6	BC-7	BC-4	BC-5	BC-8	BC-1	BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
Field Measured Water Characteristics														
Dissolved Oxygen (mg/L)	-	7.00	5.05	7.58	8.82	2.38	18.39	9.17	13.70	9.56	7.90	6.90	11.64	10.74
Specific Conductance (µS/cm)	-	1,819	1,368	1,012	875	751	866	214	1,044	846	968	954	824	449
pH	-	7.1	7.3	6.7	7.3	7.7	7.5	8.2	8.4	8.2	9.1	9.5	7.7	7.8
Water Temperature (°C)	-	0.01	-0.02	0.14	-0.06	-0.03	0.16	6.97	11.30	10.80	8.96	9.50	8.20	8.00
Laboratory Measured Water Characteristics														
Bicarbonate (mg/L)	-	1,070	808	368	358	410	411	99	536	381	407	378	379	236
Carbonate (mg/L)	-	<5	<5	<5	<5	<5	<5	<5	9	5	<5	<5	<5	<5
Hydroxide (mg/L)	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Alkalinity, Total (as $CaCO_3$)(mg/L)	-	877	662	302	294	336	337	81	455	321	333	310	311	194
Total Dissolved Solids (calculated) (mg/L)	-	1,780	1,380	1,370	1,250	928	979	189	875	707	693	686	711	384
Hardness (as $CaCO_3$) (mg/L)	-	543	487	985	882	424	476	124	334	268	362	339	342	213

- = no water present at time of sampling

3.1.2 Concentrations of Chemicals of Concern in Water

To maintain consistency with the previous ERA monitoring program, the Chemicals of Concern (COC) analyzed for the 2008 Profiling Program remained the same as those identified in the 2004 ERA (Golder 2004). For the water matrix, the COCs are as follows:

- aluminum, barium, boron, calcium, chloride, iron, magnesium, manganese, sodium, strontium and napthenic acids.

COC water chemistry results for March and September are summarized in Table 3.2, and are graphically presented below. Water chemistry results are not available for Site BC-1 in March, as water was not present at the site during the sampling period.

COC concentrations are compared to CCME guidelines for the protection of aquatic life, where available (CCME 1999). Complete water chemistry results (raw data) are presented in Appendix I.

Aluminum

Total aluminum concentrations in water samples from all sites in 2008 ranged from 0.02 mg/L at sites BC-7 and BC-8 to 0.65 mg/L at site BC-3 in March, and 0.01 mg/L at sites BC-5 and BC-7 to 0.25 mg/L at site BC-1 in September (Figure 3.1). Aluminum concentrations at sites BC-3 in March, and BC-8 in September were above the CCME guideline of 0.1 mg/L. Surface water aluminum concentrations at BC-1 (upstream reference site) also exceeded the CCME guideline in September when a concentration of 0.25 mg/L was recorded.

Figure 3.1 Beaver Creek Surface Water Aluminum Concentrations for March and September, 2008

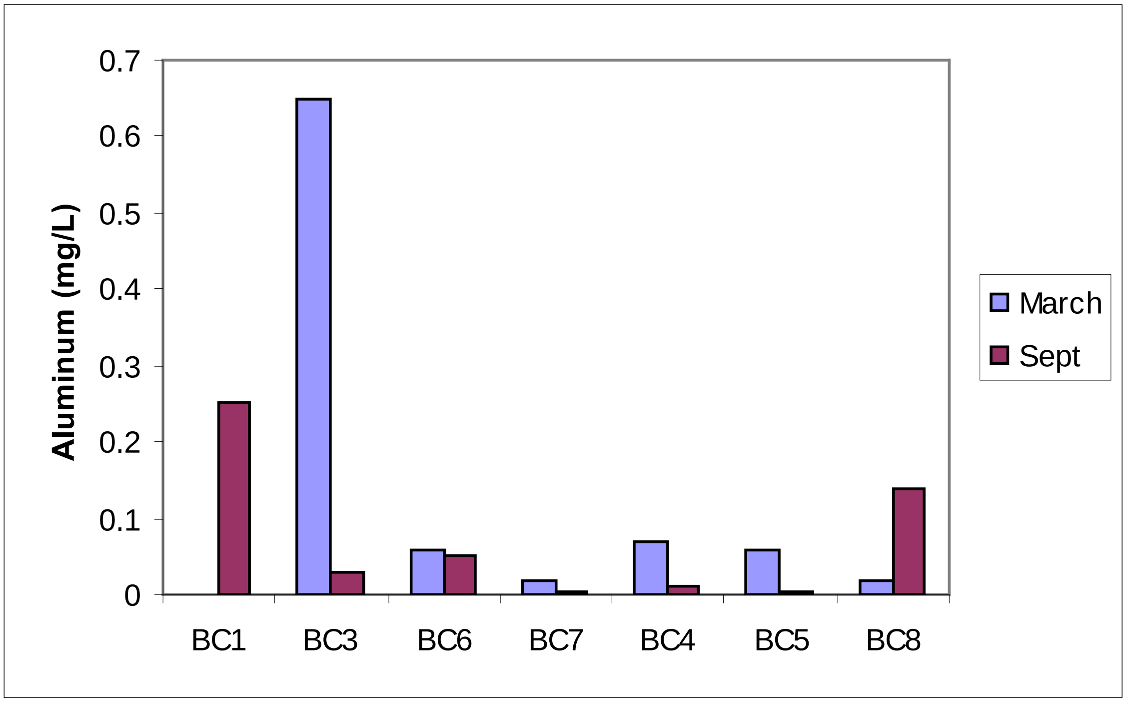


Table 3.2 Summary of Surface Water Concentrations of COC in Beaver Creek; March and September 2008

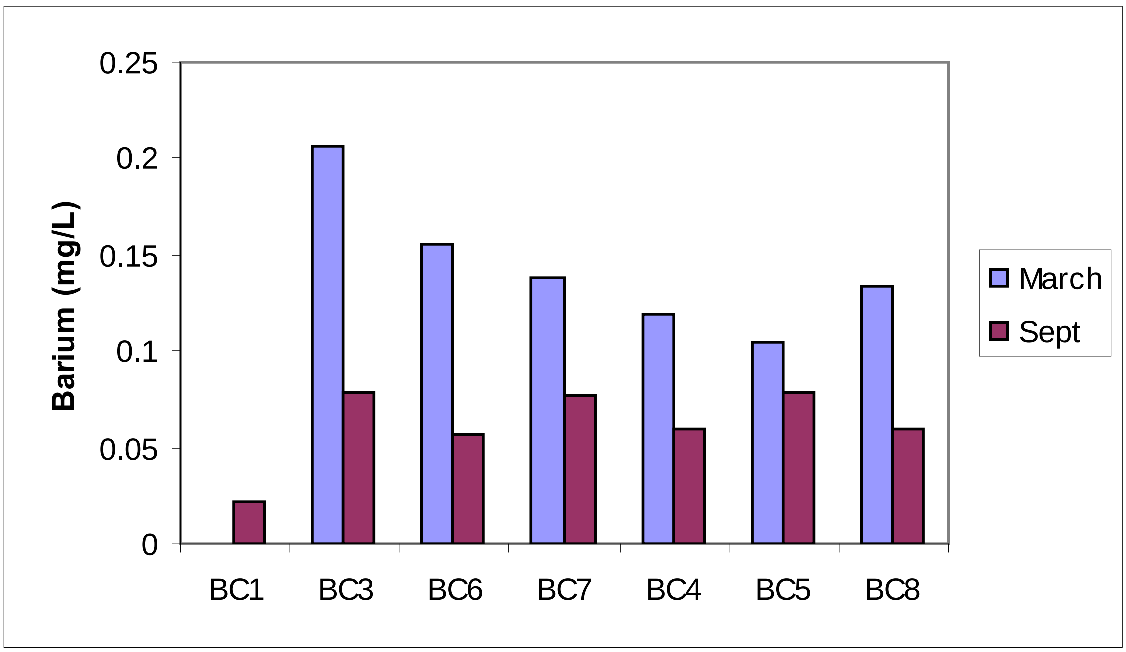
Parameter	BC-1		BC-3		BC-6		BC-7		BC-4		BC-5		BC-8	
	Mar	**Sept**	**Mar**	**Sept**	**Mar**	**Sept**	**Mar**	**Sept**	**Mar**	**Sept**	**Mar**	**Sept**	**Mar**	**Sept**
Chloride (mg/L)	-	25	518	172	416	143	178	96	178	108	170	118	232	68
Aluminum (mg/L)	-	0.25	0.65	0.03	0.06	0.05	0.02	<1.00	0.07	0.01	0.06	<1.00	0.02	0.14
Barium (mg/L)	-	0.022	0.207	0.079	0.155	0.056	0.138	0.077	0.119	0.060	0.105	0.078	0.133	0.059
Boron (mg/L)	-	<0.05	0.39	0.37	0.39	0.36	0.07	0.24	0.09	0.26	0.17	0.19	0.15	0.12
Calcium (mg/L)	-	30.8	127.0	77.8	82.9	47.5	265.0	87.0	258.0	72.0	112.0	92.8	107.0	58.5
Iron (mg/L)	-	0.655	19.500	0.314	1.720	0.336	9.970	0.534	1.250	0.440	0.606	0.417	3.0	2.59
Magnesium (mg/L)	-	11.2	51.5	35.7	58.3	33.3	61.5	38.1	63.1	37.0	31.2	30.1	31.4	17.3
Manganese (mg/L)	-	0.014	1.450	0.016	0.775	0.064	0.594	0.030	0.434	0.067	0.074	0.020	0.484	0.212
Sodium (mg/L)	-	26	540	215	363	164	95	117	108	128	181	134	165	70
Strontium (mg/L)	-	0.154	0.519	0.324	0.532	0.280	0.470	0.313	0.486	0.291	0.267	0.249	0.48	0.25
Napthenic Acids (mg/L)	-	<1	15	5	9	3	1	2	1	2	3	2	3	<1

- = no water present at time of sampling

Barium

In March, barium concentrations were highest at site BC-3 and gradually decreased with distance downstream (with the exception of site BC-8). This trend was not evident in September. At all sites, barium concentrations were higher in March. Concentrations ranged from 0.11 mg/L at BC-5 to 0.21 mg/L at BC-3 in March, and from 0.02 mg/L at BC-1 to 0.08 mg/L at BC-5 and BC-7 in September (Figure 3.2). There is no CCME guideline for barium.

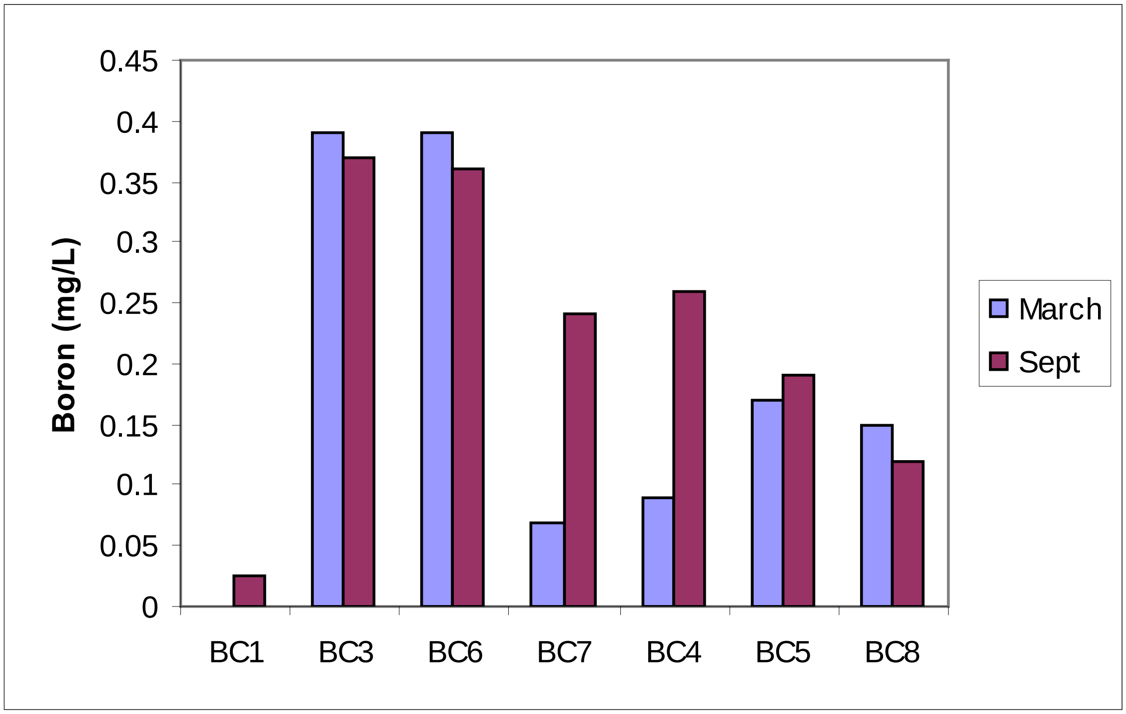
Figure 3.2 Beaver Creek Surface Water Barium Concentrations for March and September, 2008



Boron

Total boron concentrations in water samples ranged from 0.07 mg/L at site BC-7 to 0.39 mg/L at BC-3 and BC-6 in March, and from < 0.05 mg/L at BC-1 to 0.37 mg/L at BC-3 in September (Figure 3.3). For both sample periods, Boron concentrations were highest at sites BC-3 and BC-6. There is no CCME guideline for boron.

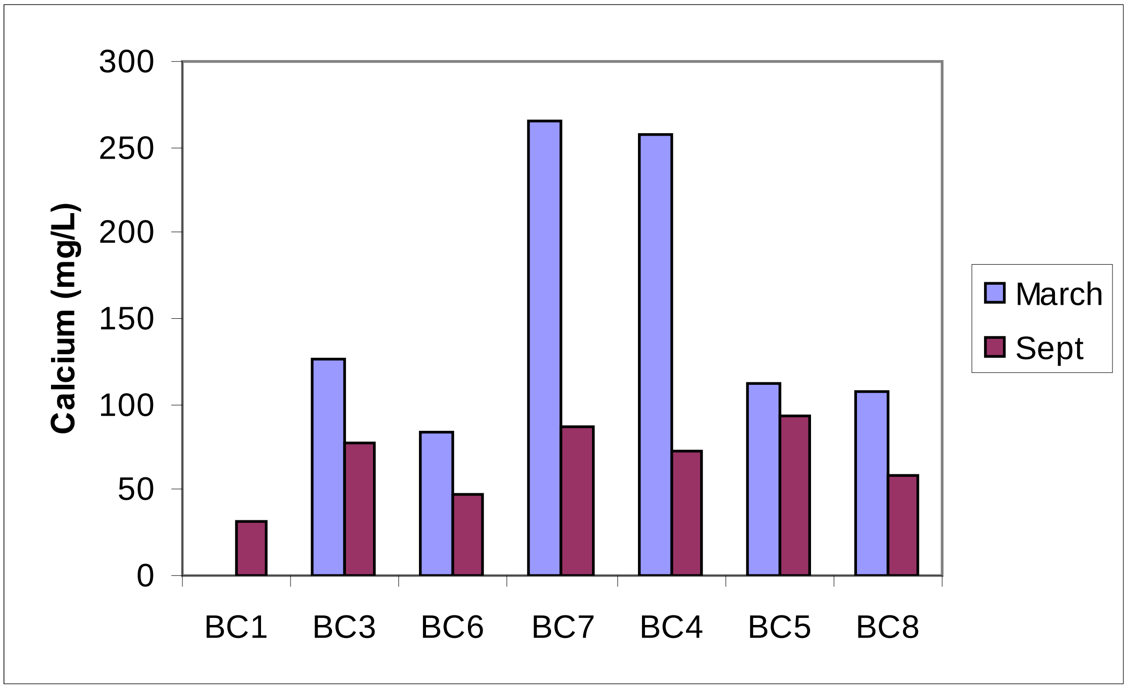
Figure 3.3 Beaver Creek Surface Water Boron Concentrations for March and September, 2008



Calcium

Calcium concentrations were highest at sites BC-7 and BC-4 in March. Concentrations in water samples ranged from 82.9 mg/L at BC-6 to 265 mg/L at BC-7 in March, and from 30.8 mg/L at BC-1 to 92.8 mg/L at BC-5 (Figure 3.4). Calcium concentrations in water collected at BC-1 in September were lower (30.8 mg/L) relative to all other sites (Figure 3.4). There is no CCME guideline for calcium.

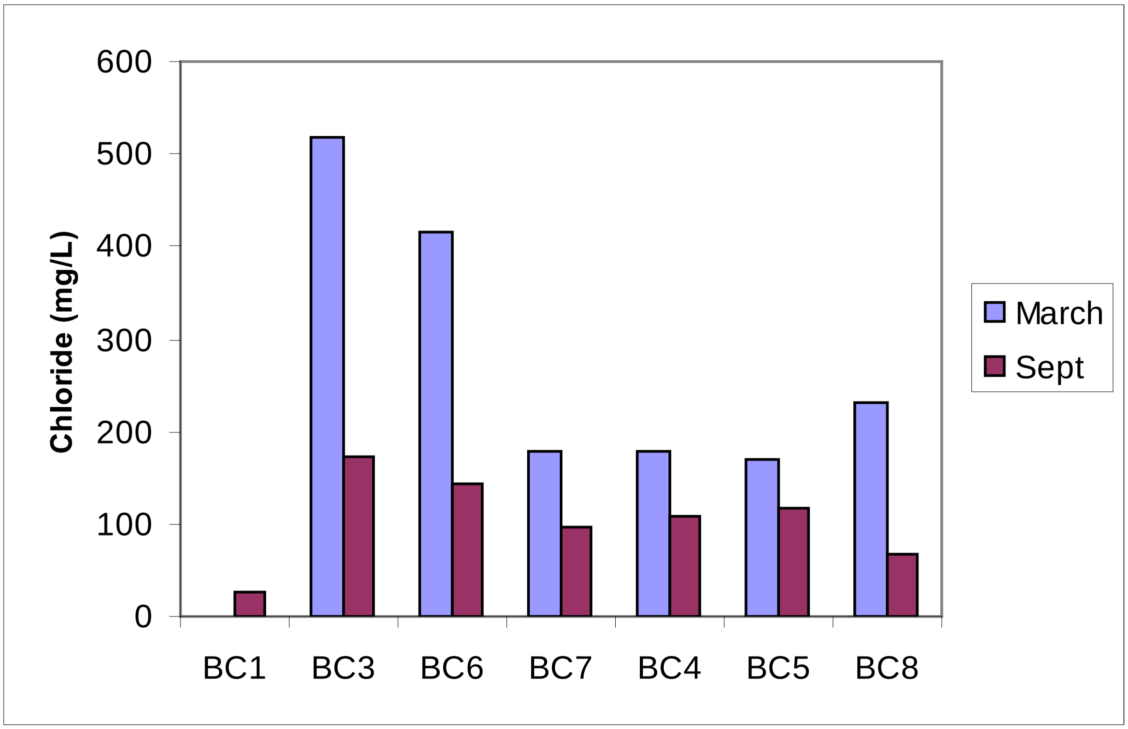
Figure 3.4 Beaver Creek Surface Water Calcium Concentrations for March and September, 2008



Chloride

In March, chloride concentrations were highest at sites BC-3 (518 mg/L) and BC-6 (416 mg/L) (Figure 3.5). Chloride concentrations at these sites were lower in September (172 and 143 mg/L respectively).

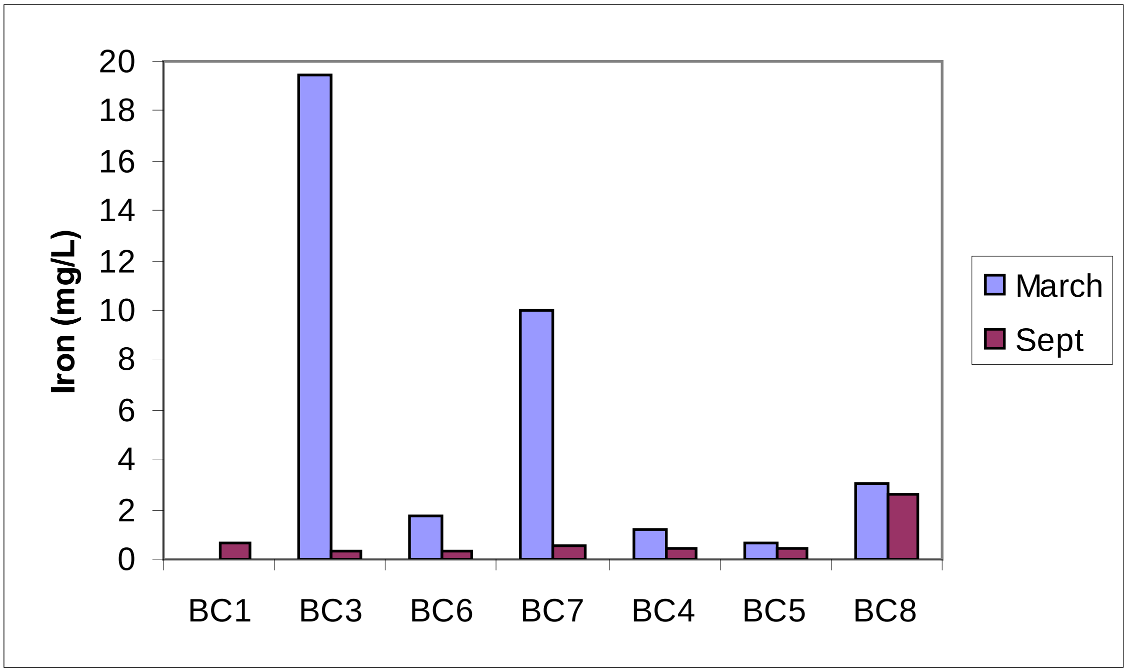
Figure 3.5 Beaver Creek Surface Water Chloride Concentrations for March and September, 2008



Iron

Total iron concentrations ranged from 0.61 mg/L at BC-5 to 19.5 mg/L at BC-3 in March, and from 0.31 mg/L at BC-3 to 2.59 mg/L at BC-8 in September (Figure 3.6). The CCME surface water quality guideline for iron is 0.3 mg/L (CCME 1999). Surface water iron concentrations at BC-1 (upstream reference site) also exceeded the CCME guideline where a value of 0.66 mg/L was recorded.

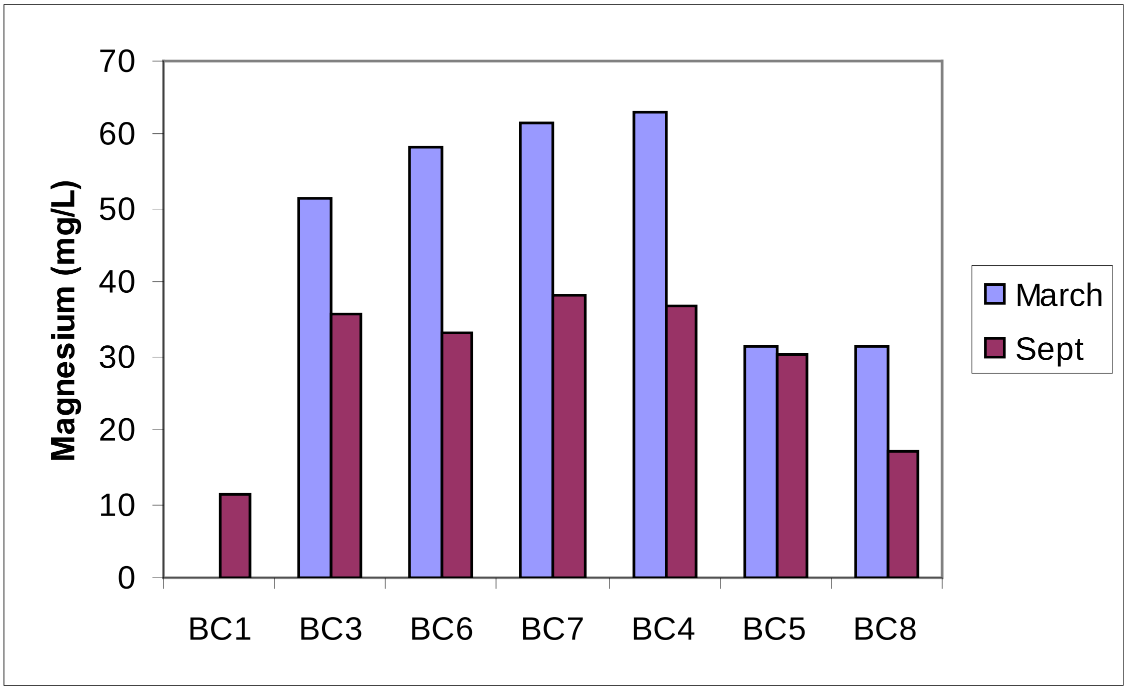
Figure 3.6 Beaver Creek Surface Water Iron Concentrations for March and September, 2008



Magnesium

At all sites downstream of the MLSB magnesium concentrations were higher in March than in September. Concentrations ranged from 31.2 mg/L at BC-5 to 63.1 mg/L at BC-4 in March, and from 11.2 mg/L at BC-1 to 38.1 mg/L at BC-7 in September (Figure 3.7). There is no CCME guideline for magnesium.

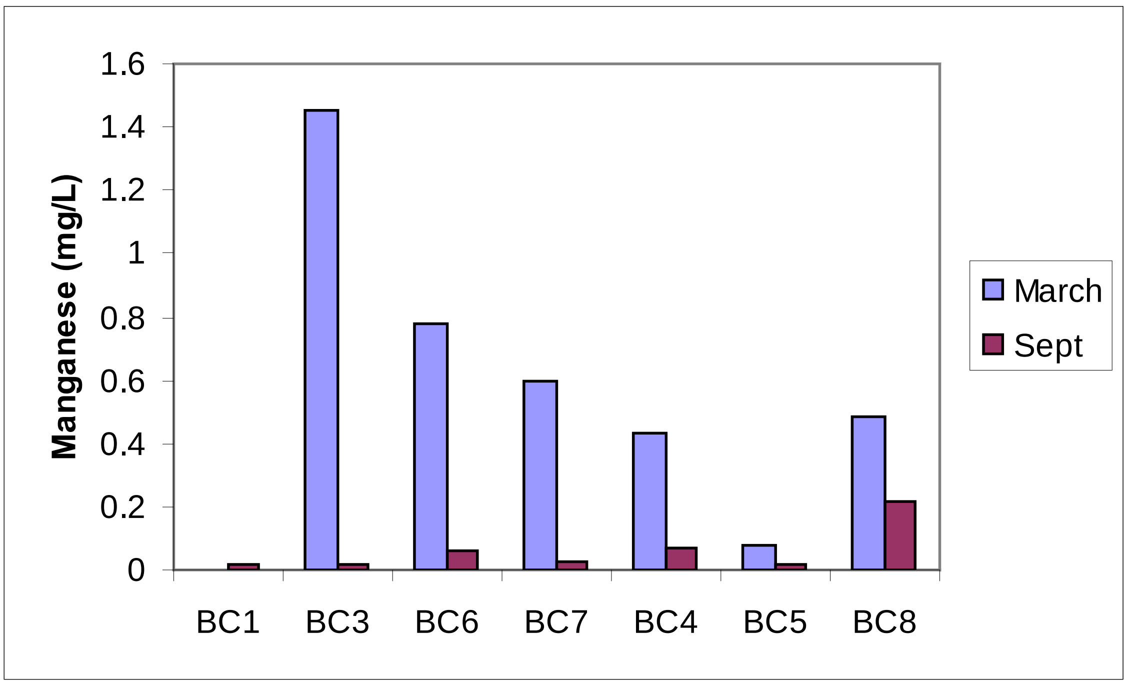
Figure 3.7 Beaver Creek Surface Water Magnesium Concentrations for March and September, 2008



Manganese

In March, manganese concentrations were highest at site BC-3 and gradually decreased with distance downstream (with the exception of site BC-8). Concentrations ranged from 0.074 mg/L at BC-5 to 1.45 mg/L at BC-3 in March, and from 0.014 mg/L at BC-1 to 0.212 mg/L at BC-8 in September (Figure 3.8). There is no CCME guideline for manganese.

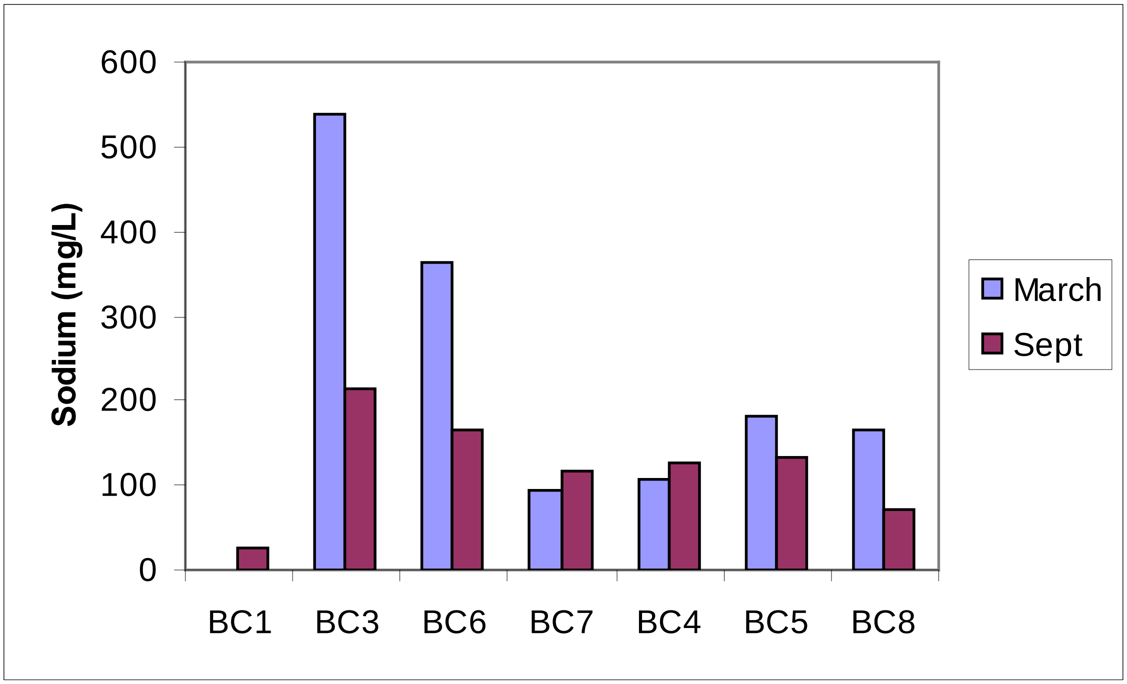
Figure 3.8 Beaver Creek Surface Water Manganese Concentrations for March and September, 2008



Sodium

The highest sodium concentrations were measured at sites BC-3 and BC-6 in March. Concentrations ranged from 95 mg/L at BC-7 to 540 mg/L at BC-3 in March, and from 26 mg/L at BC-1 to 215 mg/L at BC-3 in September (Figure 3.9).

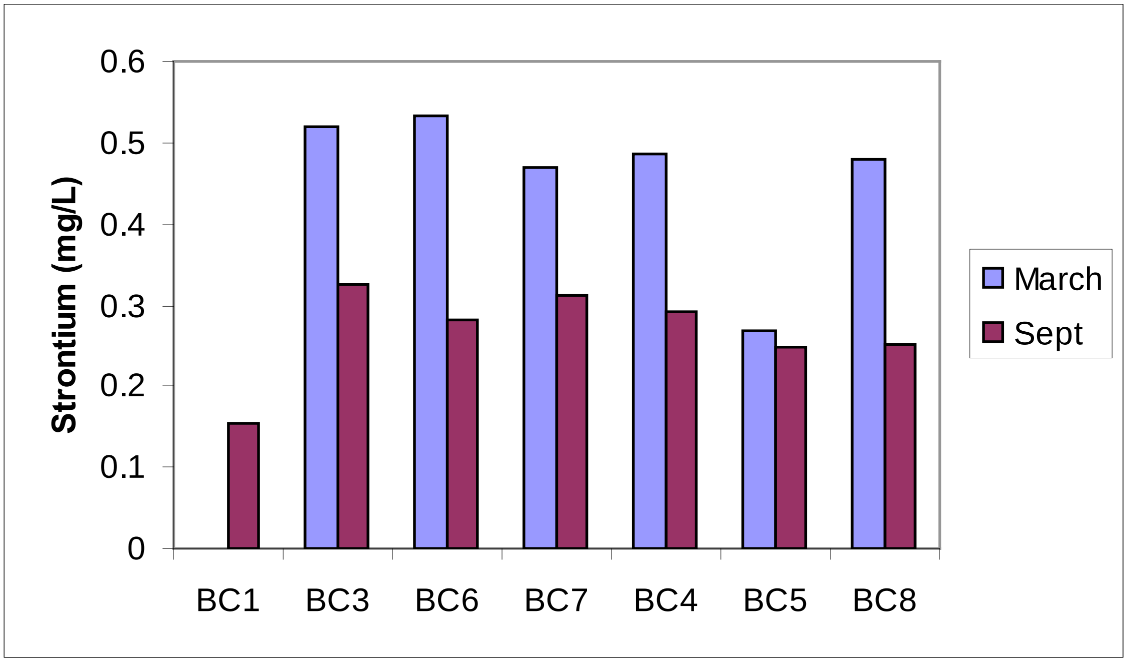
Figure 3.9 Beaver Creek Surface Water Sodium Concentrations for March and September, 2008



Strontium

In March, strontium concentrations were lowest at site BC-5 (0.27 mg/L). Concentrations at all other sites downstream of the MLSB were similar (ranging from 0.53 mg/L at BC-6 to 0.47 mg/L at BC-7). With the exception of site BC-1, total strontium concentrations were also similar among sites in September (Figure 3.10) where concentrations ranged from 0.25 mg/L at sites BC-5 and BC-8 to 0.32 mg/L at site BC-3.

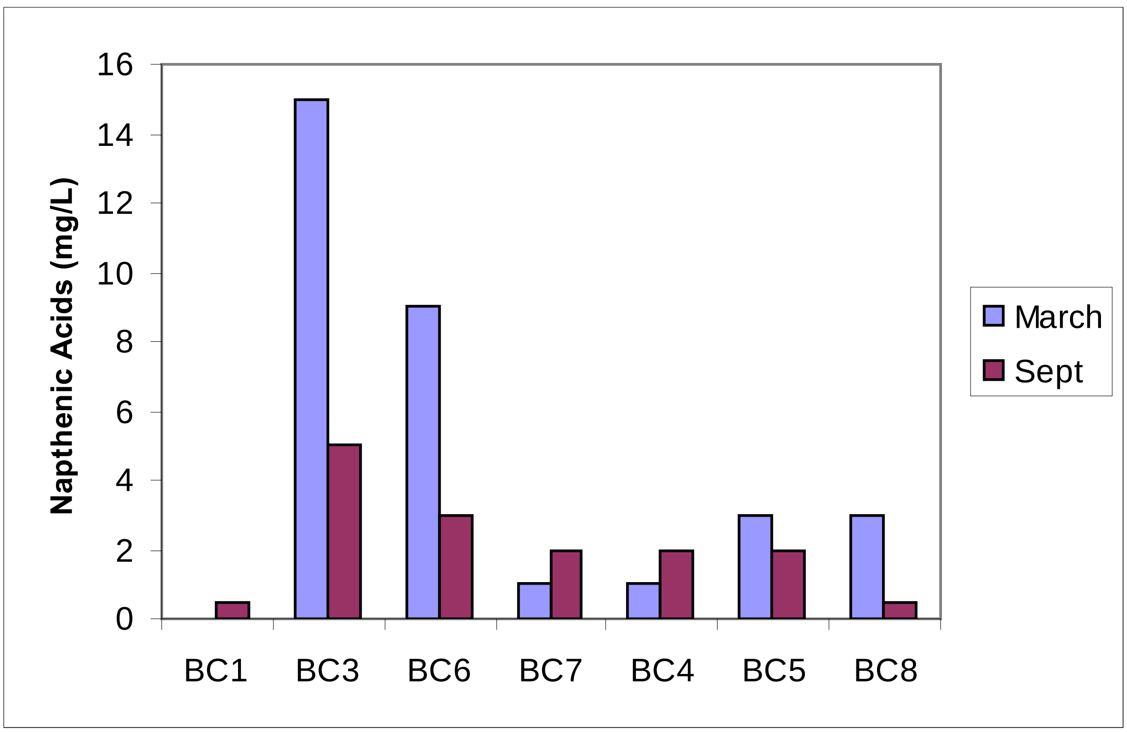
Figure 3.10 Beaver Creek Surface Water Strontium Concentrations for March and September, 2008



Total Naphthenic Acids

Total naphthenic acid concentrations showed a decreasing trend as distance downstream from the seepage dam increased. The highest naphthenic acid concentrations were measured at sites BC-3 and BC-6 in March. Concentrations at these sites were lower in September. Total naphthenic acid concentrations ranged from 1 mg/L at sites BC-4 and BC-6 to 15 mg/L at BC-3 in March, and from <1.0 mg/L at BC-1 and BC-8 to 5 mg/L at BC-3 in September (Figure 3.11).

Figure 3.11 Beaver Creek Surface Water Total Naphthenic Acid Concentrations for March and September, 2008



3.1.3 Quality Assurance/Quality Control (QA/QC)

Duplicate water samples were taken at site BC-3 on each sampling date. With the exception of a reported RPD of >20% for aluminum and barium concentrations in March and manganese in September, the RPDs for all other COC on both sampling occasions were less than 20%.

On both sampling occasions, COC concentrations in the field blank water samples were all below detection limits.

3.2 TOXICITY TESTS

The 2008 results for the 96-hour FETAX, 96-hour rainbow trout, 7-day fathead minnow and 10-day chironomid survival and growth toxicity tests are presented in the following sections.

3.2.1 FETAX Results

FETAX Definitive Test

The results of the March and September 2008 FETAX definitive tests conducted on samples collected at BC-3 are presented in Table 3.3.

In March, the frequency of mortality induced by the five treatment concentrations (50%, 75%, 90%, 95% and 100%) ranged from 7.0% to 35.0% (Table 3.3) and was not significantly different from the laboratory control (100% FETAX solution) treatment (p=0.063). Therefore the No Observed Effect Concentration (NOEC) for mortality was 100%. Mean malformation frequencies ranged from 3.1% to 90.5% (Table 3.3). Only the frequency of malformation induced by the 100% treatment was significantly different from the control treatment ($p < 0.001$). Thus, the NOEC value for malformation was determined as 95% while the Lowest Observed Effect Concentration (LOEC) value was 100%. Mean growth across the five treatments ranged from 82.4% to 98.8% of the control (Table 3.3). Significant decreases in growth, when compared to the laboratory control, were detected at the 50% 90%, 95% and 100% concentrations, but not at the 75% concentration. The NOEC for decreased growth was determined to be 75%, while the LOEC was determined as 90%. The LC_{50} and EC_{50} values were determined to be greater than 100% and 96.3% (95% Confidence interval = 95.0% to 97.6%), respectively.

Table 3.3 2008 Results for the Definitive Frog Embryo Teratogenesis Assay - *Xenopus* (FETAX) at Site BC-3

	Positive Control		Laboratory Control (100% FETAX Solution)	100%	95%	90%	75%	50%
	6-AN Reference Toxicant (2,500 mg/L)	6-AN Reference Toxicant (5.5 mg/L)						
March								
mean mortality (%)	100.0	8.0	6.0	35.0	8.0	15.0	7.0	13.0
mean malformations (%)	-	58.7	2.1	90.5[a]	27.8	14.4	3.1	0.0
mean growth[b] (%)	-	-	-	82.4[a]	96.5[a]	96.0[a]	98.8	94.6[a]
September								
mortality (%)	94.0	2.0	2.0	5.0	3.0	3.0	2.0	3.0
malformations (%)	100.0	49.0	2.0	8.3	5.2	3.0	4.1	3.0
mean growth[b] (%)	-	-	-	97.7[a]	96.7[a]	97.0[a]	99.8	98.8

[a] Significantly different from control treatment ($p < 0.05$).

[b] Mean sample length divided by mean FETAX solution control length, expressed as % growth.

- = not available.

In September, the frequencies of mortality induced by the five treatment concentrations ranged from 2.0% to 5.0%, and were not significantly different from the lab control (p=0.749; Table 3.3). Therefore the NOEC for mortality was determined to be 100%. The frequencies of malformation ranged from 3.0% to 8.3%, with no significant differences observed when compared with the lab control (p=0.186; Table 3.3). Thus, the NOEC was determined to be 100% for malformation. The mean growth ranged from 96.7% to 99.8% of laboratory controls (Table 3.3). Significant differences in growth compared to the laboratory control were detected at 90%, 95% and 100% concentrations. The NOEC value was therefore reported at 75% and the LOEC at 90% concentrations. LC_{50} and EC_{50} values could not be determined due to the low frequencies of mortalities and malformation observed in the September FETAX.

FETAX Screen Tests

FETAX screen tests were conducted in March and September of 2008 at all Beaver Creek sampling sites downstream of the seepage dam (BC-3, BC-6, BC-7, BC-4, BC-5, and BC-8).

In March, the six water samples induced frequencies of mortality ranging from 4.0% to 35.0% when tested at 100% concentrations (Table 3.4). Sample BC-3 was the only sample to induce significantly different frequencies of mortality when tested against the control (p = 0.008). Frequencies of malformation ranged from 2.1% to 90.5% (Table 3.4). BC-3 was significantly greater than the control in frequencies of malformation (p=0.015). The mean growth data from the six screening samples ranged from 82.4% to 98.4% of the control. Larval growth in samples from BC-3, BC-6, BC-7, BC-4, and BC-8 were all significantly different from the control treatment (p < 0.001).

Table 3.4 2008 Results for the Screen Frog Embryo Teratogenesis Assay - *Xenopus* (FETAX) at Beaver Creek sampling sites

	Positive Control		Laboratory Control (100% FETAX Solution)	BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
	6-AN Reference Toxicant (2,500 mg/L)	6-AN Reference Toxicant (5.5 mg/L)							
March									
mean mortality (%)	100.0	8.0	6.0	35.0[a]	12.0	16.0	4.0	5.0	13.0
mean malformations (%)	-	58.7	2.1	90.5[a]	2.2	8.7	2.1	3.4	4.6
mean growth[b] (%)	-	-	-	82.4*	96.6[a]	93.6[a]	95.5[a]	98.4	92.5[a]
September									
mortality (%)	94.0	2.0	2.0	5.0	4.0	7.0	3.0	4.0	2.0
malformations (%)	100.0	49.0	2.0	8.3	4.2	3.1	1.0	2.0	2.1
mean growth[b] (%)	-	-	-	97.7*	96.4[a]	95.8[a]	96.8[a]	95.0[a]	100.3

[a] Significantly different from control treatment (p < 0.05).
[b] Mean sample length divided by mean FETAX solution control length, expressed as % growth.
- = no data.

When tested at the 100% concentrations in September 2008, the six water samples induced frequencies of mortality and malformation ranging from 2.0% to 7.0% for mortality and 1.0% to 8.3% for malformation (Table 3.4). There were no significant differences in either the frequency of mortality (p=0.70) or malformation (p=0.08) between the control and the Beaver Creek samples. The mean growth of the six samples ranged from 95.0% to 100.3% of the control (Table 3.4). Larval growth in samples from BC-3, BC-6, BC-7, BC-4 and BC-5 were all significantly different from the control treatment (p<0.001).

3.2.2 Rainbow Trout and Fathead Minnow Results

Fathead minnow toxicity tests were not performed in March as a result of fish supply issues at HydroQual. Results of the 96-hr rainbow trout static acute toxicity test (March and September) and the 7-day fathead minnow survival and growth toxicity test (September only) are presented in Tables 3.5 and 3.6, respectively. There was no mortality in rainbow trout or fathead minnows and no significant difference in fathead minnow growth.

Table 3.5 2008 Results of the 96-hour Rainbow Trout Toxicity Test, Site BC-5

Parameter	March	September
LC_{25}	>100%	>100%
LC_{50}	>100%	>100%
NOEC	100%	100%
LOEC	>100%	>100%

LC_{25} Lethal concentration for 25% of the organisms.
LC_{50} Lethal concentration for 50% of the organisms.
NOEC No observed effects concentration.
LOEC Lowest observed effects concentration.

Table 3.6 2008 Results of the 7-day Fathead Minnow Toxicity Test, Site BC-5

Endpoint	Parameter	March	September
Mortality (%)	LC_{25}	-	>100%
	LC_{50}	-	>100%
	NOEC	-	100%
	LOEC	-	>100%
Growth (mg dry wt)	IC_{25}	-	>100%
	IC_{50}	-	>100%
	NOEC	-	100%
	LOEC	-	>100%

LC_{25} Lethal concentration for 25% of the organisms.
LC_{50} Lethal concentration for 50% of the organisms.
IC_{25} Concentration causing inhibition of growth among 25% of the organisms.
IC_{50} Concentration causing inhibition of growth among 50% of the organisms.
NOEC No observed effects concentration.
LOEC Lowest observed effects concentration.
- = No data available due to laboratory fish supply issues.

3.2.3 *Chironomus* Results

Survival and growth were both significantly lower in sediment from site BC-6 (Dunnett's test, survival: $P < 0.0005$; growth; $P < 0.0001$) when compared to the laboratory controls (Table 3.7). No statistically significant effects on survival and growth were observed in sediments from the other sample locations.

Table 3.7 2008 Results of the 10-day *Chironomus tentans* Static Survival and Growth Test

Site[a]	Survival (Number of Live Organisms)			Growth (mg dry wt./organism)		
	Mean	CV (%)[b]	% of Control	Mean	CV (%)[b]	% of Control
Lab Control	8	14	100	1.97	17	100
BC-3	8	17	93	1.83	18	93
BC-6	5[c]	27	57	0.52[c]	9	26
BC-7	8	17	93	1.78	19	91
BC-4	6	14	76	1.70	12	86
BC-5	7	17	79	2.43	16	123
BC-8	7	19	81	1.44	23	73

(a) Sites are ordered from upstream to downstream.

(b) CV = coefficient of variation.

(c) Significantly different from the laboratory control (one-way ANOVA, $P < 0.05$; Dunnett's test, $P < 0.05$).

4 COMPARISON OF 2008 RESULTS TO PREVIOUS FIELD STUDIES

4.1 CONCENTRATIONS OF COC IN SURFACE WATER

Data comparing maximum concentrations of COC in water samples collected from 2004 to 2008 are presented in Table 3.8. It is important to note that 2004 water chemistry data were collected during a single sampling event in the fall (September) only. For 2005, 2006 and 2007, water chemistry data were collected during four sampling events; March, May, September, and October. In 2008 water chemistry data were collected in March and September only.

Generally, 2008 surface water concentrations of each COC (i.e., aluminum, barium, boron, calcium, chloride, iron, magnesium, manganese, sodium, strontium, and naphthenic acids) were within the range of values reported in previous years (Table 3.8).

Table 3.8 Comparison of Maximum Concentrations (mg/L) of COC in Surface Water Samples Collected from 2004 to 2008

Parameter	BC-1					BC-3					BC-6					BC-7					BC-4					BC-5					BC-8				
	2004	2005	2006	2007	2008[(a)]	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
Total Metals																																			
Aluminum	0.30	0.40	0.23	0.51	0.25	0.05	1.00	0.86	2.49	0.65	0.03	0.40	0.40	0.08	0.06	0.02	0.20	1.97	0.77	0.02	0.02	0.09	0.18	0.69	0.07	0.06	0.14	0.03	0.10	0.06	0.22	0.65	0.32	0.46	0.14
Barium	0.017	0.021	0.019	0.022	0.022	0.16	0.5	0.243	0.45	0.207	0.07	0.2	0.171	0.2	0.155	0.09	0.13	0.34	0.12	0.138	0.1	0.15	0.137	0.140	0.119	0.098	0.14	0.148	0.13	0.105	0.049	0.14	0.123	0.13	0.133
Boron	0.05	0.05	0.03	0.06	<0.05	0.29	0.34	0.53	0.42	0.39	0.34	0.46	0.45	0.49	0.39	0.24	0.28	0.35	0.28	0.24	0.18	0.2	0.23	0.28	0.26	0.15	0.17	0.22	0.22	0.19	0.10	0.15	0.18	0.23	0.15
Calcium	20.5	25.9	22.2	22.2	30.8	119.0	148.0	146.0	160.0	127.0	47.3	107.0	114.0	92.8	82.9	79.4	147.0	154.0	122.0	265.0	116.0	226.0	259.0	266.0	258.0	81.3	117.0	116.0	118.0	112.0	39.1	120.0	117.0	114.0	107.0
Iron	0.6	0.7	0.39	0.78	0.66	8.46	59.6	31.7	29.4	19.5	0.269	3.34	3.54	0.85	1.72	0.225	1.37	40.9	1.23	9.97	0.225	3.14	1.760	2.64	1.25	0.32	1.230	1.46	1.24	0.606	1.83	3.71	4.1	2.19	3.0
Magnesium	8.0	10.0	9.0	8.1	11.2	41.6	57.8	65.7	73.0	51.5	0.1	72.7	70.6	56.5	58.3	0.0	52.1	55.7	48.2	61.5	40.1	51.5	62.5	64.8	63.1	25.5	32.3	32.1	33.3	31.2	11.9	32.4	34.0	33.7	31.4
Manganese	0.03	0.03	0.011	0.023	0.014	0.82	0.96	1.93	1.91	1.45	0.099	0.79	0.808	1.46	0.775	0.034	0.71	2.03	0.8	0.59	0.01	0.89	1.1	0.717	0.434	0.017	0.19	0.119	0.107	0.074	0.103	0.539	0.435	0.812	0.480
Sodium	19	24	21	22	26	353	642	334	382	540	348	555	336	370	363	224	191	166	166	117	145	207	127	162	128	153	203	185	195	181	58	173	160	242	165
Strontium	0.11	0.13	0.11	0.11	0.15	0.411	0.6	0.581	0.812	0.52	0.255	0.59	0.615	0.559	0.532	0.316	0.52	0.525	0.45	0.47	0.33	0.33	0.499	0.497	0.486	0.213	0.31	0.326	0.318	0.267	0.178	0.519	0.471	0.669	0.480
Major Ions																																			
Chloride	3	19	21	5	25	369	630	318	387	518	449	669	349	395	416	327	274	169	192	178	258	270	184	196	178	173	197	168	181	170	62	224	185	372	232
General Organics																																			
Naphthenic Acids	2	1	1	0.5	<1	19	28	10	12	15	11	19	12	13	9	8	6	4	4	1	4	4.7	2	3	2	5	5	3	3	3	3	4	2	2	3

[(a)] 2008 results are from a single sample collected in September.

Sites ordered from upstream (left) to downstream (right).

2004 results are from a single sample collected in September.

4.1.1 COC Temporal and Spatial Trends

As recommended in the ERA (Golder 2004), and continued in the 2008 Profiling Program, temporal and spatial trends in the concentrations of surface water COC were examined. This was done in an attempt to address the following questions:

1. Do changes in the concentrations of surface water COC follow a distinct seasonal pattern?

2. Are the seasonal patterns consistent among years?

3. Do concentrations of surface water COC increase, decrease, or remain the same annually?

4. Do the concentrations of surface water COC follow a distinct spatial pattern?

4.1.1.1 Temporal Trends

Seasonal Trends

In general, changes in surface water concentrations of each COC follow a consistent seasonal pattern. Previously (from 2005 to 2007), concentrations peaked in March, declined by May, and remained low through to the fall (Figure 4.1). Results from the 2008 Profiling Program were consistent with previous years, in that concentrations were higher in March and had declined significantly by September (with the exception of boron).

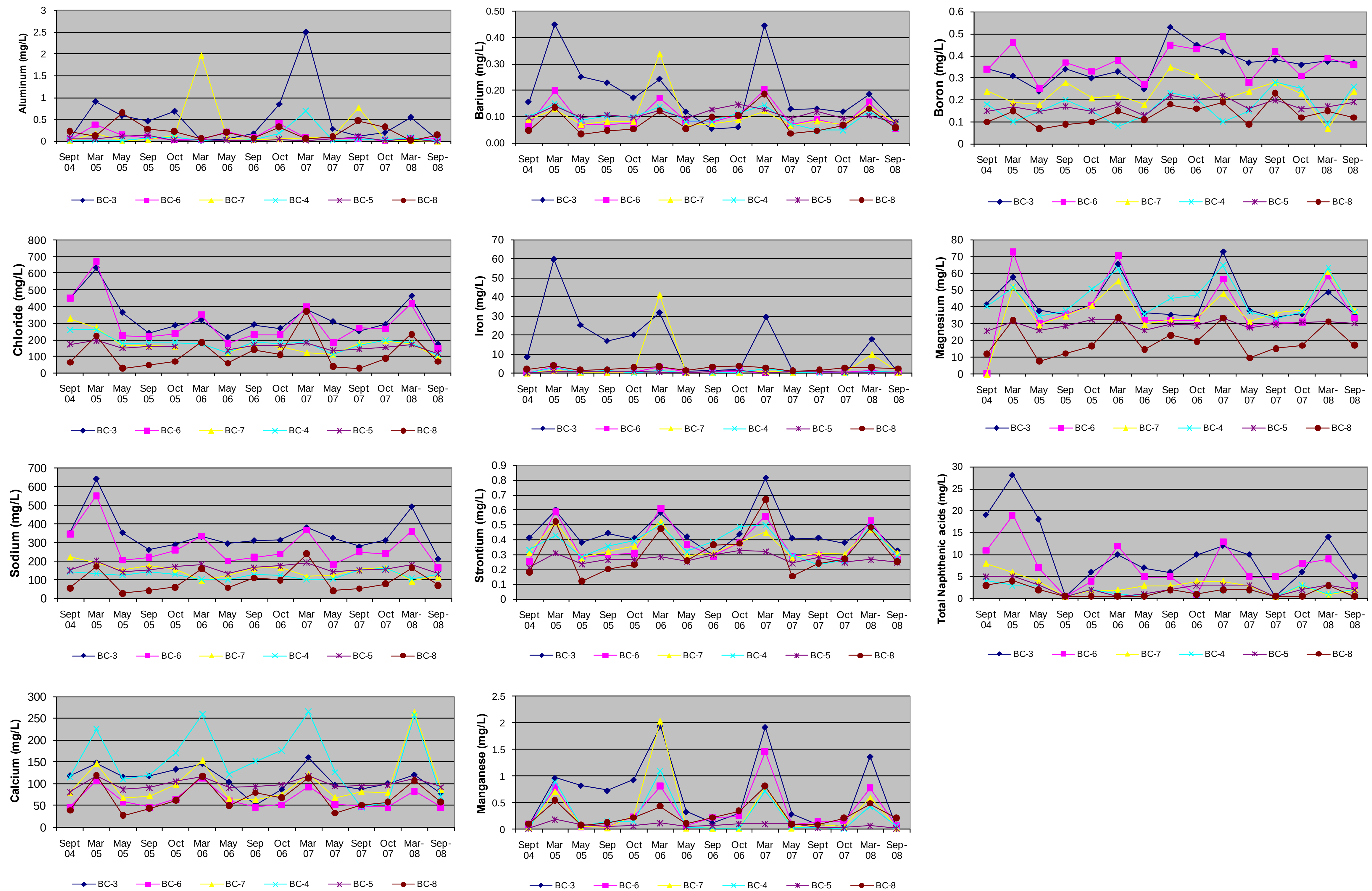
Annual Trends

Concentrations of naphthenic acids, iron, chloride and sodium were highest in 2005 (particularly at sites BC-3 and BC-6) (Figure 4.1). Since 2005, concentrations of these COC have declined from 2005 levels and have remained stable into 2008. Concentrations of the remaining COC (aluminum, barium, boron, magnesium, manganese, strontium and cadmium) have remained relatively stable from 2004 to 2008.

4.1.1.2 Spatial Trends

In general, surface water concentrations of each COC were highest at sites BC-3 and BC-6 and decreased in a downstream direction toward BC-8 (Figure 4.1). However, calcium concentrations were consistently higher at site BC-4, when compared to the other sample sites, from 2004 to 2008.

Figure 4.1 Surface Water Concentrations of COC



4.2 TOXICITY TESTING

4.2.1 FETAX

In 2004 and 2005, FETAX assays for the Beaver Creek ERA monitoring program were conducted by HydroQual laboratories. However, due to husbandry issues, which resulted in increased mortality in some of the control treatments, a decision was made to conduct subsequent testing (from 2006 onwards) at Fort Environmental Laboratories. Therefore, direct comparisons of 2006, 2007 and 2008 FETAX results with previous years' data are not possible.

Fetax Definitive Tests at BC-3

Definitive testing on water samples collected at site BC-3 commenced in October 2006. Prior to this date, only screen tests were performed on water from this site. The general observation that can be made from the results of the definitive test is that the highest concentrations in the dilution series (100% and 95%) produce a significant effect on mortality, malformations and growth in *Xenopus* larvae (Table 4.1). A growth effect can also sometimes be seen in the lower dilution concentrations (90%, 75% and 50%). This trend was not observed however in samples collected in March 2007 and September 2008.

The fact that adult frogs and tadpoles have been observed in Beaver Creek suggests the water at BC-3 is not acutely toxic to local amphibian populations and that local populations are capable of growing and developing into adults and reproducing.

Fetax Screen Tests

In 2006, FETAX screen testing was conducted on water samples from site BC-3 only. In 2007 and 2008 screening tests were conducted on water samples from all sample sites downstream of the seepage dam.

Table 4.2 presents the results of the Fetax screen tests. Data for 2007 and 2008 show that statistically significant differences from the control treatments for malformations are evident in water samples collected from site BC-3 only and occur in water samples collected during the spring months (March and May). This significant result in an increase in malformations is usually not accompanied by an increase in mortality (except in March 2008). Screen test results for BC-3 in 2006 show no significant effects on malformations (except in October), but a significant effect for mortality and growth (Table 4.1).

With the exception of a significant effect on mortality at sites BC-6 and BC-8 in October 2007, Fetax screen results for all other sites downstream of the seepage dam (BC-6, BC-7, BC-4, BC-5 and BC-8) show no significant effect on malformations and mortality. However, a significant effect on growth at all sites downstream of the dam has been evident in 2007 and 2008 (Table 4.2). This growth response, however, is less than 10% of the control mean growth over the test period and does not necessarily confer biological effect.

Table 4.1 Comparison of Results of the Frog Embryo Teratogenesis Assay - *Xenopus* (FETAX) Conducted on Surface Water Samples from BC-3 in 2006, 2007 and 2008

Year	Month	Endpoint	Treatment							
			Positive Control		Laboratory Control (100% FETAX Solution)	100%	95%	90%	75%	50%
			6-AN Reference Toxicant (2,500 mg/L)	6-AN Reference Toxicant (5.5 mg/L)						
2006	March	Mean Mortality (%)	100.0	2.0	2.0	6.0[a]	-	-	-	-
		Mean Malformations[d] (%)	-	53.1	4.1	5.3	-	-	-	-
		Mean Growth[e] (%)	-	-	-	99.8[a]	-	-	-	-
	May	Mean Mortality (%)	100.0	6.0	4.0	15.0[a]	-	-	-	-
		Mean Malformations (%)	-	55.3	1.0	3.5	-	-	-	-
		Mean Growth(%)	-	-	-	91.5[a]	-	-	-	-
	September	Mean Mortality (%)	100.0	4.0	0.0	11.0*	-	-	-	-
		Mean Malformations (%)	-	43.8	2.0	3.4	-	-	-	-
		Mean Growth[f] (%)	-	-	-	93.8[a]	-	-	-	-
	October	Mean Mortality (%)	100.0	80.0	2.0	11[a][b]	7[c]	5.0	5.0	1.0
		Mean Malformations (%)	-	50.0	2.6	3.9[a][c]	3.2	2.1	1.1	1.0
		Mean Growth (%)	-	-	-	90.7[a]	92.2[a]	92.5[a]	94.3[a][b]	98.4[c]
2007	March	Mean Mortality (%)	100.0	2.0	0.0	0.0[c]	0.0	0.0	0.0	0.0
		Mean Malformations (%)	-	55.1	2.0	15.0[c]	5.0	1.0	0.0	0.0
		Mean Growth (%)	-	-	-	98.0[c]	98.0	98.2	98.2	99.6
	May	Mean Mortality (%)	100.0	100.0	3.0	11.0[c]	19.0	16.0	18.0	3.0
		Mean Malformations (%)	-	-	0.0	16.9*	12.3[a][b]	10.7[c]	6.1	0.0
		Mean Growth (%)	-	-	-	91.7*	92.6[a]	92.3[a]	93.1[a]	95.5[a][b]

Table 4.1 Comparison of Results of the Frog Embryo Teratogenesis Assay - *Xenopus* (FETAX) Conducted on Surface Water Samples from BC-3 in 2006, 2007 and 2008 (continued)

Year	Month	Endpoint	Treatment							
			Positive Control		Laboratory Control (100% FETAX Solution)	100%	95%	90%	75%	50%
			6-AN Reference Toxicant (2,500 mg/L)	6-AN Reference Toxicant (5.5 mg/L)						
	September	Mean Mortality (%)	100.0	100.0	8.0	36.0[a][b]	28.0[c]	42.0[a]	26.0	25.0
		Mean Malformations (%)	-	-	2.1	15.8[a][c]	4.9	7.4	2.7	2.7
		Mean Growth (%)	-	-	-	91.1[a]	94.1[a]	91.7[a]	93.9[a]	94.8[a][b]
	October	Mean Mortality (%)	100.0	100.0	5.0	16.0[a]	20.0[a]	19.0[a]	18.0[a]	20.0[a][b]
		Mean Malformations (%)	-	-	2.1	13.2[a][b]	7.6[c]	5.0	4.9	2.6
		Mean Growth (%)	-	-	-	96.6[a][b]	98.7[c]	98.1	97.5[a]	99.5
2008	March	Mean Mortality (%)	100.0	8.0	6.0	35.0	8.0	15.0	7.0	13.0
		Mean Malformations (%)	-	58.7	2.1	90.5[a]	27.8	14.4	3.1	0.0
		Mean Growth (%)	-	-	-	82.4[a]	96.5[a]	96.0[a]	98.8	94.6[a]
	September	Mortality (%)	94.0	2.0	2.0	5.0[c]	3.0	3.0	2.0	3.0
		Malformations (%)	100.0	49.0	2.0	8.3[c]	5.2	3.0	4.1	3.0
		Mean Growth (%)	-	-	-	97.7[a]	96.7	97.0[b]	99.8[c]	98.8

[a] Significantly different from control treatment ($p < 0.05$)
[b] Lowest Observed Effect Concentration (LOEC).
[c] No Observed Effect Concentration (NOEC).
[d] Percent malformations are calculated from the number of malformed larva remaining in surviving populations at the end of the 96 hour test.
[e] Mean sample length divided by mean FETAX solution control length, expressed as % growth.
- = test not performed.

Table 4.2 Comparison of Results of the Screen Frog Embryo Teratogenesis Assay - *Xenopus* (FETAX) Conducted on Surface Water Samples from Beaver Creek in 2007 and 2008

Year	Month	Endpoint	Positive Control		Laboratory Control (100% FETAX Solution)	BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
			6-AN Reference Toxicant (2,500 mg/L)	6-AN Reference Toxicant (5.5 mg/L)							
2007	March	Mean Mortality (%)	100.0	2.0	0.0	0.0	0.0	2.0	4.0	4.0	2.0
		Mean Malformations (%)	-	55.1	2.0	15.0[a]	2.0	6.1	2.1	6.3	7.1
		Mean Growth[d] (%)	-	-	-	98.0	98.1	97.1[a]	96.4[a]	96.1[a]	96.0[a]
	May	Mortality (%)	100.0	100.0	3.0	11.0	5.0	6.0	8.0	6.0	8.0
		Malformations (%)	-	-	0.0	16.9[a]	2.1	3.2	3.3	3.2	8.7[a]
		Mean Growth (%)	-	-	-	91.7[a]	92.0[a]	92.2[a]	94.5[a]	92.2[a]	90.2[a]
	September	Mortality (%)	100.0	100.0	5.0	-	5.0	3.0	6.0	6.0	1.0
		Malformations (%)	-	-	2.1	-	4.2	5.2	1.1	3.1	4.0
		Mean Growth (%)	-	-	-	-	92.6[a]	93.4[a]	99.2	97.8	88.7[a]
	October	Mortality (%)	100.0	100.0	5.0	16.0	35.0[a]	17.0	16.0	10.0	27.0[a]
		Malformations (%)	-	-	2.1	13.2	5.1	3.4	3.5	5.4	5.4
		Mean Growth (%)	-	-	-	96.6[a]	104.2[a]	102.0	99.2	99.8	103.2[a]
2008	March	Mean Mortality (%)	100.0	8.0	6.0	35.0	12.0	16.0	4.0	5.0	13.0
		Mean Malformations (%)	-	58.7	2.1	90.5	2.2	8.7	2.1	3.4	4.6
		Mean Growth (%)	-	-	-	82.4[a]	96.6[a]	93.69[a]	95.5[a]	98.4	92.5[a]
	September	Mortality (%)	94.0	2.0	2.0	5.0	4.0	7.0	3.0	4.0	2.0
		Malformations (%)	100.0	49.0	2.0	8.3	4.2	3.1	1.0	2.0	2.1
		Mean Growth (%)	-	-	-	97.7[a]	96.4[a]	95.8[a]	96.8[a]	95.0[a]	100.3

(a) Significantly different from control treatment ($p < 0.05$).
(b) Lowest Observed Effect Concentration (LOEC).
(c) No Observed Effect Concentration (NOEC).
(d) Percent malformations are calculated from the number of malformed larva remaining in surviving populations at the end of the 96 hour test.
(e) Mean sample length divided by mean FETAX solution control length, expressed as % growth.
\- = test not performed.

4.2.2 Rainbow Trout and Fathead Minnow

Results of the 96-hr toxicity tests conducted with rainbow trout from 2004 to 2008 show no mortality during any of the tests (Table 4.3). Similarly, results of the 7-day fathead minnow toxicity tests from 2004 to 2008 did not show mortality or decreased growth during any of the tests (Table 4.4).

These results indicate that water collected from BC-5 is not toxic to rainbow trout or fathead minnows.

4.2.2.1 Chironomus

In 2008, statistically significant differences were detected between the laboratory control and treatments consisting of sediment collected from site BC-6 for both *Chironomus tentans* survival and growth (Table 3.7). Both *C. tentans* survival and growth were significantly lower in sediment from Site BC-6 compared to laboratory controls (Table 3.7). This suggests that sediment from Site BC-6, located downstream of the seepage dam, had a possible effect on the benthic invertebrate community in 2008. This is similar to the 2007 results, when *C. tentans* toxicity tests on sediment from Site BC-6 also detected lower survival and growth compared to laboratory controls (Tables 4.5 and 4.6). This differs from previous years (2004 to 2006) when no statistically significant differences between laboratory controls and field samples were detected in *C. tentans* toxicity test results. However, it is unlikely that this effect was caused by seepage from the dam because no statistical differences were detected in chironomid survival or growth at Site BC-3, which is located immediately downstream of the seepage dam.

Table 4.3 Comparison of Results of the 96-hour Rainbow Trout Toxicity Test Conducted on Surface Water Samples at BC-5 from 2004 to 2008

Parameter	2004	2005				2006				2007				2008	
	September	March	May	September	October	March	May	September	October	March	May	September	October	March	September
LC_{25}	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%
LC_{50}	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%
NOEC	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LOEC	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%

LC25 Lethal concentration for 25% of the organisms.
LC50 Lethal concentration for 50% of the organisms.
NOEC No observed effects concentration.
LOEC Lowest observed effects concentration.

Table 4.4 Comparison of Results of the 7-day Fathead Toxicity Test Conducted on Surface Water Samples at BC-5 from 2004 to 2008.

Endpoint	Parameter	2004	2005				2006				2007				2008	
		Sept	March	May	Sept	Oct	March	May	Sept	Oct	March	May	Sept	Oct	March	Sept
Mortality (%)	LC_{25}	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	-	>100%
	LC_{50}	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	-	>100%
	NOEC	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	-	100%
	LOEC	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	-	>100%
Growth (mg dry wt)	IC_{25}	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	-	>100%
	IC_{50}	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	-	>100%
	NOEC	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	-	100%
	LOEC	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	>100%	-	>100%

LC25 Lethal concentration for 25% of the organisms.
LC50 Lethal concentration for 50% of the organisms.
IC25 Concentration causing inhibition of growth among 25% of the organisms.
IC50 Concentration causing inhibition of growth among 50% of the organisms.
NOEC No observed effects concentration.
LOEC Lowest observed effects concentration.
- = No data available.

Table 4.5 Comparison of 2004 to 2008 Survival Results of Sediment Toxicity Tests Using *Chironomus tentans*

Site[a]	Mean Number of Live Organisms					CV[b] (%)					% of Control				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
Lab Control	10	8	8	8	8	6	5	16	20	14	100	100	100	100	100
BC-1	8	5	-	-	-	25	67	-	-	-	80	63	-	-	-
BC-3	9	5	7	7	8	10	37	27	74	17	90	63	88	93	93
BC-6	9	3	8	3[c]	5[c]	6	92	30	32	27	90	34	102	40	57
BC-7	9	4	4	7	8	9	83	105	72	17	90	54	44	90	93
BC-4	10	5	7	5	6	6	34	46	46	14	100	59	80	58	76
BC-5	6	4	8	5	7	60	68	25	45	17	60	46	98	58	79
BC-8	9	7	8	6	7	10	14	13	64	19	90	80	100	80	81

[a] Sites are ordered from upstream to downstream.

[b] CV = Coefficient of variation.

[c] Significantly different from the laboratory control (one-way ANOVA, $P < 0.05$; Dunnett's test, $P < 0.05$) for 2007 and 2008.

- = not available.

Table 4.6 Comparison of 2004 to 2008 Growth Results of Sediment Toxicity Tests Using *Chironomus tentans*

Site [a]	Mean Dry Weight (mg)					CV[b] (%)					% of Control				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
Lab Control	2.9	1.7	2.2	2.1	2.0	9	12	34	39	17	100	100	100	100	100
BC-1	2.6	3.0	-	-	-	12	41	-	-	-	90	174	-	-	-
BC-3	2.6	2.5	1.6	1.4	1.8	24	24	41	34	18	90	145	75	67	93
BC-6	2.6	3.8	1.9	0.5[c]	0.5[c]	8	22	49	34	9	90	217	88	21	26
BC-7	2.2	4.5	2.0	1.9	1.8	25	13	41	19	19	76	261	92	87	91
BC-4	2.7	3.3	2.0	1.9	1.7	9	9	35	35	12	93	191	94	88	86
BC-5	2.4	4.2	2.7	3.5	2.4	14	20	30	59	16	83	241	126	164	123
BC-8	2.0	4.3	2.1	1.5	1.4	10	32	12	37	23	69	249	95	72	73

[a] Sites are ordered from upstream to downstream.

[b] CV = Coefficient of variation.

[c] Significantly different from the laboratory control (one-way ANOVA, $P < 0.05$; Dunnett's test, $P < 0.05$) for 2007.

- = not available.

5 SUMMARY AND CONCLUSIONS

This study represents a scaled-down version of the three year ERA monitoring program conducted from 2005 to 2007. The purpose of the 2008 Profiling Program was to address the following objectives:

- Objective 1: To confirm that seasonal/annual/spatial trends observed in 2008 were consistent with trends observed during previous years of study.
- Objective 2: To ensure that the conclusions from the three year ERA monitoring program remained valid, i.e., there are no unacceptable ecological risks to Beaver Creek due to the seepage of process water from the MLSB.

Conclusions for Objective 1

Based on the results of the surface water testing, the conclusions for the first study objective were:

1. Surface water concentrations of most parameters were highest in March and decreased by fall. This trend is evident through 2005 to 2008 suggesting that perhaps contributions from spring thaw and surface water runoff are the main source(s) of inorganic parameters in Beaver Creek, not seepage from the wastewater control system.

2. Surface water COC concentrations were generally highest immediately below the seepage dam at site BC-3 and decreased in a downstream direction toward BC-8.

3. The wastewater control system is operating effectively as surface water concentrations of naphthenic acids, a tracer of process-affected water, have decreased in samples from sites BC-3 and BC-6 since modifications were made to the pumping system below the dam.

Conclusions for Objective 2

Based on the results of the toxicity testing, the conclusions for the second objective were:

1. Water collected from site BC-3 has a statistically significant effect on mortality and malformations in *Xenopus* larvae. This effect does not occur at the sites downstream of BC-3. A growth effect of less than 10% of the control mean growth is observable at all sites downstream of the seepage dam but this does not necessarily confer biological effect.

2. Water collected from BC-5 is not acutely toxic to rainbow trout or fathead minnows. This result has been consistently demonstrated from 2004 to 2008.

3. Significant differences in *Chironomus tentans* survival and growth were detected in sediment from Site BC-6 from Beaver Creek in 2008. This is similar to the 2007 *C. tentans* toxicity test results, when survival and growth were significantly different from controls at site BC-6. However, no differences were detected in growth and survival at Site BC-3 located immediately downstream of the seepage dam. This suggests that the effects detected in sediment samples are unlikely to be related to toxicity of substances released from the seepage dam. Rather, a localized effect in the vicinity of Site BC-6 may account for the sediment effects observed at this location.

6 RECOMMENDATIONS

Overall, the results of the 2008 Beaver Creek Profiling Program indicate that conditions have remained stable in Beaver Creek since the culmination of the three year ERA field program and the wastewater control system is working effectively to limit seepage water from entering the creek. There were no substantial changes to COC concentrations in 2008, when compared to the ERA study from 2005 and 2007, indicating that conditions in Beaver Creek are relatively stable. There are no unacceptable ecological risks to Beaver Creek due to seepage of process water, which supports the overall goal of the original ERA.

7 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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APPENDIX I

RAW WATER CHEMISTRY DATA

Table I-1 March 2008 Water Quality

Parameter	Units	Site					
		BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
Field Measured							
pH		7.1	7.3	6.7	7.3	7.7	7.5
Specific Conductance	µS/cm	1,819	1,368	1,012	875	751	866
Temperature	°C	0.01	-0.02	0.14	-0.06	-0.03	0.16
Dissolved Oxygen	mg/L	7.00	5.05	7.58	8.82	2.38	18.39
Conventional Parameters							
Conductance	µS/cm	3,070	2,400	1,970	1,860	1,530	1,620
Hardness	mg/L	543	487	985	882	424	476
pH		7.8	7.9	7.9	7.8	8.1	8.1
Total Alkalinity	mg/L	877	662	302	294	336	337
Total Dissolved Solids	mg/L	1780	1,380	1,370	1,250	928	979
Major Ions							
Bicarbonate	mg/L	1,070	808	368	358	410	411
Calcium	mg/L	125	88.8	283	246	115	127
Carbonate	mg/L	<5	<5	<5	<5	<5	<5
Chloride	mg/L	518	416	178	178	170	232
Magnesium	mg/L	56	64.5	67.7	65	33.3	38.5
Potassium	mg/L	2.9	2.9	1.6	2.5	1.5	1.9
Sodium	mg/L	492	352	103	106	184	190
Sulphate	mg/L	60.2	61.7	552	481	223	187
Nutrients							
Nitrate + Nitrite	mg/L	<0.1	<0.1	< 0.1	< 0.1	< 0.1	<0.1
Nitrate	mg/L	<0.1	<0.1	< 0.1	< 0.1	< 0.1	<0.1
Nitrite	mg/L	<0.05	<0.05	< 0.05	< 0.05	< 0.05	<0.05
Nitrogen - ammonia	mg/L	0.74	1.23	0.1	0.13	< 0.05	0.17
General Organics							
Naphthenic acids	mg/L	15	9	1	1	3	3
Metals (Total)							
Aluminum (Al)	mg/L	0.65	0.06	0.02	0.07	0.06	0.02
Antimony (Sb)	mg/L	<0.0004	<0.0004	<0.0004	0.0005	<0.0004	<0.0004
Arsenic (As)	mg/L	0.0033	0.0023	0.002	0.0012	0.0009	0.0014
Barium (Ba)	mg/L	0.207	0.155	0.138	0.119	0.105	0.133
Beryllium (Be)	mg/L	< 0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth (Bi)	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Boron (B)	mg/L	0.39	0.39	0.07	0.09	0.17	0.15

Table I-1 March 2008 Water Quality (continued)

Parameter	Units	Site					
		BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
Cadmium (Cd)	mg/L	0.0014	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Calcium (Ca)	mg/L	127	82.9	265	258	112	107
Chromium (Cr)	mg/L	0.0033	0.0051	0.0022	0.0033	0.0038	0.002
Cobalt (Co)	mg/L	0.0025	0.0004	0.0006	0.0005	0.0002	0.0007
Copper (Cu)	mg/L	0.002	<0.001	0.003	0.003	0.004	0.003
Iron (Fe)	mg/L	19.5	1.72	9.97	1.25	0.606	3
Lead (Pb)	mg/L	0.0019	0.0009	<0.0001	0.0002	<0.0001	<0.0001
Magnesium (Mg)	mg/L	51.5	58.3	61.5	63.1	31.2	31.4
Manganese (Mn)	mg/L	1.45	0.775	0.594	0.434	0.074	0.484
Mercury (Hg)	mg/L	-	-	-	-	-	-
Molybdenum (Mo)	mg/L	0.0002	0.0001	0.0001	0.0001	0.0003	0.0002
Nickel (Ni)	mg/L	0.0077	0.0039	0.0064	0.007	0.0038	0.0043
Potassium (K)	mg/L	3.7	3.7	2.1	3	1.8	1.2
Selenium (Se)	mg/L	<0.0004	<0.0004	<0.0004	0.0009	0.0005	0.0007
Silver (Ag)	mg/L	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Sodium (Na)	mg/L	540	363	95	108	181	165
Strontium (Sr)	mg/L	0.519	0.532	0.47	0.486	0.267	0.48
Thallium (Tl)	mg/L	0.0012	0.0009	<0.0001	<0.0001	<0.0001	<0.0001
Tin (Sn)	mg/L	<0.0004	<0.0004	0.0017	0.0024	0.0011	0.0053
Titanium (Ti)	mg/L	0.019	<0.005	<0.005	<0.005	<0.005	<0.005
Uranium (U)	mg/L	0.0004	0.0002	0.0007	0.0007	0.0016	0.0005
Vanadium (V)	mg/L	0.0034	0.0019	0.0015	0.0021	0.0018	0.0017
Zinc (Zn)	mg/L	0.037	0.013	0.007	0.032	0.015	0.007
Target PAHs and Alkylated PAHs							
Naphthalene	µg/L	0.06	<0.01	0.19	0.96	<0.01	<0.01
C1 subst'd naphthalenes	µg/L	0.04	<0.01	0.09	0.4	<0.01	<0.01
C2 subst'd naphthalenes	µg/L	0.1	<0.04	0.08	0.25	<0.04	<0.04
C3 subst'd naphthalenes	µg/L	0.07	<0.04	0.05	0.15	<0.04	<0.04
C4 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	0.07	<0.04	<0.04
Acenaphthene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1 subst'd acenaphthene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Acenaphthylene	µg/L	<0.01	<0.01	0.01	0.03	<0.01	<0.01
Anthracene	µg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(a,h) anthracene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(a) anthracene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table I-1 March 2008 Water Quality (continued)

Parameter	Units	Site					
		BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
C1 subst'd benzo(a) anthracene / chrysene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd benzo(a) anthracene / chrysene	µg/L	<0.04	< 0.04	<0.04	<0.04	<0.04	<0.04
Benzo(a)pyrene	µg/L	<0.01	< 0.01	<0.01	<0.01	<0.01	<0.01
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	µg/L	<0.04	< 0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	µg/L	<0.04	< 0.04	<0.04	<0.04	<0.04	<0.04
Benzo(b)fluoranthene	µg/L	<0.01	< 0.01	<0.01	<0.01	<0.01	<0.01
Benzo(k)fluoranthene	µg/L	<0.01	< 0.01	<0.01	<0.01	<0.01	<0.01
Benzo(j)fluoranthene	µg/L	<0.01	< 0.01	<0.01	<0.01	<0.01	<0.01
Benzo(g,h,i)perylene	µg/L	<0.01	< 0.01	<0.01	<0.01	<0.01	<0.01
Biphenyl	µg/L	<0.01	< 0.01	<0.01	0.01	<0.01	<0.01
C1 subst'd biphenyl	µg/L	<0.04	< 0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd biphenyl	µg/L	0.04	< 0.04	<0.04	0.07	<0.04	<0.04
Chrysene	µg/L	<0.01	< 0.01	<0.01	<0.01	<0.01	<0.01
Dibenzothiophene	µg/L	<0.01	< 0.01	<0.01	<0.01	<0.01	<0.01
C1 subst'd dibenzothiophene	µg/L	<0.04	< 0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd dibenzothiophene	µg/L	<0.04	< 0.04	<0.04	< 0.04	<0.04	<0.04
C3 subst'd dibenzothiophene	µg/L	<0.04	< 0.04	<0.04	<0.04	<0.04	< 0.04
C4 subst'd dibenzothiophene	µg/L	<0.04	< 0.04	<0.04	<0.04	<0.04	<0.04
Fluoranthene	µg/L	< 0.01	< 0.01	<0.01	<0.01	<0.01	<0.01
C1 subst'd fluoranthene / pyrene	µg/L	<0.04	< 0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd fluoranthene / pyrene	µg/L	<0.04	< 0.04	<0.04	<0.04	<0.04	<0.04
C3 subst'd fluoranthene / pyrene	µg/L	<0.04	< 0.04	<0.04	<0.04	<0.04	<0.04
Fluorene	µg/L	<0.01	<0.01	<0.01	0.02	<0.01	<0.01
C1 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	0.07	<0.04	<0.04
C3 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Indeno(c,d-123)pyrene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table I-1 March 2008 Water Quality (continued)

Parameter	Units	Site					
		BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
Phenanthrene	µg/L	0.02	<0.01	<0.01	0.03	<0.01	<0.01
C1 subst'd phenanthrene / anthracene	µg/L	0.05	<0.04	<0.04	0.05	<0.04	<0.04
C2 subst'd phenanthrene / anthracene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C3 subst'd phenanthrene / anthracene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C4 subst'd phenanthrene / anthracene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
1-Methyl-7-isopropyl-phenanthrene (Retene)	µg/L	0.01	<0.01	<0.01	0.01	<0.01	<0.01
Pyrene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Target PANHs							
Quinoline	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Acridine	µg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Note: Site BC-1 not sampled in march since water not present at site.

Table I-2 September 2008 Water Quality

Parameter	Units	Site						
		BC-1	BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
Field measured								
pH		8.2	8.4	8.2	9.1	9.5	7.7	7.8
Specific Conductance	µS/cm	214	1,044	846	968	954	824	449
Temperature	°C	6.97	11.30	10.80	8.96	9.50	8.20	8.00
Dissolved Oxygen	mg/L	9.17	13.70	9.56	7.90	6.90	11.64	10.74
Conventional Parameters								
Conductance	µS/cm	332	1,510	1,250	1,200	1,170	1,260	693
Dissolved Organic Carbon	mg/L	-	-	-	-	-	-	-
Hardness	mg/L	124	334	268	362	339	342	213
pH		7.8	8.4	8.4	8.2	8.3	8.3	8.2
Total Alkalinity	mg/L	81	455	321	333	310	311	194
Total Dissolved Solids	mg/L	189	875	707	693	686	711	384
Major Ions								
Bicarbonate	mg/L	99	536	381	407	378	379	236
Calcium	mg/L	30.5	75	48.9	81.5	72.3	88.5	57
Carbonate	mg/L	<5	9	5	<5	<5	<5	< 5
Chloride	mg/L	25	172	143	96	108	118	68
Magnesium	mg/L	11.5	35.6	35.4	38.6	38.5	29.3	17.2
Potassium	mg/L	1.4	0.6	1.3	1.7	1.6	1.4	1
Sodium	mg/L	27	202	167	121	129	124	65
Sulphate	mg/L	45.2	117	119	154	151	163	59.7
Nutrients								
Nitrate + Nitrite	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrogen - ammonia	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrogen - Kjeldahl	mg/L	-	-	-	-	-	-	-
Nitrogen - nitrate		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrogen - nitrite		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
General Organics								
Naphthenic acids	mg/L	<1	5	3	2	2	2	<1
Metals (Total)								
Aluminum (Al)	mg/L	0.25	0.03	0.05	<0.01	0.01	<0.01	0.14
Barium (Ba)	mg/L	0.022	0.079	0.056	0.077	0.06	0.078	0.059
Beryllium (Be)	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Boron (B)	mg/L	<0.05	0.37	0.36	0.24	0.26	0.19	0.12
Cadmium (Cd)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium (Ca)	mg/L	30.8	77.8	47.5	87	72	92.8	58.5
Chromium (Cr)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt (Co)	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Table I-2 September 2008 Water Quality (continued)

Parameter	Units	Site						
		BC-1	BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
Copper (Cu)	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	0.011	0.001
Iron (Fe)	mg/L	0.655	0.314	0.336	0.534	0.44	0.417	2.59
Lead (Pb)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium (Mg)	mg/L	11.2	35.7	33.3	38.1	37	30.1	17.3
Manganese (Mn)	mg/L	0.014	0.016	0.064	0.03	0.067	0.02	0.212
Molybdenum (Mo)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel (Ni)	mg/L	0.003	0.003	0.002	0.003	0.003	0.003	0.003
Potassium (K)	mg/L	1.6	1.4	2.1	2.5	2.4	1.9	1.4
Selenium (Se)	mg/L	-	-	-	-	-	-	-
Silver (Ag)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium (Na)	mg/L	26	215	164	117	128	134	70
Strontium (Sr)	mg/L	0.154	0.324	0.28	0.313	0.291	0.249	0.25
Thallium (Tl)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Tin (Sn)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Titanium (Ti)	mg/L	0.003	0.001	0.001	<0.001	<0.001	<0.001	0.003
Vanadium (V)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc (Zn)	mg/L	0.005	0.006	0.006	0.008	0.007	0.014	0.007
Target PAHs and Alkylated PAHs								
Naphthalene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
C1 subst'd naphthalenes	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
C2 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C3 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C4 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
Acenaphthene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
C1 subst'd acenaphthene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
Acenaphthylene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
Anthracene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
Dibenzo(a,h) anthracene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
Benzo(a)Anthracene / Chrysene	µg/L	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.03
C1 subst'd benzo(a) anthracene / chrysene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C2 subst'd benzo(a) anthracene / chrysene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
Benzo(a)pyrene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03

Table I-2 September 2008 Water Quality (continued)

Parameter	Units	Site						
		BC-1	BC-3	BC-6	BC-7	BC-4	BC-5	BC-8
C1 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C2 subst'd benzo(b&k) fluoranthene / benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
Benzo(g,h,i)perylene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
Biphenyl	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
C1 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C2 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
Dibenzothiophene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
C1 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C2 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C3 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C4 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
Fluoranthene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
C1 subst'd fluoranthene / pyrene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
Fluorene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
C1 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C2 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
Indeno(c,d-123)pyrene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
Phenanthrene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05
C1 subst'd phenanthrene / anthracene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C2 subst'd phenanthrene / anthracene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C3 subst'd phenanthrene / anthracene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
C4 subst'd phenanthrene / anthracene	µg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.1
Pyrene	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03