Aquatic Resources Baseline Report

YESAB Project Proposal Phase V/VI

June 2013

Prepared for:

Minto Explorations Ltd.

EXECUTIVE SUMMARY

The Minto Mine's region includes the Yukon and smaller Yukon River tributaries, including 7 km upstream to Big Creek and 13 km downstream to Wolverine Creek. The local study area related to the Minto Mine centres on three small drainages in the mine area that drain directly to the Yukon River: Minto Creek, Creek A, and McGinty Creek.

Minto Creek, with its headwaters in the mine area, is the primary drainage affected by the Minto Phase V/VI project. Minto Creek flows northeast from the existing mine site over roughly 17 km to the Yukon River, and covers an approximate area of 41 km^2. The creek has five primary tributaries along its length, and flows through large tracts of land that have been influenced by forest fire recently. Water from the mine area flows into the upper reaches of Minto Creek through the water storage pond and other conveyances. Investigations into Minto Creek have found it to be generally shallow, ephemeral in nature, and to have frequent build-ups of layered ice during the winter (sometimes to the substrate).

Creek A is a small watercourse that drains an area adjacent to, and traversed by, the Minto Mine access road, into the Yukon River. The headwaters of Creek A are approximately 4 km southeast of Minto Creek and it flows for 7 km along a riparian floodplain into the Yukon River.

McGinty Creek (formerly referred to as Unnamed Creek B) is located to the north of Minto Creek and flows north-northeast for 9.5 km to the Yukon River confluence. Minto North Pit, which is to be mined in the Phase V/VI project, is located near McGinty Creek headwaters.

Fish and Fish Habitat

A variety of resident and migratory fish species inhabit the Yukon River near Minto Mine. These include Chinook, Coho and chum salmon, lake trout, least cisco, Bering cisco, round whitefish, lake whitefish, inconnu, Arctic grayling, northern pike, burbot, longnose sucker, and slimy sculpin.

Previous studies on the Yukon River within the vicinity of Minto Mine have identified both spawning and rearing areas for salmon. Spawning shoals are present in the Ingersoll Islands (downstream of the project area) as well as around islands upstream of Minto Mine, near Big Creek. These offer an extensive network of side channels and sloughs which provide good spawning gravel.

This portion of the Yukon River also provides rearing habitat for Chinook salmon, as evidenced by past studies in the project area. Juvenile Chinook salmon generally spend up to 1.5 years feeding and growing in fresh water tributaries prior to out-migrating to the ocean, and feed or stage in various tributaries to the Yukon River during this slow outmigration. Usage of project area tributaries by juvenile Chinook salmon (JCS) is outlined further below.

Yukon River salmon runs have observed moderate variability over the last 50 years; however, there has been a general decrease in salmon returns over the last ten to fifteen years. Chinook returns began to drop markedly beginning in 1998, and poor runs are still observed to this time. Chum salmon returns demonstrated a marked reduction in 1997 through 2002, but have been demonstrating more positive trends for summer and fall since 2001 and 2003, respectively.

Fish and fish habitat studies of Minto Creek have been ongoing for many years, with contemporary studies including those from 1994 through 2012. Generally, Minto Creek has been noted to provide only limited habitat to fish. Flows within the stream are quite variable on a yearly basis, with intermittent flows and extensive ice build-up during winter that limits the potential for overwintering habitat for fish. Also, the distribution of fish within Minto Creek has been observed to be limited to the lower 1.5 km of the watercourse, as there is a barrier and steep canyon upstream of that location. As noted above, Chinook salmon, slimy sculpin, Arctic grayling, longnose sucker, burbot, and round whitefish have been captured in Minto Creek; however, the latter have not been observed since the original baseline studies in 1994. Slimy sculpin have been observed consistently, but at a low density.

During baseline studies, it was noted that trends in annual Chinook salmon occurrence in Minto Creek can be related to water temperature on a seasonal basis. During the early summer (e.g., May/ June), the occurrence of JCS has been low, with individuals captured more frequently near the Yukon River confluence. Catches in July, August, and September have generally been higher, presumably because out-migrating Chinook seek out non-natal tributaries as foraging habitat at cover. During the summer of 2009, there was a marked increase in Chinook salmon captures which coincided with an emergency release of water from the Minto Mine tailings dam (catch per unit effort (CPUE) of at least three times the previous highest catch records). Similarly, high numbers of JCS were captured in 2010, when the mine was discharging water into Minto Creek. It is believed that the stable, elevated flow and warmer, more consistent temperature regime (i.e. a narrower diurnal temperature fluctuation) associated with the release may have attracted JCS into the system from the Yukon River. In response to the observed high density of JCS in Minto Creek during these releases, a fish transfer program was initiated during the fall of 2009 and 2010 to prevent these fish being stranded by the onset of winter.

Creek A was investigated during the 1994 baseline study program at the project site, at which time no fish were observed or captured (including a site at the road crossing location). Creek A is not considered to offer high quality habitat for fish.

Arctic grayling and slimy sculpin were captured in McGinty Creek in 1994, through electrofishing and minnow trapping. Because substantial deadfall caused by a forest fire changed creek conditions, only minnow trapping was used in 2009–2011, yielding very low numbers of slimy sculpin. Since these captures were made in consistent locations, these fish were presumed to be associated with the Yukon River, as opposed to McGinty Creek. These results are similar to those found in the 1994 survey, in that fish were only captured in close proximity to the Yukon River confluence. The physical nature of the McGinty Creek drainage is not conducive to a consistent year-round use by fish. Many factors, including gradient, discharge volume, depth, configuration, and paucity of an upstream reservoir, limit wintering habitat potential for fish. Also, several potential natural fish barriers were observed and documented in the lower reach of McGinty Creek.

Aquatic Environment and Habitat

Stream sediments were studied for particle size and metal concentrations in 1994, and annually since 2006. Sediment particle size distribution was notably different when comparing earlier sampling years to more recent years. The change in distribution from 1994–2009 compared to 2010–2012 reflects methodological changes that were implemented in 2010. Sediment metal concentrations were also complicated by the change in methodology. With this qualification in mind, concentrations of arsenic, copper, and occasionally chromium exceeded the interim sediment quality guideline (ISQG) levels over the years but not greater than the probable effect level (PEL). Copper was the only metal that consistently exceeded guideline levels every year, including during baseline sampling in 1994. This could indicate that there are naturally high levels of copper at the exposure area. Arsenic was above the ISQG in most sampling years except during baseline sampling in 2007 and 2009.

Benthic macroinvertebrates are non-backboned animals inhabiting the bottom substrates of aquatic habitats. The abundance, diversity, and taxonomic composition of benthos can be used as indicators of changing environmental conditions as their distribution and abundance can be influenced by a wide variety of physical parameters. Baseline and numerous other benthic invertebrate studies were undertaken in the Minto Mine area from 2006–2012.

Basic results of the 2008 and 2011 environmental effects monitoring (EEM) benthic analyses indicated that Minto Creek (treatment) had a significantly higher benthic invertebrate density and slightly lower number of taxa (not significant) compared to McGinty Creek (reference). The 2011 EEM benthic results show that Minto Creek had significantly higher number of taxa and higher density compared to both reference sites. Increased taxa, higher density, and lower evenness is indicative of an site that is experiencing nutrient enrichment.

Under the terms of Minto's Water Use License #QZ06-006, benthic macroinvertebrate communities are required to be annually monitored in Minto Creek. In 2011, the mean number of taxa in lower Minto Creek was less than in the reference area in lower Wolverine Creek and less than the 1994 baseline. However, the 2011 count was an increase over that measured in 2006, another year that the mine did not discharge. Changes in density and evenness over time likely reflected high temporal variability of benthic invertebrate communities in the region, also evident at reference areas.

Periphytic algae are simple aquatic plants which inhabit the substrate of water bodies. They can provide a valuable biological monitoring tool to assess potential impacts of nutrient enrichment and metal toxicity. Chlorophyll a is the primary photosynthetic pigment common to all algae. Determining chlorophyll a concentrations provides a measure of algae biomass and thus, the primary productivity of a given location. Periphyton was sampled in 1994, 2011, and 2012, in Minto Creek (exposure) and Wolverine Creek (reference). Overall, the periphyton community of lower Minto Creek relative to lower Wolverine Creek had lower density and taxon richness. Periphyton communities of lower Minto Creek and lower Wolverine Creek in 2011 both differed from the community documented at lower Minto Creek in 1994.

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1 INTRODUCTION

This report comprehensively summarizes the baseline environmental studies of fisheries and aquatic habitat in the Minto Mine area. It is based on EBA Engineering Consultants Ltd. (EBA) 2010 Fisheries and Aquatic Baseline Study Summary. That 2010 report includes material modified from many baseline study reports and regulatory/assessment documents produced since 1994 by Hallam Knight Piesold, R&D Environmental, Access Consulting Group, and Minnow Environmental. Further work conducted in Minto Creek since EBA's report was produced in 2010 is included in this update, as well as baseline work carried out in the adjacent McGinty Creek catchment, within which the Minto North deposit lies.

2 ENVIRONMENTAL SETTING

2.1 LOCATION

The Minto Mine is located adjacent and southwest of the Yukon River in the Central Yukon, roughly 45 km southwest of the Village of Pelly Crossing (Figure 2-1). The mine is situated within the Minto Creek drainage, which flows directly into the Yukon River. The Minto North deposit lies within McGinty Creek drainage, which also empties directly into the Yukon River, just north of Minto Creek.

2.2 DESCRIPTION OF STUDY AREA

Information on fisheries and aquatic resources has been assembled from both the local and regional areas surrounding Minto Mine.

2.2.1 Regional Study Area

The Minto Mine regional area includes the Yukon River and its smaller tributaries near the project area, including 7 km upstream to Big Creek and 13 km downstream to Wolverine Creek.

2.2.2 Local Study Area

The local study area of the Minto Mine centres on three small drainages that drain directly into the Yukon River: Minto Creek, an unnamed creek (referred to as Creek A), and McGinty Creek. The primary drainage is that of Minto Creek, which flows northeast from the existing mine site over approximately 17 km to the Yukon River, and covers an area of roughly 41 km^2. Creek A flows to the north over about 7 km near the lower end of Minto Creek, drains an area of roughly 9 km^2, and is crossed by the Minto Project access road. The third drainage is that of McGinty Creek (formerly referred to as Unnamed Creek B), which is located to the north of Minto Creek and flows north-northeast nearly 9.5 km to the Yukon River confluence, and covers an area of about 34 km^2 (Figure 2-2).

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FIGURE 2-1
PROJECT LOCATION

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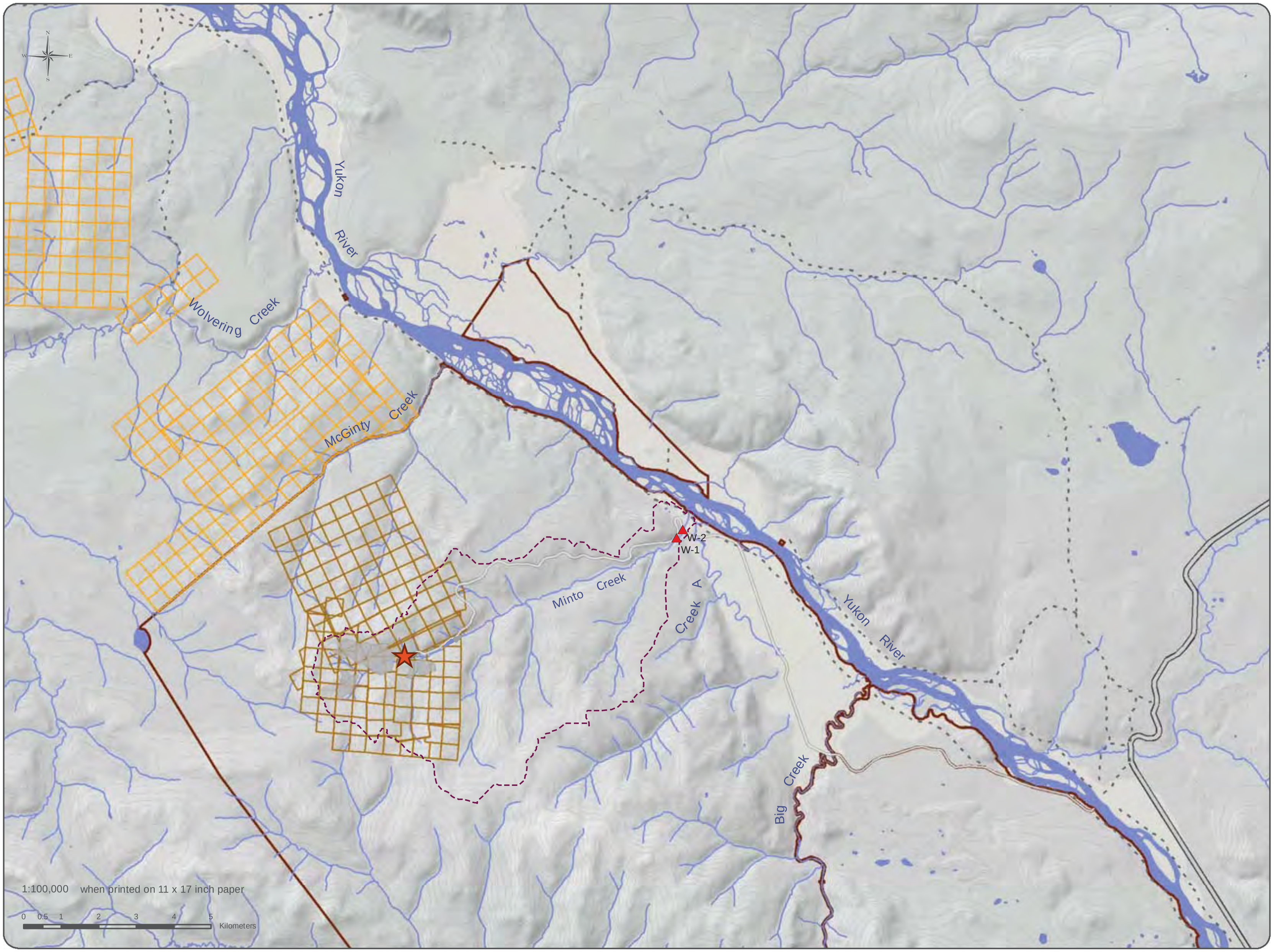

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FIGURE 2-2
AREA OVERVIEW

- Minto Mine Site
- Water Quality Station
- Mine Access Road
- Road
- Trail
- Watercourse
- Waterbody
- Existing Minto Mine Footprints
- Minto Creek Catchment
- Other Quartz Claims
- Minto Explorations Ltd. Quartz Claims
- First Nation Settlement Land

National Topographic Data Base (NTDB) and Canvec compiled by Natural Resources Canada at a scale of 1:50,000.Reproduced under license from Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources Canada. All rights reserved.

Quartz claims data obtained from Energy, Mines and Ressources, YTG. Data currrent as of August 1st 2011.

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3 FISH AND FISH HABITAT

3.1 CHRONOLOGY OF KEY STUDIES

Numerous studies on fisheries and fish habitat have been conducted over the recent history of the Minto Mine. These studies are summarized chronologically in Table 3-1, below.

Table 3-1: Summary of Key Fish and Fish Habitat Studies, Minto Mine.

Year	Firm and Study Name	Scope of Studies
1994	Hallam Knight Piesold (HKP) – IEE for Minto Project Area (HKP 1994)	• Fisheries investigations on Minto Creek and Creek A. • Backpack electrofishing, minnow trapping. • Reach definition and description, identification of barriers to fish passage.
2006–2007	Access Consulting Group (ACG), R&D Environmental – Various Fisheries Investigations for Minto Explorations Ltd. (Minnow/ACG, 2007)	• Fisheries investigations in Minto Creek to support the permitting of the Minto Mine. • Backpack electrofishing, minnow trapping.
2008	ACG, Minnow Environmental – EEM Program, Cycle 1 (Minnow/ACG, 2009)	• Fisheries investigation of Minto Creek. • Backpack electrofishing and minnow trapping.
2009	ACG – Fish Relocation Program (ACG, 2009)	• Minnow trapping in Minto Creek and transfer of fish to the Yukon River.
2010	ACG – Fish Mark and Recapture Program (ACG, 2010)	• Minnow trapping in Minto Creek and marking of captured fish (release back into Minto Creek).
2009–2011	ACG, Minnow Environmental – EEM Program, Cycle 2 (Minnow/ACG, 2012)	• Integrated assessment of effluent sub-lethal toxicity, water quality, benthic invertebrate community condition, and fish health (hatchery-based exposure study).
2011–2012	ACG – Minto Creek Fisheries Monitoring Program (ACG, 2012/ ACG, 2013)	• Minnow trapping in Minto Creek.
2009–2011	ACG – Fisheries Monitoring Program in McGinty Creek	• Fisheries Investigation of McGinty Creek through Minnow trapping.

3.2 REGIONAL OVERVIEW

3.2.1 Yukon River Fish and Fisheries

3.2.1.1 Fish Species

A variety of resident and migratory fish species inhabit the Yukon River near the Minto Mine. These include Chinook, Coho and chum salmon, lake trout, least cisco, Bering cisco, round whitefish, lake whitefish, inconnu, Arctic grayling, northern pike, burbot, longnose sucker, and slimy sculpin. The scientific names and general life history descriptions for these species are attached in Appendix A.

3.2.1.2 Local Habitat Use by Salmon

The Yukon River near the Minto Mine provides important salmon spawning and rearing areas. Spawning shoals are present in the Ingersoll Islands (downstream of the project area) and the islands upstream of the Minto Mine, near Big Creek. These offer an extensive network of side channels and sloughs which provide good spawning gravel. In support of this, spaghetti tags applied by DFO to fall chum salmon were recovered in the area along the Yukon River between Minto and Fort Selkirk in 2008 (de Graff 2008).

The Yukon River in the project vicinity also provides rearing habitat for Chinook salmon, as evidenced by numerous studies in the project area tributaries. JCS generally spend up to 1.5 years feeding and growing within fresh water tributaries prior to out-migrating to the ocean, and feed or stage in the Yukon River and its various tributaries during this protracted outmigration (Yukon River Panel 2008).

3.2.1.3 Trends in Yukon River Salmon Catch Record

Total catch data, including breakdowns of commercial and First Nations harvest for both Chinook and chum salmon in the Canadian portion of the Yukon River drainage (1961 to 2011) have been compiled using data from the Joint Technical Committee of the Yukon River US/Canada Panel (JTC) (2012) (Figures 3-1 and 3-2). Total harvest for these two species relative to spawning escapement (i.e. fish not harvested) is also presented in Figures 3-3 and 3-4 from 1982 (Chinook) and 1980 (Fall chum) to 2011. Total column heights represent the total border passage estimate, which have been subdivided into harvested and non-harvested (escapement) portions.

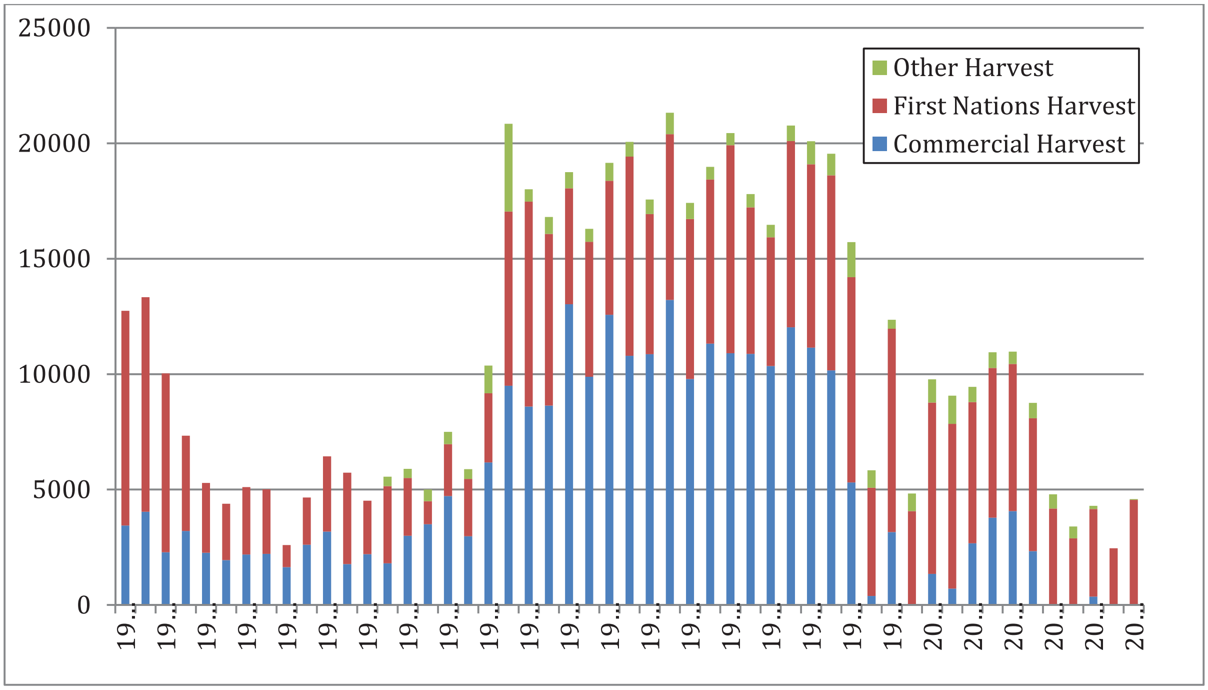

Figure 3-1: Chinook Salmon Harvest in the Canadian Portion of the Yukon River Drainage 1961–2011.

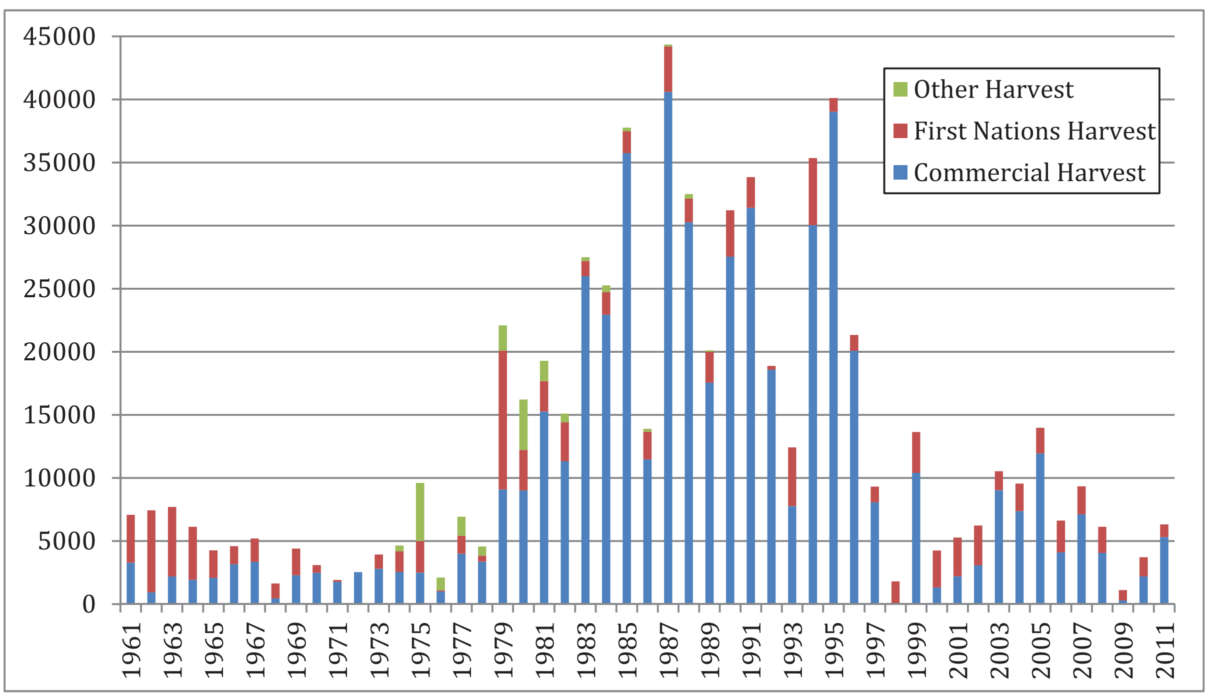

Figure 3-2: Chum Salmon Harvest in the Canadian Portion of the Yukon River Drainage 1961–2011.

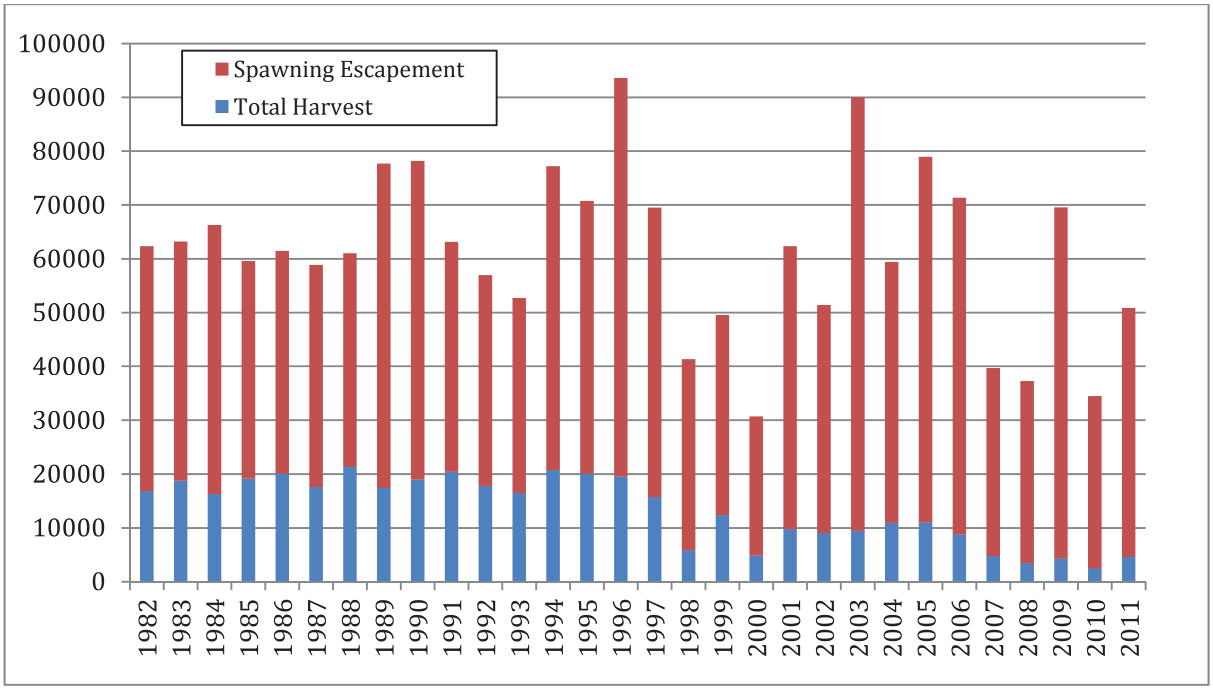

Figure 3-3: Chinook Salmon Total Harvest Versus Estimated Spawning Escapement in the Canadian Portion of the Yukon River 1982–2011.

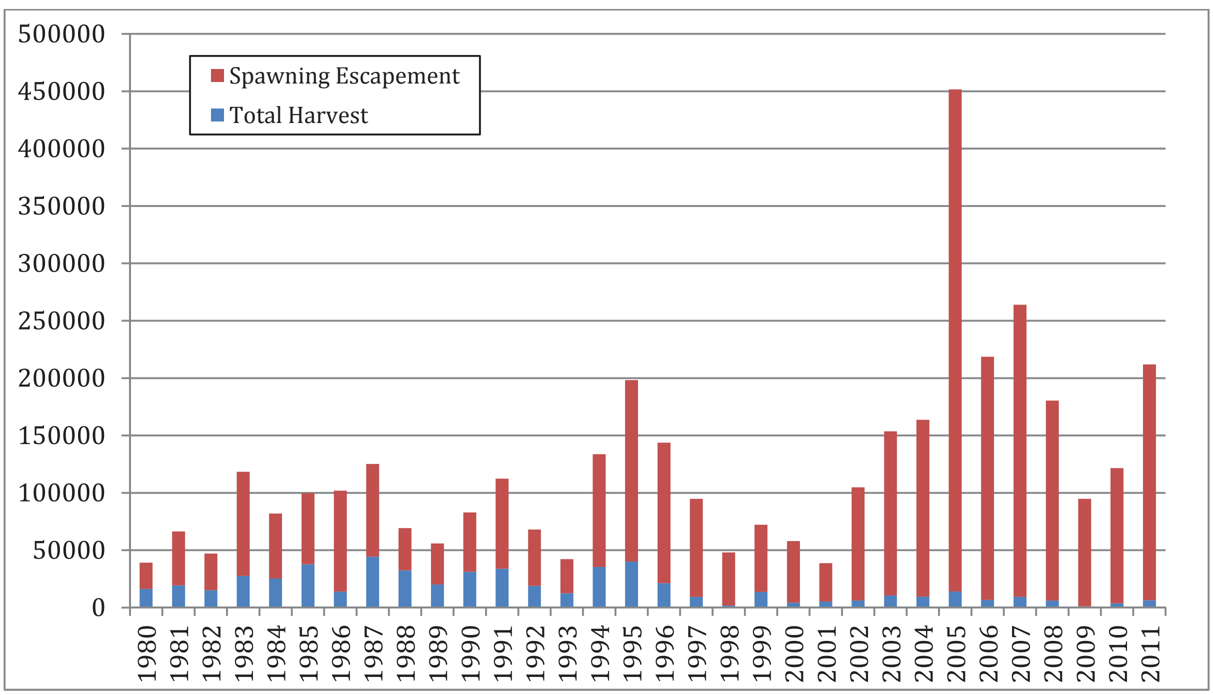

Figure 3-4: Chum salmon Total Harvest Versus Estimated Spawning Escapement in the Canadian Portion of the Yukon River 1980–2011.

Canadian Chinook salmon catch was low through the 1970s, ranging from 5,000 to 10,000, and increased in the 1980s and early 1990s to levels ranging from 16,000 to 22,000. Catches remained relatively stable at these levels until 1998, when numbers dropped significantly, because of closures and/or very limited fishing opportunities, and subsequently fluctuated between 4,000 and 12,500 until 2005. More recently, catches have remained below 5,000 with the discontinuation of most commercial fisheries since 2007.

Catches of chum salmon have traditionally been more variable, but displayed a similar overall trend with increased effort in the early 1980s resulting in a larger recorded catch, and a drastic decrease in numbers beginning in 1997 and remaining low through 2011 (JTC 2012).

The cause of the 1997 to 1998 decrease in productivity is largely unknown, although it has been suggested that the Yukon River salmon run failures were in part caused by anomalous ocean conditions (Kruse 1998). In 2000, the Alaska Board of Fisheries (BOF) classified the Yukon River Chinook salmon stock as a "stock of yield concern", and a management action plan was developed (Howard et al. 2009). As a result, both Canadian and Alaskan Yukon River drainage Chinook salmon escapement goals have generally been met over the 2005 to 2009 period, particularly in 2005 and 2006 when runs were quite high (Bue & Hayes 2009; Howard et al. 2009). However, despite ongoing conservation measures, poor runs were observed from 2007 to 2011, especially for Canadian-origin stocks (Bue & Hayes, 2009; Howard et al. 2009). Summer and fall chum salmon have been exhibiting steady improvements since 2001 and 2003, respectively (Bue & Hayes 2009).

3.3 LOCAL FISH HABITAT INVESTIGATIONS

3.3.1 Methods

The primary fish habitat data collected for the Minto Mine area was acquired by Hallam Knight Piesold (HKP) for the Initial Environmental Evaluation of the Minto Mine in 1994. During these studies, Minto Creek, McGinty Creek, Creek A, and Dark Creek were all assessed (Figure 2-2); however, only information for Minto Creek, McGinty Creek (referred to as Unnamed Creek B in HKP's report), and Creek A are summarized in this report.

Each of the above watercourses was first traversed via helicopter to observe and record obstructions such as beaver dams, log jams or waterfalls, and to determine the biophysical homogeneity of the system so that reaches could be defined. General physical attributes of the individual reaches were later determined during fish assessments, and gradients for individual reaches are assumed to have been calculated from topographic maps. Stream-based habitat assessments and surveys were later also conducted in conjunction with fish presence assessments, in order to identify spawning, rearing and overwintering areas, and barriers to fish migration.

3.3.2 Results

3.3.2.1 Minto Creek

Minto Creek originates at the Minto Mine site and flows northeast roughly 17 km before entering the Yukon River (Figure 2-2). The creek has five major tributaries which were designated as T1 through T5 by HKP (1994). The Minto Creek mainstem was described as having seven primary reaches. HKP's original reach descriptions have been transcribed, and are included in Appendix B with original photographs from the 1994 report. Reach breaks are also shown in Figure 3-5.

In Minto Creek, reach 1 leads upstream from the Yukon River confluence and is approximately 2 km in length with an average gradient of 1.7% and a wetted width of 3.3 m. Three habitat and fisheries sample sites were located in reach 1: site 1 located 30 m upstream from the Yukon River confluence (Appendix B, Plate 1), site 2 located approximately 300 m upstream from the Yukon River confluence (Appendix B, Plate 2) and site 3 located at the upper reach break. Reach 2 was approximately 2 km in length and had an average wetted width of 3 m. Within this reach, a steep canyon with a gradient 21% was noted. Reach 3 was 4 km long, had an average gradient of 1.2%, and an average wetted width of 3 m. This reach drains an area which had been severely burnt at the time, and had an abundance of debris that had accumulated in the creek mainstem. Reach 4 was 2 km long and had an average gradient of 2%. The average wetted width was 3 m. Reach 5 was 4 km in length, had a gradient of 3.5%, and a wetted width of 3 m. Two sample sites were established in reach 5: site 1, located 1.8 km upstream of the reach break, and site 2 located 800 m downstream of site 1. Reach 6 was 2 km long and had a gradient of 3.5% and average wetted width of 1.5 m. Reach 7 contained the headwaters of Minto Creek, and had a length of approximately 1 km, and average gradient of 6.9%, and a wetted width of 1 m.

The surface water in Minto Creek has been noted to have a high sediment and organic load due to the fact that a large proportion of the watershed has been burned by forest fires in the recent past. The entire creek is ephemeral with no flows and abundant glaciation (aufeis) during the coldest winter period and therefore provides no overwintering fish habitat.

Based on an assessment of Minto Creek completed under the former Yukon Fisheries Protection Authorization (1988) the creek was classified as Type II habitat, salmonid rearing stream. From an assessment of topographic maps and site habitat assessment, this Type II habitat is restricted to the lower 1.5 km of creek immediately upstream of the Yukon River and downstream of the canyon. Steep gradients above this point prevent fish from further upstream migration. The possibility of overwintering habitat is questionable, as the creek freezes completely during the winter and no flows are present within the watershed. A survey of Minto Creek conducted by Environment Canada (1977) concluded that the absence of fish in the watershed was likely attributable to the intermittent nature of the creek. During that 1977 study, Minto Creek was classified as a salmonid rearing stream, and all previous fisheries investigations had confirmed that this habitat was found in the lower sections of that watercourse. It was also previously noted that a steep canyon 1.5 km upstream of the confluence with the Yukon River represented a barrier to fish migration. The effects of forest fire (reduced cover and substrate siltation) in the upper reaches of Minto Creek have also reduced the quality of the habitat upstream of the canyon. The ephemeral nature of the creek also prohibits overwintering of fish populations in the lower reaches of the creek (HKP 1994).

3.3.2.2 Creek A

Creek A is a small watercourse that drains an area adjacent to the Minto Mine access road and the Yukon River (Figure 2-2). The headwaters of Creek A originate approximately 4 km southeast of Minto Creek and flow for 7 km along a riparian floodplain into the Yukon River. This watercourse was defined as having two reaches when surveyed by HKP (1994). Reach 1 leads from the Yukon River confluence to roughly 3 km upstream, where another tributary joins from the northeast.

Reach 2 is roughly 4 km long, and flows through riparian floodplain. HKP established two fish habitat sampling sites were established in reach 1: site 1 located approximately 2 km upstream of the Yukon River confluence and site 2 located approximately 1.5 km downstream of site 1 (at the road crossing).

3.3.2.3 McGinty Creek

McGinty Creek (referred to as Unnamed Creek B in HKP's report) headwaters originate north of the Minto Mine and flow north-northeast 9.5 km to the Yukon River confluence. Three reaches were identified when surveyed by HKP (1994). Reach 1 begins at the river confluence and stretches 2 km before the creek forks. The western fork of the creek is considered reach 2 and the eastern fork is considered reach 3. Fisheries sites were established in reaches 1 and 2. The sample site in reach 1 was located at the confluence with the Yukon River and the sample site in reach 2 was located a further 4 km upstream.

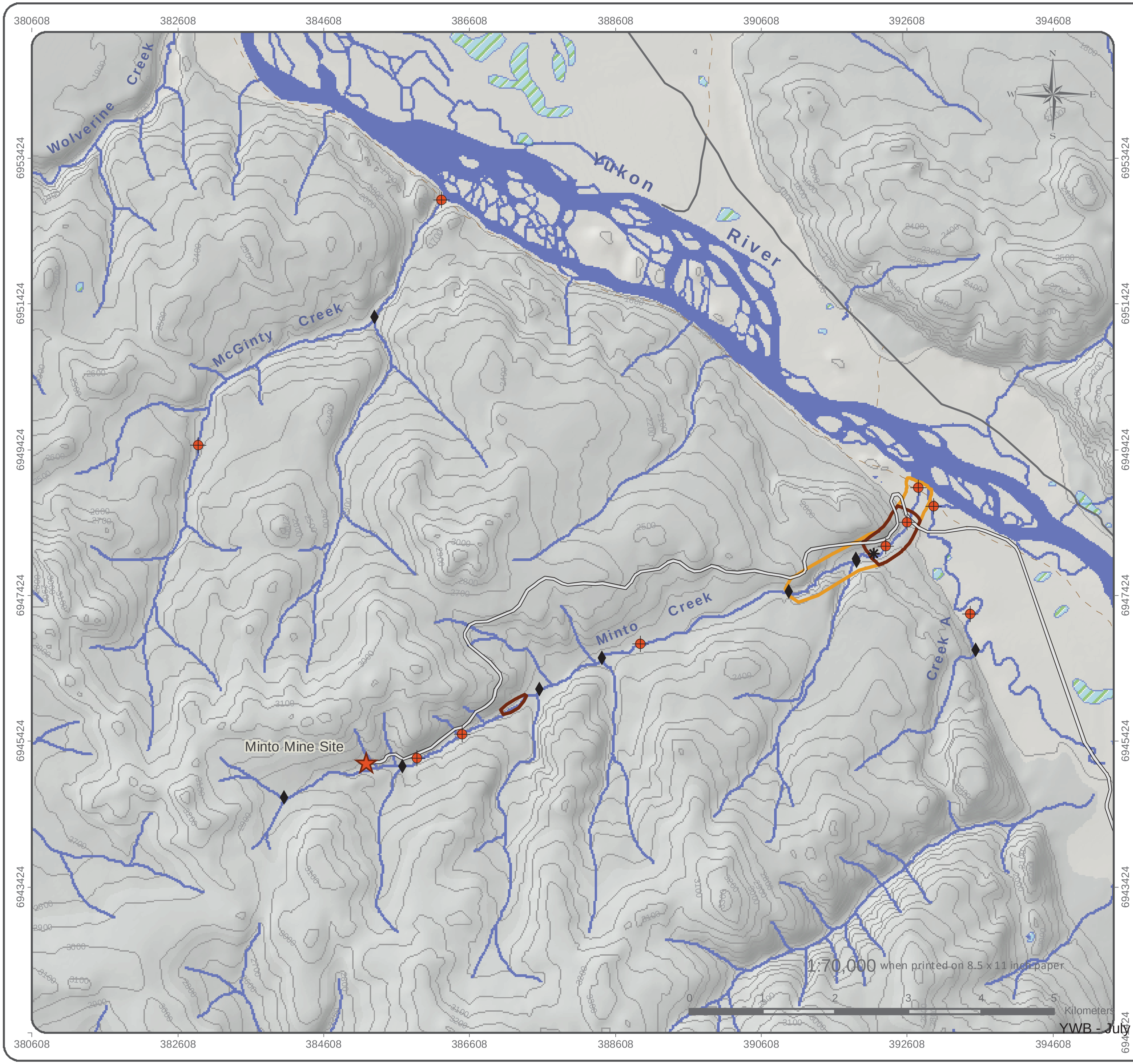

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FIGURE 3-5
FISHERIES SAMPLING LOCATIONS

- Fisheries Sampling Site (HKP 1994)
- Reach Breaks (HKP 1994)
- Obeserved Fish Barrier - Minto Creek
- Fish (2008)
- Fish (2009-2012)
- Minto Access Road
- Limited-use road
- Trail
- Contours (ft)
- Watercourse
- Waterbody
- Wetland

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3.4 LOCAL FISH ASSESSMENTS

A number of fish assessment efforts have been undertaken on watercourses of the Minto Mine area between 1994 and 2012, and are tied to sampling efforts as outlined in Table 3-1.

3.4.1 1994 Baseline Studies

3.4.1.1 Methods

HKP performed basic fisheries investigations in 1994 at a selection of fish habitat sites described in section 3.3.2 above. These investigations took place from June 4 to 7, August 10 to 14, and September 13 to 15, 1994. At those times, a combination of multiple pass electrofishing and minnow trapping was conducted. Electrofishing was accomplished using a Smith Root Model 12 backpack electrofisher, and electrofishing effort was recorded in seconds of current applied and area surveyed. Detailed methodologies are available in HKP (1994).

3.4.1.2 Results and Discussion

Minto Creek

A total of five sites in Minto Creek were assessed for the presence and abundance of fish in 1994, and detailed results outlining the timing, individual efforts, and numbers of fish captured are provided in Table 3-2 (below). No JCS were captured and no observations of spawning salmon were made. During the June 1994 surveys, only two slimy sculpin and one round whitefish were captured, at the most downstream site (reach 1, site 1). In August of 1994, slimy sculpin were again captured at the two most downstream sites (reach 1, sites 1 and 2), and two Arctic grayling were captured at site 3 of reach 1. Two Arctic grayling were again captured at site 3 of reach 1 in September. Of the Arctic grayling captured in Minto Creek during these studies, three were classified as being young of year (0+), while one was an adult. No speculation was made as to whether Minto Creek was their natal stream.

Table 3-2: Summary of Fisheries Effort and Capture Data for Minto Creek 1994.

Month	Stream/ Site	Method	Effort (s or h)	Species	Round Whitefish	Slimy Sculpin	Arctic Grayling	Chinook Salmon
June	Minto Creek, reach 1, site 1	Electrofishing	210 s	Number	1	-	-	-
				#/min	0.29	-	-	-
		Minnow Trap	NR	Number	-	2	-	-
	Minto Creek, reach 1, site 2	Electrofishing	270 s	Number	-	-	-	-
				#/min	-	-	-	-
		Minnow Trap	NR	Number	-	-	-	-
	Minto Creek, reach 5, site 1	Electrofishing	124s	Number	-	-	-	-
				#/min	-	-	-	-
		Minnow Trap	NR	Number	-	-	-	-
August	Minto Creek, reach 1, site 1	Angling	3600 s	Number	-	-	-	-
				#/min	-	-	-	-
		Minnow Trap	NR	Number	-	2	-	-
	Minto Creek, reach 1, site 2	Electrofishing	390 s	Number	-	2	-	-
				#/min	-	0.31	-	-
		Minnow Trap	NR	Number	-	2	-	-
	Minto Creek, reach 1, site 3	Electrofishing	150 s	Number	-	-	2	-
				#/min	-	-	0.21	-
	Minto Creek, reach 5, site 2	Electrofishing	292 s	Number	-	-	-	-
				#/min	-	-	-	-
		Minnow Trap	NR	Number	-	-	-	-
September	Minto Creek, reach 1, site 2	Electrofishing	270 s	Number	-	-	-	-
				#/min	-	-	-	-
		Minnow Trap	NR	Number	-	-	-	-
	Minto Creek, reach 1, site 3	Electrofishing	564 s	Number	-	-	2	-
				#/min	-	-	0.8	-
	Minto Creek, reach 5, site 1	Electrofishing	312 s	Number	-	-	-	-
				#/min	-	-	-	-
		Minnow Trap	NR	Number	-	-	-	-

At the time of the 1994 investigation, the Minto Creek valley below the canyon had not been burned by forest fire, so the creek cover (and consequent water temperatures/food source) and clean substrate in the area below the canyon provided good habitat for Arctic grayling. This area was part of a 1995 burn that impacted the majority of the watershed, resulting in a degradation of creek habitat primarily in the lower section, including reduced vegetative cover, a significant increase in large organic debris (LOD) loading and increased siltation of downstream reaches. Another forest fire in 2011 had similar effects.

Creek A

Two sites in Creek A were sampled during the 1994 studies; site 1 of reach 1 in June, and site 2 of reach 1 in August and September. No fish were captured. Details regarding the efforts employed are summarized in Table 3-3, below.

Table 3-3: Summary of Fish Assessment Efforts and Data for Creek A, 1994.

Month	Stream/ Site	Method	Effort (s or h)	Species	Round Whitefish	Slimy Sculpin	Arctic Grayling	Chinook Salmon
June	Creek A, site 2	Electrofishing	71 s	Number	-	-	-	-
				#/min	-	-	-	-
August	Creek A, site 2	Electrofishing	80 s	Number	-	-	-	-
				#/min	-	-	-	-
September	Creek A, site 2	Electrofishing	342 s	Number	-	-	-	-
				#/min	-	-	-	-

McGinty Creek

A waterfall was noted approximately 500 m upstream of the Yukon River confluence on McGinty Creek, and several log jams were also observed, the lowest one positioned approximately 100 m upstream of the river confluence. Fish were not observed in reach 2 throughout the survey. Below this barrier, the creek provides good rearing habitat for Arctic grayling. During the August survey, 16 juvenile Arctic grayling (age 0+ to 1 year) were caught using electroshocking and minnow traps. The average length of the fish was 65 mm. Three slimy sculpin were also caught. The lower reaches of McGinty Creek appeared to provide good habitat for Arctic grayling. Details regarding the efforts employed are summarized in Table 3-4, below.

Table 3-4: Summary of Fish Assessment Efforts for McGinty Creek, 1994.

Month	Stream/ Site	Method	Effort (s or h)	Species	Round Whitefish	Slimy Sculpin	Arctic Grayling	Chinook Salmon
June	McGinty Creek, site 1	Electrofishing	71 s	Number	-	-	1	-
				#/min	-	-	0.23	-
		Minnow Trap	NR	Number		1		
	McGinty Creek, site 2	Electrofishing	123 s	Number	-	-	-	-
				#/min	-	-	-	-
August	McGinty Creek, site 1	Electrofishing	80 s	Number	-	3	8	-
				#/min	-	0.69	1.85	-
		Minnow Trap	NR	Number	-	-	16	-
September	McGinty Creek, site 2	Electrofishing	342 s	Number	-	-	-	-
				#/min	-	-	-	-

3.4.2 2006–2007 Fisheries Investigations

3.4.2.1 Methods

During late 2006 and the summer of 2007, R&D Environmental performed fisheries investigations in Minto Creek as part of the permitting process for Minto Mine. These studies entailed electrofishing and minnow trapping, and efforts were all focused in reach 1 of the creek through June and August 2007, and September of both years.

3.4.2.2 Results and Discussion

During the 2006/2007 studies of Minto Creek, JCS, Arctic grayling, and slimy sculpin were captured. Overall details regarding specific effort levels are provided in Table 3-5, below.

During spring assessments in May and June 2007, 36 JCS and six slimy sculpin were captured by minnow trapping. The majority of Chinook captured were at a site roughly 1 km upstream of the Yukon River confluence.

In August 2007, the only fish species captured were young of year (YOY) Chinook salmon at the mouth of Minto Creek in the upper reach of the flood zone (backwater) of the Yukon River, a single Arctic grayling, and slimy sculpin in the same location and further upstream near the road crossing and culvert. Sculpin were only captured in the June and August 2007 sampling events. Another 29 Chinook salmon were captured by minnow trapping in September of 2007.

Changes in stream features and the expected changes in fish usage were confirmed by fisheries investigations in 2006 and 2007. Catches and catch per unit effort (CPUE) have been low in all fish studies conducted on Minto Creek between 1994 and 2007 (Tables 3-2 and 3-5). Significant effort in both trapping and electrofishing has returned very few results, most notably in the surveys of 2006 and 2007.

In addition, there is little consistency in the presence of species in the lower reaches of Minto Creek, suggesting the lack of a resident fish population. Minto Creek does not provide preferred spawning habitat for fish and the fact that it completely freezes during winter months, with no winter flow in lower Minto Creek, negates its suitability for spawning by Chinook salmon. Tellingly, there is no evidence of spawning in Minto Creek (HKP 1994; R&D 2006, 2007), nor is there traditional knowledge indicating spawning occurring in the system (HKP 1994). Lower Minto Creek is also subject to low or zero flow conditions during periods in the summer when a portion (or all) of the flow sometimes infiltrates the ground, following passage through a canyon located approximately 2.0 km upstream of the Yukon River, preventing the establishment of resident fish populations in this section of the stream. The morphological changes related to forest fire activity in the Minto Creek basin have likely also contributed to fish population changes since the initial surveys of 1994.

Table 3-5: Summary of Fish Assessment Efforts for Minto Creek 2006–2007.

Year, Study	Month	Stream/ Site	Method	Effort (s or h)	Species	Round Whitefish	Slimy Sculpin	Arctic Grayling	Chinook Salmon
2006 (R&D Environmental)	September	Minto Creek	Gee Trap	24 h	Number	-	-	-	-
					#/trap/h	-	-	-	-
2007 (R&D Environmental)	May	Yukon River backwater at mouth of Minto Creek	Electrofishing	191 s	Number	-	-	-	8
					#/min	-	-	-	2.51
			Gee Trap (x6)	5.5 h	Number	-	-	-	4
					#/trap/h	-	-	-	0.12
		Minto Creek, d/s Haul Road	Electrofishing	460 s	Number	-	-	-	-
					#/min	-	-	-	-
			Gee Trap (x8)	15 h	Number	-	-	-	-
					#/trap/h	-	-	-	-
		Minto Creek, ~100m u/s Haul Road	Gee Trap (x8)	15 h	Number	-	-	-	-
					#/trap/h	-	-	-	-
		Minto Creek, @ base of canyon	Gee Trap (x5)	15 h	Number	-	-	-	-
					#/trap/h	-	-	-	-
	June	Minto Creek, ~100m u/s Yukon River	Gee Trap (x5)	18 h	Number	-	1	-	24
					#/trap/h	-	0.01	-	0.27
		Minto Creek, d/s Haul Road	Electrofishing	212 s	Number	-	-	-	-
					#/min	-	-	-	-
			Gee Trap (x8)	22 h	Number	-	4	-	-
					#/trap/h	-	0.02	-	-
		Minto Creek, ~100m u/s Haul Road	Gee Trap (x2)	22 h	Number	-	1	-	-
					#/trap/h	-	0.02	-	-
		Minto Creek, @ base of canyon	Gee Trap (x5)	20 h	Number	-	-	-	-
					#/trap/h	-	-	-	-
	August	Minto Creek, ~100m u/s Yukon River	Gee Trap (x5)	22 h	Number	-	-	1	3
					#/trap/h	-	-	0.01	0.01
		Minto Creek, d/s Haul Road	Gee Trap (x5)	27 h	Number	-	-	-	3
					#/trap/h	-	-	-	0.02
		Minto Creek, ~100m u/s Haul Road	Gee Trap (x5)	27 h	Number	-	2	-	32
					#/trap/h	-	0.01	-	0.24
		Minto Creek, @	Gee Trap (x0)	0	Number	-	-	-	-
					#/trap/h	-	-	-	-

Year, Study	Month	Stream/ Site	Method	Effort (s or h)	Species	Round Whitefish	Slimy Sculpin	Arctic Grayling	Chinook Salmon
		base of canyon							
	September	Minto Creek, ~100m u/s Yukon River	Gee Trap (x1)	23 h	Number	-	-	-	5
					#/trap/h	-	-	-	0.22
		Minto Creek, d/s Haul Road	Gee Trap (x4)	23 h	Number	-	-	-	-
					#/trap/h	-	-	-	-
		Minto Creek, ~100m u/s Haul Road	Gee Trap (x5)	23 h	Number	-	-	-	24
					#/trap/h	-	-	-	0.21
		Minto Creek, @ base of canyon	Gee Trap (x0)	0	Number	-	-	-	-
					#/trap/h	-	-	-	-

3.4.3 MMER Environmental Effects Monitoring Cycle 1 - 2008 Fish Sample Collection

3.4.3.1 Methods

In accordance with the approved study design of the Cycle 1 EEM (environmental effects monitoring) program, a fish population survey was undertaken in lower Minto Creek in June and September of 2008. During that study, fish communities of Minto Creek were sampled by backpack electrofishing and minnow trapping from June 26 to 27, 2008, and from September 9 to 11, 2008. Electrofishing was conducted as a combination of both closed station (quantitative) and open station, and minnow trapping was conducted using standard Gee traps baited with salmon roe. Detailed information regarding sampling methods is available in the EEM Interpretive Report (Minnow/ACG 2009).

3.4.3.2 Results and Discussion

No fish were captured during the June sampling event, despite electrofishing effort of 393 seconds of applied current and coverage of approximately 289 m^2 of lower Minto Creek. Ten trap-days of minnow trapping effort were also applied (Table 3-6). JCS were the only fish captured in September 2008 and were found in low abundance. Backpack electrofishing yielded one fish (observed and shocked but not captured) in 403 seconds of applied current and coverage of approximately 340 m^2. Minnow trapping in September yielded a total of 17 JCS in a total effort of 18.6 minnow trap-days. It should be noted that the spatial coverage of fishing in June and September represents approximately 40% of the area of lower Minto Creek downstream of an observed fish barrier that is believed to prohibit fish passage to upper Minto Creek.

Table 3-6: Summary of fish Assessment Effort and Data from the 2008 EEM Cycle 1 Program.

Period	Method	Effort[1]	Summary Statistics	Units	Juvenile Chinook Salmon
June	Backpack electrofishing	393 s 289 m^2	Catch	#	0
			CPUE[2]	Fish/min	0.00
			CPUA[3]	Fish/100m^2	0.00
	Baited Gee minnow trapping	10 days	Catch	#	0
			CPUE[2]	Fish/day	0.00
September	Backpack electrofishing	403 s 340 m^2	Catch[4]	#	1
			CPUE[2]	Fish/min	0.15
			CPUA[3]	Fish/100m^2	0.74
	Baited Gee minnow trapping	18.6 days	Catch	#	17
			CPUE[2]	Fish/day	0.91

Note: [1] *Effort refers to number of seconds electrofishing current was applied to the water.*
[2] *Catch per unit effort represented in specified units.*
[3] *Catch per unit area represented in specified units.*
[4] *In the September electrofishing, one fish was observed and electroshocked but not captured.*

Both the absence of Chinook salmon in June and their presence in low abundance later in the summer are supported by the scientific knowledge of Chinook salmon life history and the documented physical characteristics of Minto Creek. Briefly, Chinook salmon spawn in the fall, preferentially in larger streams, but also in river main stems and small streams (Eiler et al. 2004 and 2006; McPhail 2007). They typically prefer faster water and coarser spawning substrate than other salmon, and require well oxygenated sub-gravel water flow (McPhail 2007). Minto Creek does not provide preferred spawning habitat and becomes completely glaciated (covered with layered ice (aufeis)) in the winter and therefore provides no suitable over-wintering habitat for eggs, fry, or juveniles. Accordingly, there is no evidence of spawning into Minto Creek (HKP 1994, R&D 2006 and 2007), nor is there traditional knowledge of spawning in Minto Creek (HKP 1994). Thus, use of Minto Creek by Chinook salmon appears to be limited to transient use by out-migrating young of year whose natal streams are tributaries of the Yukon River upstream of Minto Creek. Juvenile Chinook of the Yukon River drainage typically emerge in spring and early summer (e.g., mid-May) and enter non-natal tributaries (such as Minto Creek) in late June following temperature equilibration of the river and tributaries (Bradford et al. 2001). This is supported by the findings of this study. Use of non-natal streams may be saltatory, with fish stopping in suitable feeding areas as they move downstream (Bradford et al. 2001). There is little information in the scientific literature on the duration of saltatory use of creeks although it appears that this use can range from days (e.g., Scrivener et al. 1994) to complete over-wintering (Bradford et al. 2001). Because over-wintering appears not to occur in Minto Creek, use of the creek by out-migrating JCS is likely of short duration and is often restricted by the drying of lower Minto Creek in summer months.

Based on this information, the EEM program interpretation concluded that out-migrating JCS are not exposed to mine effluent for significant periods of time, nor are they distinct from out-migrating Chinook salmon temporarily populating other regional creeks draining into the Yukon River.

JCS captured in lower Minto Creek in September 2008 were of similar size (mean fork length of 76 mm). This is consistent with the expectation that all of the juvenile Chinook were of the same out-migrating cohort (of 2008 hatches, spawned in 2007). Due to the timing of the catches and the size of the fish, the captured juvenile Chinook were all likely young of year (YOY; i.e., 0+ fish). Specifically, although YOY can over-winter in the Yukon River and some tributaries, all 1+ fish are out of the upper areas by June (e.g., Duncan & Bradford 2004). As previously indicated, the water of Minto Creek is much colder in June than that of the Yukon River, so use of Minto Creek by 1+ fish would not be expected at that time of year. This was generally confirmed by the fact that no fish were captured in June 2008.

In summary, the fish survey implemented in 2008 under the EEM indicated and confirmed that Minto Creek is not used by fish in June and was used by very small numbers of JCS in September. The JCS captured in Minto Creek in August were out-migrating 0+ fish, that use Minto Creek and other creeks flowing into the Yukon River transiently, so exposure to Minto Creek likely occurs only for very short periods.

3.4.4 2009 Fish Sample Collection and Fish Relocation Program

3.4.4.1 Methods

During work by ACG at the Minto Mine site during the summer of 2009, efforts to again determine the use of Minto Creek by fish were undertaken. On June 25 and 26 of that year, a total of 6 minnow traps were deployed in Minto Creek for 24 hours (3 upstream and 3 downstream of the culvert at the road crossing). In July of 2009, an additional trapping session of 10 trap days was undertaken during an emergency release of water from the Minto Mine. All non-consumptive trapping was carried out using ¼" mesh Gee minnow traps. Traps were baited with Yukon River-origin Chinook salmon roe and soaked for a nominal 24 hour period at each location. All captured specimens were identified, measured, enumerated, and released in the immediate area of their capture.

Under the assumption that increased flow in Minto Creek resulting from the emergency water discharge during the summer/fall of 2009 was attracting JCS into that watercourse and the fact that the discharge was to occur until late October, Fisheries and Oceans Canada (DFO) identified the potential that many of the fish could get stranded once the discharge ended and the creek froze. Therefore, DFO recommended that Minto conduct a program to capture and relocate fish from lower Minto Creek to another open system. Minto, working with their consultants, executed this program from September 29 to October 14, 2009. The program also involved establishing a temporary fish barrier on Minto Creek near the Yukon River in order to prevent additional recruitment of fish into the system.

3.4.4.2 Results and Discussion

During June sampling in 2009, no fish were captured in Minto Creek (Table 3-7). In contrast, 142 fish were captured during the sampling event in late July, with only a 60% increase in sampling effort (Table 3-7). No other sampling event to date had yielded such a high CPUE. In fact, the CPUE for this event was at least an order of magnitude higher than any previous sampling event.

As noted, this July sampling occurred while Minto was conducting an emergency release of water from the mine site, which resulted in stable, high flow conditions in lower Minto Creek. It is believed that this stable, elevated flow and warmer, more consistent temperature regime (i.e., narrow diurnal temperature fluctuation) may have attracted JCS into the system from the Yukon River.

Table 3-7: Summary of Effort and Data from June and July 2009 Fish Assessment in Minto Creek.

Period	Method	Effort	Summary Statistics	Units	Juvenile Chinook Salmon	Slimy Sculpin
June	Baited Gee Minnow Trapping	6 Days	CPUE	#	0	0
				Fish/day	0	0
July	Baited Gee Minnow Trapping	10 Days	CPUE	#	136	6
				Fish/day	13.6	0.6

During the relocation program a total of 986 JCS were captured and released into the Yukon River and/or Big Creek. This included 822 Chinook salmon in 114 traps set from September 30 to October 2, 2009, and 165 Chinook salmon in 66 traps set from October 12 to 14, 2009. In addition to the salmon only one sculpin and one juvenile burbot were caught. A natural upstream fish barrier was identified during the program and confirmed by zero fish captured in traps set upstream. Fish capture and relocation continued until CPUE dropped well below 10% of the CPUE established during the first day of capture. A detailed summary of the fish relocation program is attached to this report as Appendix C.

3.4.5 2010 Minto Creek Mark-Recapture Study

In order to better understand the dynamics of the JCS population using Minto Creek, a mark-recapture study was undertaken in the summer and fall of 2010. The study was developed to determine how use of the system by JCS changes throughout the open-water season and to determine how long individual fish may stay in the creek system (i.e. residency time).

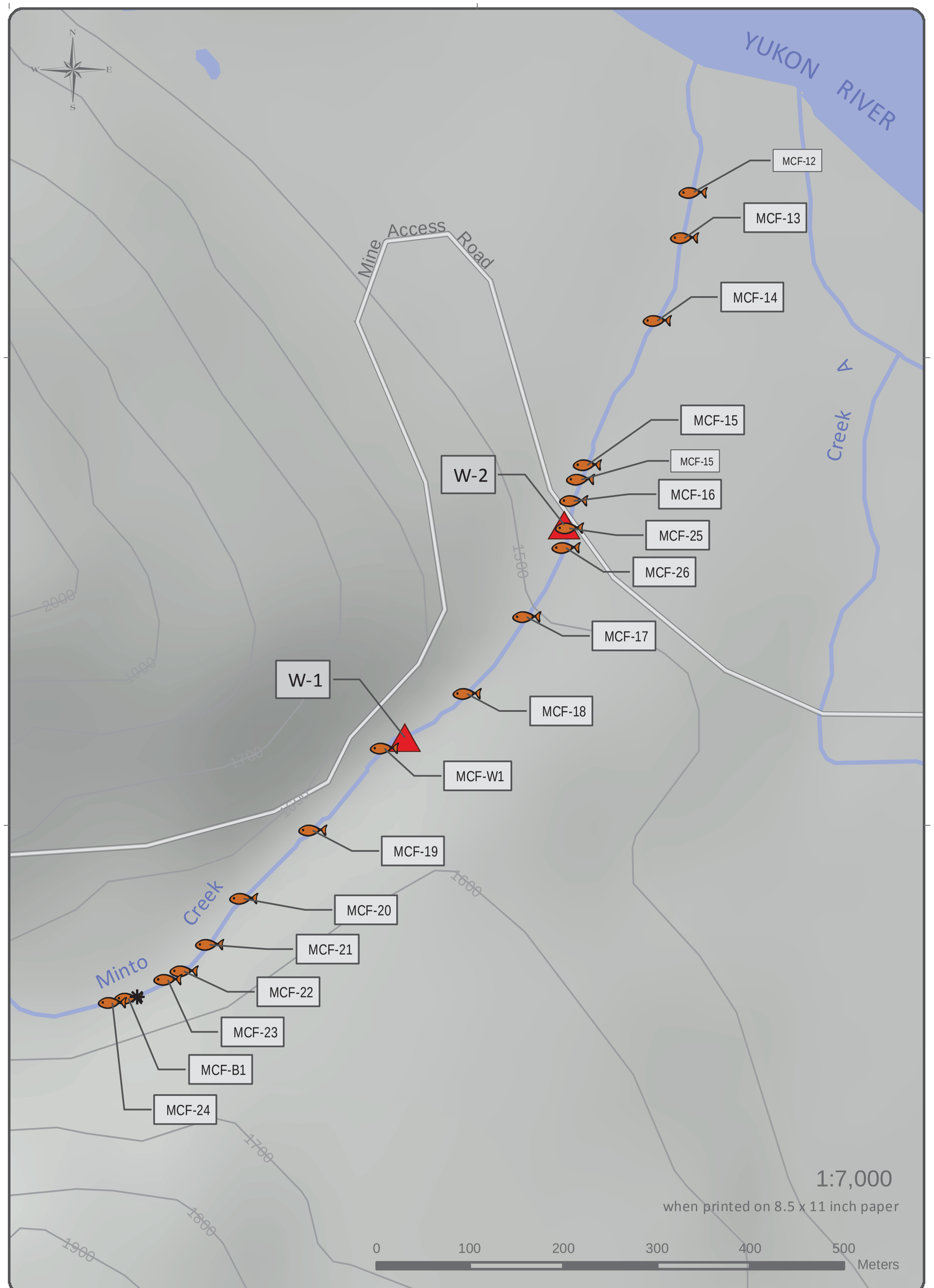
3.4.5.1 Methods

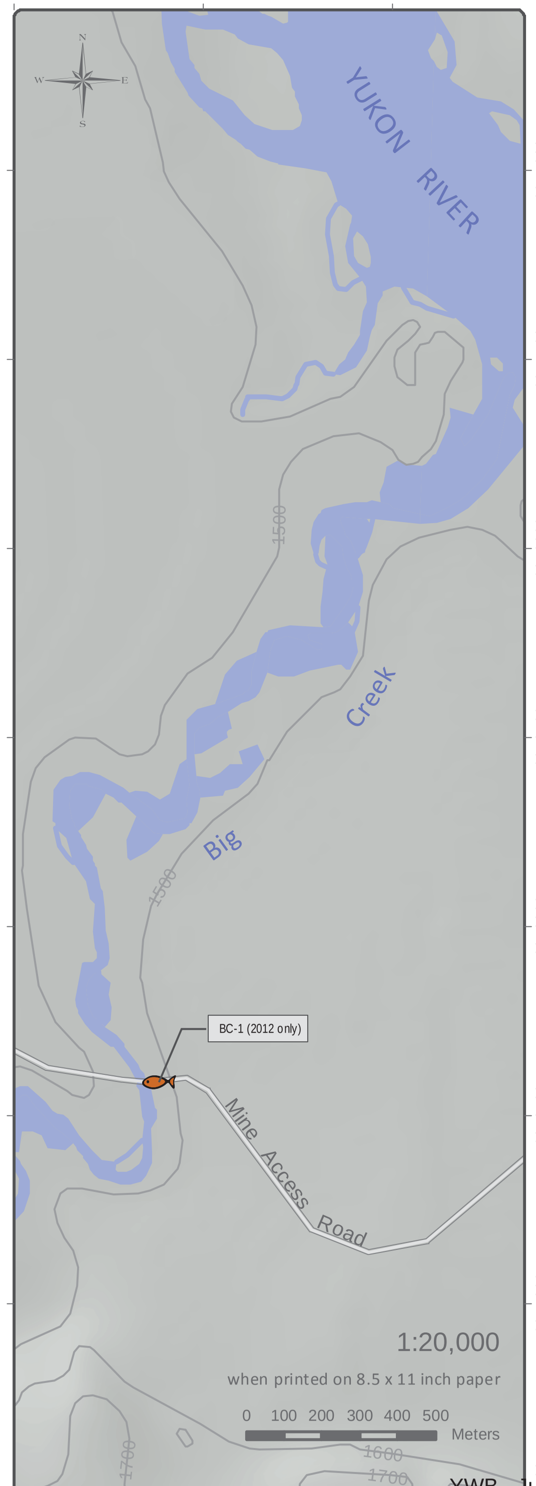
The study was conducted between June 28 and November 3, 2010, period during which the mine was discharging water into Minto Creek. During this time frame, the study involved 9 trapping events. Of these, the first six events involved marking of fish at approximately two week intervals. No further marking was done after the September 9 marking, however three further trapping events were conducted in order to re-capture marked fish. During each trapping event, minnow traps baited with Yukon River salmon roe were placed in 16 suitable trapping locations in lower Minto Creek, from immediately upstream of the natural fish barrier (MCF-24), to about 400m downstream of the culvert at km 11 of the Minto Mine Road (MCF-13), and left overnight (soak time ranging from 18 to 26 hours). The same sites (Figure 3-6) were used throughout the duration of the project.

3.4.5.2 Results and Discussion

No juvenile Chinook salmon (JCS) or other species were encountered in Minto Creek during a late June sampling event. This is consistent with previous studies in that few fish if any have been encountered in the creek prior to July. During this study fish were still present in the system in early November.

Numbers of Chinook salmon increased on subsequent events from July 14 until August 11 when the peak number were captured. The estimated population of JCS in the creek at this time (based on the 2009 CPUE ratio) was 1,500 after which the numbers declined. Figure 3-7 below shows the number of JCS caught at each sampling event, as well as the estimated population size. The number of fish captured in 2009 and 2010 were much higher on a CPUE basis than in years previous to 2009. As in 2009, Minto Mine was influencing the flow regime in Minto Creek through a controlled water discharge from the mine site throughout much of the summer until early November 2010. This likely influenced an increased use of the system by JCS.





MINTO MINE

AQUATIC RESOURCES BASELINE REPORT

FIGURE 3-6 MINTO CREEK AND BIG CREEK FISHERIES MONITORING STATIONS

- Observed Fish Barrier
- Fish Monitoring Station
- Water Quality Monitoring Station
- Mine Access Road
- Contours (ft)
- Watercourse
- Waterbody

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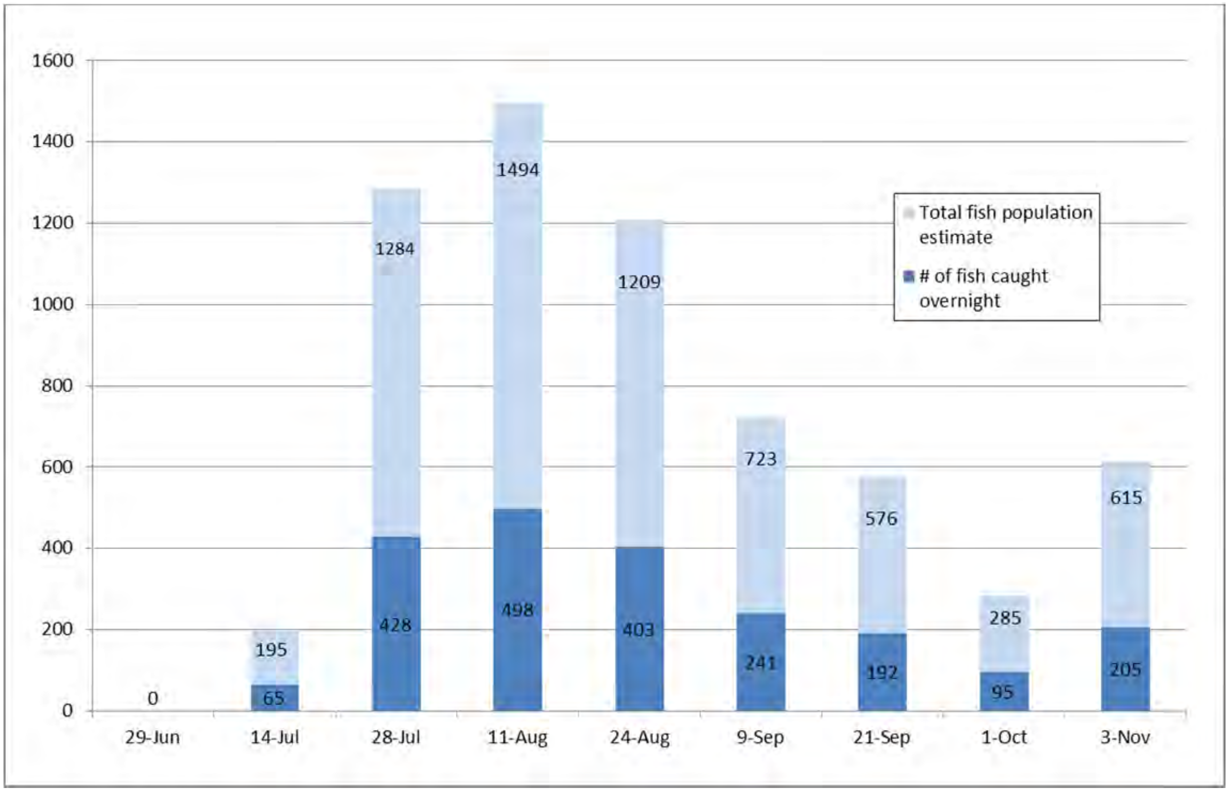


Figure 3-7: Number of Juvenile Chinook Salmon Captured during the 2010 Mark/Recapture Study (Catch Based on Consistent Catch Per Unit Effort) and Estimated Population Size.

Analysis of marked fish recaptured indicates that much of the population does not remain in the creek for an extended period of time and that there is a high degree of immigration and emigration of the population in the creek. The data suggests that 90% of the population may only spend up to approximately two weeks in the system. Only a few individuals (1%) spent an extended period of time (> 12 weeks) in the system.

JCS growth leveled off towards the end of August, likely a reflection of cooling water temperatures. Overall however, the growth of individuals in the system is consistent with JCS populations in other tributaries of the Yukon River. Note that the November event is not included in the above graph as it consisted mostly in the relocation of JCS from Minto Creek to Yukon River, in anticipation of stopping water discharge in Minto Creek.

A more comprehensive report on this study is available in Appendix D.

3.4.6 MMER Environmental Effects Monitoring Cycle 2

The Minto Mine is required to undertake EEM (environmental effects monitoring) under the federal Metal Mining Effluent Regulations (MMER). The Cycle 2 EEM conducted at the Minto Mine over the 2009–2011 period and consisted of an integrated assessment of effluent sub-lethal toxicity, water quality, benthic invertebrate community condition, and fish health. The sections below present methods and results of the fish health component.

3.4.6.1 Methods

Based on previously documented low Chinook salmon captures in Minto Creek, a hatchery-based study was undertaken at the McIntyre Creek Hatchery in Whitehorse from July 7 to August 18, 2011, and was supported by concurrent field-based fish collection and processing. On July 5, a total of approximately 420 fry from the McIntyre Creek fish hatchery were randomly selected from a larger group of approximately 7,000 fry for inclusion in the hatchery exposure. The tank for the control fish was supplied with water provided by the artesian spring at the facility site, the same water that was used to complete incubation of this group of fish and initiate rearing. The tank for the exposure group was supplied with water hauled to the McIntyre Creek facility from the Minto Mine site on a weekly basis. Water from the WSP was diluted with water from lower Minto Creek to achieve an effluent concentration in the exposure tank which was equivalent to that typically observed in lower Minto Creek. Fish in the two tanks were fed the same amount at the same frequency and water flow; dissolved oxygen, temperature and pH were monitored in the control and exposed tanks.

On July 7 (pre-exposure date or day 0), approximately 420 fish were measured (length and weight), assessed for abnormalities and then randomly and equally distributed between the two tanks (i.e., exposure and control). On two occasions during the exposure (day 14 and day 28) a sub-sample of about 100 fry were randomly captured in their respective tanks, removed, measured, and examined for abnormalities. On the last day of the trial (day 42), all fish were removed from each tank, examined, and measured. Fish were checked daily for mortalities and any visible signs of impaired health (e.g., abnormal behaviour, fungal growth on body). Mortalities were removed, measured, and assessed for abnormalities. Chinook salmon fry collected from each tank were held in aerated buckets, measured, and examined at the hatchery. Following measurements, all live fish were placed in recovery buckets containing aerated McIntyre Creek water. On August 21, all fish were released into Fox Creek, a tributary of the Yukon River.

3.4.6.2 Results and Discussion

Summary statistics of length, weight, mortalities, and abnormalities were calculated for the effluent-exposed and control fish for each sampling period. Very few differences in fish health endpoints were indicated between the exposure and control groups at days 14 and 28 of the experiment. Following 42 days of hatchery exposure (i.e., experiment conclusion on August 18, 2011), Chinook salmon mortality rates were comparable between the effluent-exposed and control groups. In addition, abnormality rates between groups were similar, with a variety of abnormality types noted but no noticeable pattern appearing among either the effluent-exposed or control fish. Although effluent-exposed fish were significantly heavier and had significantly greater body condition compared to the control fish, the magnitude of difference between groups was small (<10%). (Minnow/Access, 2012)

"Overall, the results suggested that exposure to mine-influenced water may result in a very slight increase in fish size and body condition, but that a minimum of five to six weeks of constant effluent exposure would be required to elicit this response. Although this result was consistent with enrichment response observed in the benthic invertebrate community survey, the mechanism for increased fish growth in the hatchery experiment was unclear (i.e., no clear mechanism was evident explaining how slightly higher water nutrient concentrations could result in increased fish growth in the hatchery-based exposure)." (Minnow/Access, 2012)

3.4.7 2011–2012 Fisheries Monitoring Program in Minto Creek

3.4.7.1 Methods

Minnow trapping was conducted monthly at the same trapping sites as for the 2010 mark-recapture study (Figure 3-6), from July to October 2011, and from June to September 2012. Between 12 and 22 traps (depending on creek conditions) were set at each sampling event and left to soak overnight. Fish were then counted, measured, and weighed whenever possible. Fish were subsequently released at the site where they were caught. In addition to Minnow trapping, electrofishing was employed in June 2012.

Big Creek was also sampled for fish in 2012, and used as a reference site. Five or six minnow traps were set in the vicinity of the bridge at each sampling event, and electrofishing was employed in July 2012.

3.4.7.2 Results and Discussion

Three species of fish were caught in the Minnow traps throughout the course of the study, namely JCS salmon, slimy sculpin, and longnose suckers, all in relatively low numbers. Table 3–8 summarizes the results for Minto Creek. Note that fish length refers to fork length for Chinook salmon, and to total length for other species.

Fisheries assessments conducted in Minto Creek have relied on the use of electrofishing and gee-trapping technique to determine presence/absence. The creek however has a lot deadfall (as a result of recent forest fire activity) that has fallen across and into the system in the lower fish-bearing reach. This has limited the use of an electrofisher for reasons of both access and safety. Electrofishing effort has been applied to the creek during several of the studies but this first required that sections of the creek be cleared of fallen trees and debris. It was not practical or environmentally desirable to clear large sections of the creek to allow for the application of electrofishing. Additionally, electrofishing is much more intrusive than gee-trapping, requiring two persons walking in the creek (it has steep banks) and applying an electro-shock to the fish present. The species of fish most prevalent in the system however are Chinook salmon and slimy sculpin which are readily captured in Gee-traps. Arctic grayling have also been encountered in the creek on occasion but not in the numbers observed for salmon or sculpin.

Consideration was given to whether or not low Arctic grayling numbers are attributable to sampling methodology as they may not be as readily captured in Gee-traps as are salmon juveniles or sculpin. Electrofishing was used for fish sampling in the system during studies in 1994, 2007, 2008, and 2012. During these electrofishing sampling events Arctic grayling were only encountered during 1994 and 2012 and in very low numbers. No Arctic grayling were encountered during other electrofishing sampling events but were captured on occasion via gee-traps. Arctic grayling can readily access Minto Creek from the Yukon River and therefore likely migrate in and out of the system on occasion throughout the open water season. However, their use of the system appears to be more transitory and they do not use it for rearing and/or reproduction, as indicated by observations and numbers captured over the sampling years.

Table 3-8: Summary of Effort and Data from 2011 and 2012 Fish Assessment in Minto Creek.

Year	Period	Method	Effort	Units	Juvenile Chinook Salmon			Slimy Sculpin			Longnose Suckers		Arctic Grayling	
					#	Avg Length (mm)	Avg Weight (g)	#	Avg Length (mm)	Avg Weight (g)	#	Avg Length (mm)	#	Avg Length (mm)
2011	July	Baited Gee Minnow Trapping	22 Days	#	1	56	n/r	2	96.5	n/r	0	n/a	0	n/a
				Fish/day	0.05			0.09			0		0	
	August	Baited Gee Minnow Trapping	19 Days	#	3	66.3	n/r	0	n/a	n/a	9	108.4	0	n/a
				Fish/day	0.16			0			0.47		0	
	Sept	Baited Gee Minnow Trapping	14 Days	#	6	74.3	4.410	4	81.3	n/r	1	105.0	0	n/a
				Fish/day	0.43			0.29			0.07		0	
	Oct	Baited Gee Minnow Trapping	16 Days	#	2	86.5	5.540	1	97.0	n/r	0	n/a	0	n/a
				Fish/day	0.13			0.06			0		0	
2012	June	Baited Gee Minnow Trapping	15 Days	#	0	n/a	n/a	4	74.3	4.9	0	n/a	0	n/a
				Fish/day	0			0.27			0		0	
		Electrofishing	1051 s	#	0	n/a	n/a	3	103.7	9.9	0	n/a	1	215
				Fish/min	0			0.17			0		0.06	
	July	Baited Gee Minnow Trapping	16 Days	#	0	n/a	n/a	1	79	n/r	0	n/a	0	n/a
				Fish/day	0			0.06			0		0	
	August	Baited Gee Minnow Trapping	12 Days	#	0	n/a	n/a	0	n/a	n/a	0	n/a	0	n/a
				Fish/day	0			0			0		0	
	Sept	Baited Gee Minnow Trapping	16 Days	#	3	7.4	4.4	1	7.8	n/r	0	n/a	0	n/a
				Fish/day	0.19			0.06			0		0	

Notes: n/r = not recorded n/a = not applicable

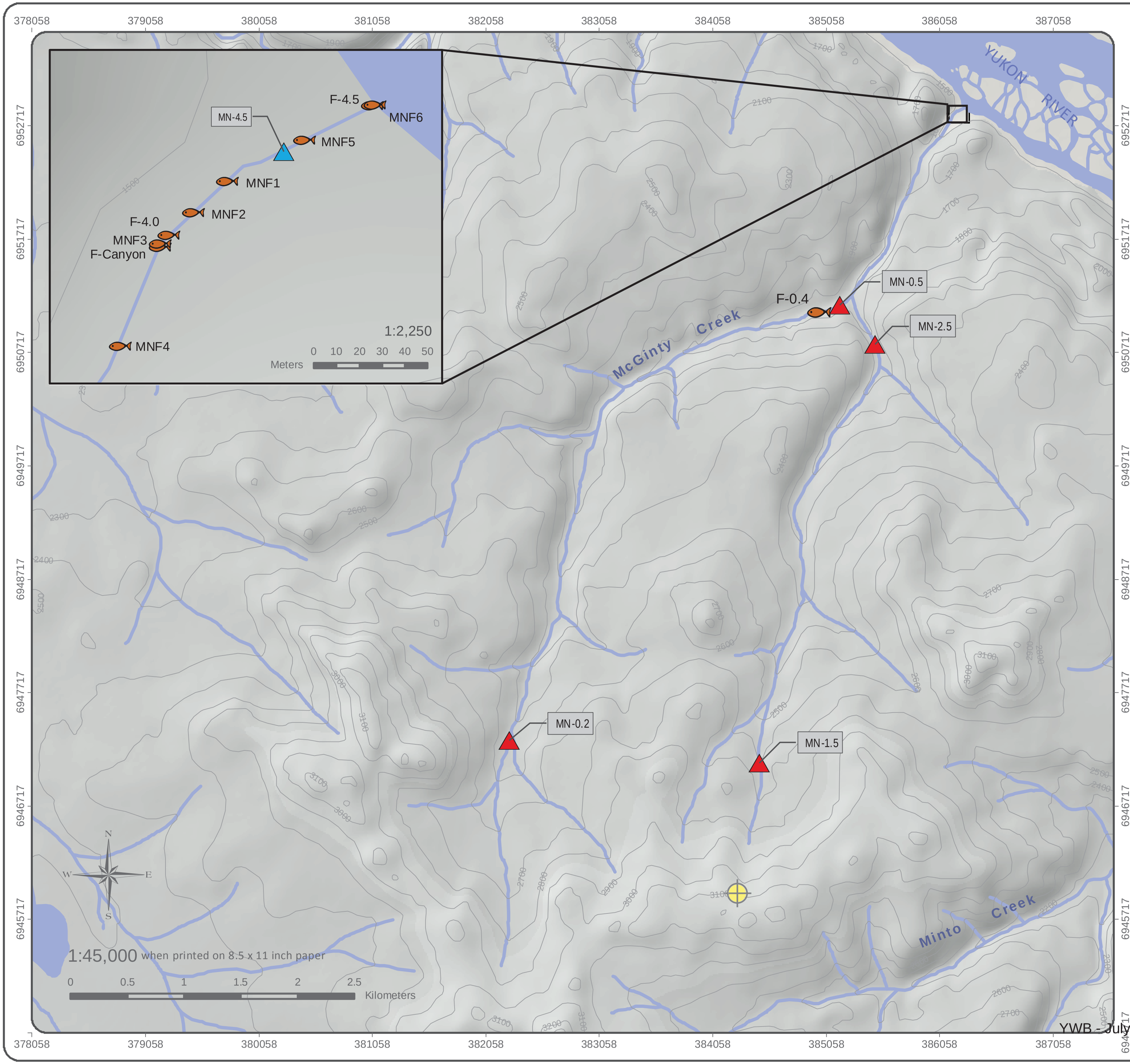
3.4.8 2009–2011 Fisheries Monitoring Program in McGinty Creek

3.4.8.1 Methods

All non-consumptive trapping was carried out using ¼" mesh Gee's minnow traps. Traps were baited with Yukon River-origin Chinook salmon roe and soaked for a nominal 24-hour period at each location. All captured specimens were identified, measured, enumerated, and released in the immediate area of their capture.

Whenever possible, traps were placed in areas of the creek where the flow was minimal, such as back eddies. Areas with back eddies and small pools were difficult to find or non-existent, particularly in the upper reaches of the drainage, because of the narrow, high gradient nature of the creek.

A visual assessment was made during the initial investigation in May 2009 to determine the potential for additional fish sampling methods, such as electrofishing, beach seining, and/or angling. It was determined that additional sampling methods were not practical and/or safe because of the very limited creek access, the small size of the creek, and the associated physical hazards (i.e., large amount of deadfall across the creek as a result of forest fires in the area). The lack of suitable pools and/or back eddies, and the very shallow average depth of the creek, were also limiting factors. Subsequent sampling events were limited to minnow trapping, and trapping locations varied from one sampling event to another according to creek conditions and previous results. Note that a sampling event was attempted in August 2010 but as a result of elevated flows and turbid waters, no suitable eddies to place fish traps were found. The map in Figure 3-8 shows all the trapping locations used in 2009, 2010, and 2011. Note that trapping efforts in 2011 were focused around the mouth of McGinty Creek based on previous results, and on fish barriers documented during that trip.



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AQUATIC RESOURCES BASELINE REPORT

FIGURE 3-8 MCGINTY CREEK FISHERIES MONITORING STATIONS

- Minto North Deposit
- McGinty Creek Fish Monitoring Station
- Water Quality Monitoring Station
- Water Quality and Hydrology Monitoring Station
- Contours (ft)
- Watercourse
- Waterbody

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3.4.8.2 Results and Discussion

Results for the trapping events conducted during the 2009, 2010, and 2011 sampling seasons are presented in Table 3-9.

Table 3-9: Minnow Trapping Results—McGinty Creek 2009–2011.

Stations	Date	# Traps	Soak Time (hrs)	Results
F-4.5	May 29, 2009	2	23	1 SS
	June 26, 2009	2	24	5 SS
	September 29, 2009	2	24	Nil
	July 2, 2010	1	21	2 SS
	September 13, 2011	1	21	Nil
F-Canyon	May 29, 2009	2	23	Nil
	June 26, 2009	2	24	Nil
F-RF	May 29, 2009	2	22	Nil
MN-0.5	June 26, 2009	2	24	Nil
	July 2, 2010	1	23	Nil
MN-1.5	June 26, 2009	2	24	Nil
MN-2.5	May 29, 2009	2	20.5	Nil
	June 26, 2009	2	24	Nil
	July 2, 2010	1	23.5	Nil
MN-4.5	May 29, 2009	2	23	Nil
	September 29, 2009	2	24	Nil
	July 2, 2010	1	21	Nil
F-4.0	July 2, 2010	1	21	Nil
MNF1	September 13, 2011	1	22	Nil
MNF2	September 13, 2011	1	22	Nil
MNF3	September 13, 2011	1	21.5	Nil
MNF4	September 13, 2011	1	21	Nil
MNF5	September 13, 2011	1	21	Nil

Note: SS = Slimy Sculpin (Cottus cognattus)

The fisheries assessment (minnow trapping) events indicated that a low number of fish use McGinty Creek. Only one species, the Slimy Sculpin, was documented over three sampling seasons (2009 to 2011), and due to the consistent location of the captures, these fish were presumed to be associated with the Yukon River as opposed to McGinty Creek. These results are similar to those found in the 1994 survey, in that fish were only captured in close proximity to the Yukon River confluence. No JCS were encountered during the 1994 or 2009–2011 surveys. However, during the 1994 investigations, Arctic grayling were also captured (HKP 1994).

As with Minto Creek, McGinty Creek has been subject to forest fire activity resulting in significant amount of deadfall falling across the creek. This has largely prevented the use of an electrofisher in the system for fisheries sampling in response to access and safety concerns. Barriers to fish passage were noted in the 1994 investigations and since 1994 additional forest fire activity and subsequent debris build-up has resulted in additional barriers forming closer to the Yukon River. These barriers limit fish use of the system to its lowest reach and this reach is characterized by a high gradient resulting in a cascading system with few pools and resting areas for fish. Since 1994 no fish have been captured in the creek except immediate to its confluence with the Yukon River. It should be noted that 24 Arctic Grayling were captured in the lower reach of McGinty during the 1994 investigations but that 16 (66%) of these were captured in gee traps. This may reflect the fact that at that time there were very few suitable locations for setting traps in the system as is currently the case and that any grayling in the system were congregating in the limited pool habitat that is also best suited for placement of gee traps. Suitable gee-trap placement sites in the lower fish bearing reach is very limited based on the cascading, high gradient nature of the creek. As with Minto Creek Arctic Grayling and other species can migrate into the lower reach of McGinty Creek but their use of the creek appears to be very low and transitory only.

The physical nature of the McGinty Creek drainage is not conducive to a consistent year-round use by fish. The gradient, discharge volume, depth, configuration and absence of an upstream reservoir limit the wintering habitat potential. Very minimal to no flows were observed in McGinty Creek during the winter. Fish likely make use of the creek only after temperatures between the creek and Yukon River equilibrate, as is the case in similar systems along the Yukon River. Also, McGinty Creek offers very minimal pool/resting habitat and fish would have to exert much energy to sustain themselves in the system for any period of time. This is likely a strong deterrent for fish to enter and/or remain in the creek for any length of time.

Several potential natural fish barriers were also observed and documented in the lower reach of McGinty Creek during the September 2011 sampling event. One is located just upstream of the water quality station MN-4.5, or between trapping sites MNF5 and MNF1, and was found to be 25cm high. Two more potential barriers were located between trapping sites MNF2 and MNF3, roughly 30m apart, and represented drops of 45cm and 36cm respectively.

3.5 FISH USAGE AND TRADITIONAL KNOWLEDGE SURVEYS

3.5.1 Fish Tissue Analysis

There is no known documentation or instance of any human use of fish from Minto Creek as a food source. Fish tissue analysis from populations in Minto Creek was conducted by HKP in 1994. The highest copper, mercury, and zinc concentrations from this study were detected in Arctic grayling muscle tissue from the mouth of McGinty Creek (which was used as a reference during HKP's 1994 study), and the highest arsenic concentrations were observed in slimy sculpin from the mouth of Minto Creek. Arsenic and zinc concentrations in Minto Creek grayling muscle tissue may not be representative of site-specific values arising from the transient nature of the grayling in the lower reaches of Minto Creek (HKP 1994).

A selenium study was also conducted in 2012 to determine if Minto Creek is used as spawning habitat by any fish species and if so, if selenium is accumulating in their body tissue. This study is presented in a separate memorandum.

3.5.2 1999 First Nations Interview (Pelly Crossing)

An interview was conducted with 12 members of the Selkirk First Nation residing in Pelly Crossing between November 25 and 30, 1999. Each person was provided with a brief background of the project and then asked to answer a series of questions. The purpose of this questionnaire was to integrate local knowledge into Minto's understanding of the local environment and to help document environmental conditions in the project area. The key fisheries-related information acquired during these interviews is summarized below:

- All interviewees have fished within their traditional territory in the Minto Mine area;
- The fishing area considered most important is the stretch from Minto to Fort Selkirk on the Yukon River, including the creek mouths in this region;
- Minto Landing is fished for grayling, spring salmon and dog salmon (chum salmon) from May to November with rod and reel, stickline hook and net; Fort Selkirk is fished for whitefish and salmon from May to November using the net and stick method; Carpenter Slough is fished for whitefish and salmon from July to November with nets; and the Yukon River area is fished for grayling, whitefish and pike from July to November with nets;
- Known spawning locations are Big Creek for Chinook salmon (king, spring), dog salmon (chum), and Arctic grayling; the Yukon River for burbot, inconnu, lake whitefish, longnose sucker, mountain whitefish, and northern pike; and Slough Creek for lake whitefish, longnose sucker and northern pike;
- Most of the interviewees noticed that over the years, fish populations have grown smaller and runs are taking place later, and one participant also noted that fish body size was getting smaller;
- Table 3-10 outlines the answers of interviewees when questioned about the quality of fish caught in the river or tributaries and if they had noticed any changes.

Table 3-10: Selkirk First Nation Summary of Yukon River System Fish Quality (1999)

Species	Fish Quality (Number of Answers)
Whitefish	Less fat (2)
King Salmon	100% good (6) 25% soft and deformed (7) 75–85% good (4)
Dog Salmon	100% good (4) 70–80% good (8) 25% soft and deformed (4) 35% less fat (1)
Inconnu	Small (4) Soft (1)
Grayling	Small (7) Not so fat (9) Some not so fat (2)

4 AQUATIC ENVIRONMENT

4.1 STREAM SEDIMENT ANALYSES

4.1.1 Chronology of Key Studies

Stream sediments have been monitored for relevant metals, physical properties, and particle size distribution in several key studies from 1994 to present, as summarized in Table 4-1.

Table 4-1: Summary of Key Sediment Monitoring Studies, Minto Mine.

Year	Firm and Study	Scope of Studies
1994	Hallam Knight Piesold–IEE for Minto Creek (HKP, 1994)	Sediment Collection and Analysis from four sites in Minto Creek
2006–2009	Minnow Environmental Inc (Minnow 2009a)	Sediment Chemistry of Minto Creek
2010	Minnow Environmental Inc (Minnow 2011)	Sediment and benthic invertebrate community assessment
2010	Minnow Environmental Inc	Stream sediment sampling in McGinty Creek (2 locations were sampled)
2011	Minnow Environmental Inc (Minnow 2012a)	Sediment, periphyton, and benthic invertebrate community assessment
2012	Minnow Environmental Inc (Minnow 2013)	Sediment, periphyton, and benthic invertebrate community assessment

4.1.2 1994 Baseline Study Program

4.1.2.1 Methods

Baseline sediment quality data were first collected during the original Minto Mine baseline studies, prior to the initiation of mine operations (HKP 1994). During this study, triplicate samples of fine sediments were collected at four locations within the Minto Creek mainstem. Three of the sampling locations corresponded to water sampling stations W9 (S1), W3 (S2), and W2 (S4) and the other was situated at the junction of Minto Creek and the tributary where sampling site W6 is located (S3; approx. 100 m downstream of W6) (Figure 4-1).

These 1994 samples were sent to Analytical Services Laboratories (ASL) Ltd. for analysis of moisture, total metals and grain size. Metals analysed included antimony, arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, silver and zinc. Metal determination was conducted through hydride vapour atomic absorption spectrophotometry (HVAAS) for antimony and either atomic absorption spectrophotometry (AAS) or atomic emission spectrophotometry (ICP) for the other metals.

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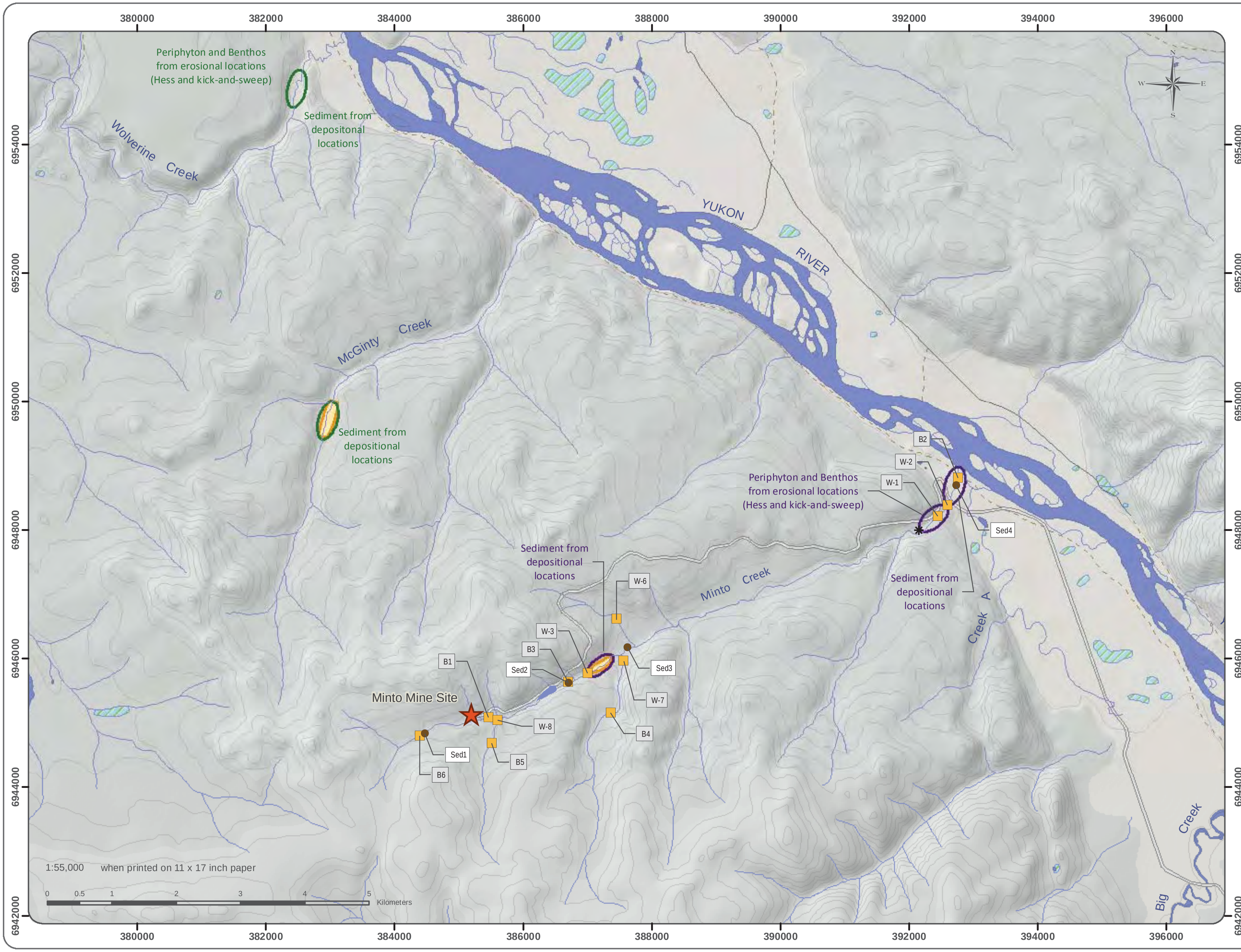
BASELINE REPORT

FIGURE 4-1
AQUATIC SAMPLING SITES



- Fish Barrier
- Sediment Sample Sites (HKP 1994)
- Benthic, Water Quality, and Periphyton Sample Sites (2005-2009)
- Mine Access Road
- Limited-use road
- Trail
- Watercourse
- Waterbody
- Wetland
- Benthic Sampling Area (2008 EEM)
- Reference Area
- Exposure Area

National Topographic Data Base (NTDB) and Canvec compiled by Natural Resources Canada at a scale of 1:50,000.Reproduced under license from Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources Canada. All rights reserved.

Quartz claims data obtained from Energy, Mines and Ressources, YTG. Data currrent as of August 1st 2011.

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4.1.2.2 Results

During the 1994 baseline stream sediment analysis, prior to the commencement of mine operations, sediments in Minto Creek were composed mostly of sand, with some gravel and minimal fractions of silt and clay (Table 4-2). Over time this composition does change and some of these differences arise from sampling protocol improvements that were implemented in 2010. Levels of antimony, arsenic, cadmium, mercury, molybdenum, and silver were low at all sites. Levels of chromium and zinc were highest at site S3 (approx. 100 m downstream of W6), with average values of 23.3 mg/kg and 48.53 mg/kg, respectively. Copper levels were elevated at site S1 (W9) in the vicinity of the deposit (Table 4-2). (Results detailed in Appendix E)

Table 4-2: Baseline Stream Sediments Results (HKP 1994).

Analysis	Guideline Levels		Sampling Location			
	ISQG	PEL	S1 (W9) Average	S2 (W3) Average	S3 (~100m d/s W6) Average	S4 (W2) Average
Physical Tests:						
Moisture %	-	-	25.2	21.7	24.1	18.5
Total Metals*:						
Antimony	-	-	0.36	0.42	0.44	0.29
Arsenic	5.9	17	4.1	4.4	4.2	4.4
Cadmium	0.6	3.5	0.07	0.13	< 0.10	< 0.10
Chromium	-	-	17.2	22.1	23.3	14.0
Copper	35.7	197	103	48	40	14
Lead	35	91.3	3.4	3.9	3.8	1.6
Mercury	0.17	0.486	0.02	0.01	0.01	0.01
Molybdenum	-	-	< 4.0	< 4.0	< 4.0	< 4.0
Silver	-	-	< 2.0	< 2.0	< 2.0	< 2.0
Zinc	123	315	35.7	47.8	48.5	29.4
Particle Size:						
Gravel – % (>2.00 mm)	-	-	9.2	4.9	1.8	28.8
Sand – % (2.00 – 0.063 mm)	-	-	72.2	75.2	77.9	62.6
Silt – % (0.063 mm – 4 µm)	-	-	14.1	13.9	14.1	6.6
Clay – % (<4 µm)	-	-	4.6	6.0	6.3	1.9

*Note: *Results are expressed as milligram per dry kilogram*
Adapted from Table 5.9 in HKP 1994

4.1.3 2006–2011 Sediment Monitoring Program

4.1.3.1 Methods

Under the terms of Minto's current Water License (QZ96-006), sediment monitoring has been required on an annual basis. To date, the Minto Mine has collected sediment samples in Minto Creek and tributaries on seven occasions since mine operations began (2006–2012). On all occasions, sediment samples were collected from two locations exposed to mine effluent in Minto Creek (Stations W2 and W3; Figure 4-1) and two reference stations. From 2006 to 2008, W6 was used as Reference 1 ("upper" creek reference). In 2010 to 2012, Reference 1 was changed to upper McGinty Creek. Reference 2 ("lower" creek reference) from 2006 to 2009 was site W7. This was changed to lower Wolverine Creek for 2010 to 2012 sampling.

Prior to 2010, all samples were collected within the active channel of the creek using an aluminum or Teflon scoop. Sampling methodology was modified for sediment collection in 2010–2012. Physical characterizations were collected at lower Minto Creek and lower Wolverine Creek using a stainless steel ponar grab in depositional areas. Composite samples were created by collecting the surficial 2 cm of sediment from three acceptable grabs. A Lexan® core tube was used to collect sediment for chemical analysis. The surficial 2 cm from three acceptable core samples were used to generate a composite sample. In the upper reaches of the creeks, sediment depositional areas were rare and shallow so therefore it was not possible to collect samples by ponar or coring. A stainless steel spoon was used to collect the top 2 cm of sediment and transfer into a sample jar. All samples were kept under refrigeration until they were submitted to an analytical laboratory. In the earlier years (1994–2009) only sediment that could pass through a 230 mesh sieve (< 63 µm fraction) was digested and analyzed for metals. In the later collections (2010–2012) chemical analysis was conducted on the whole sediment.

4.1.3.2 Results and Discussion

Sediment particle size distribution was notably different when comparing earlier sampling years to more recent years. The change in distribution from 1994–2009 compared to 2010–2012 reflects the methodological changes that were implemented in 2010. Gravel was present in the earlier sampling years, where samples collected in the later years had little or no gravel . Distribution of silt/clay is less represented in the earlier years when compared to 2010–2012 collections. Figure 4-2 shows the distribution of sediment particle size.

Sediment metal concentrations were also complicated by the change in methodology. With this qualification in mind, concentrations of arsenic, copper and occasionally chromium exceeded the interim sediment quality guideline (ISQG) levels over the years, but not greater than the probable effect level (PEL). When values are above ISQG, occasional adverse effects can be seen; whereas when values are over the PEL, adverse effects are expected. Copper was the only metal to exceed guideline levels every year, including during baseline sampling in 1994 (Figure 4-3). This could indicate that there are naturally high levels of copper at the exposure area. Arsenic was above the ISQG in most sampling years, except during baseline sampling, 2007, and 2009 (Figure 4-4).

Due to the predominantly erosional habitat in upper Minto Creek, there are relatively few areas where sediment is deposited and then only in small quantities that likely wash away each year during freshet.

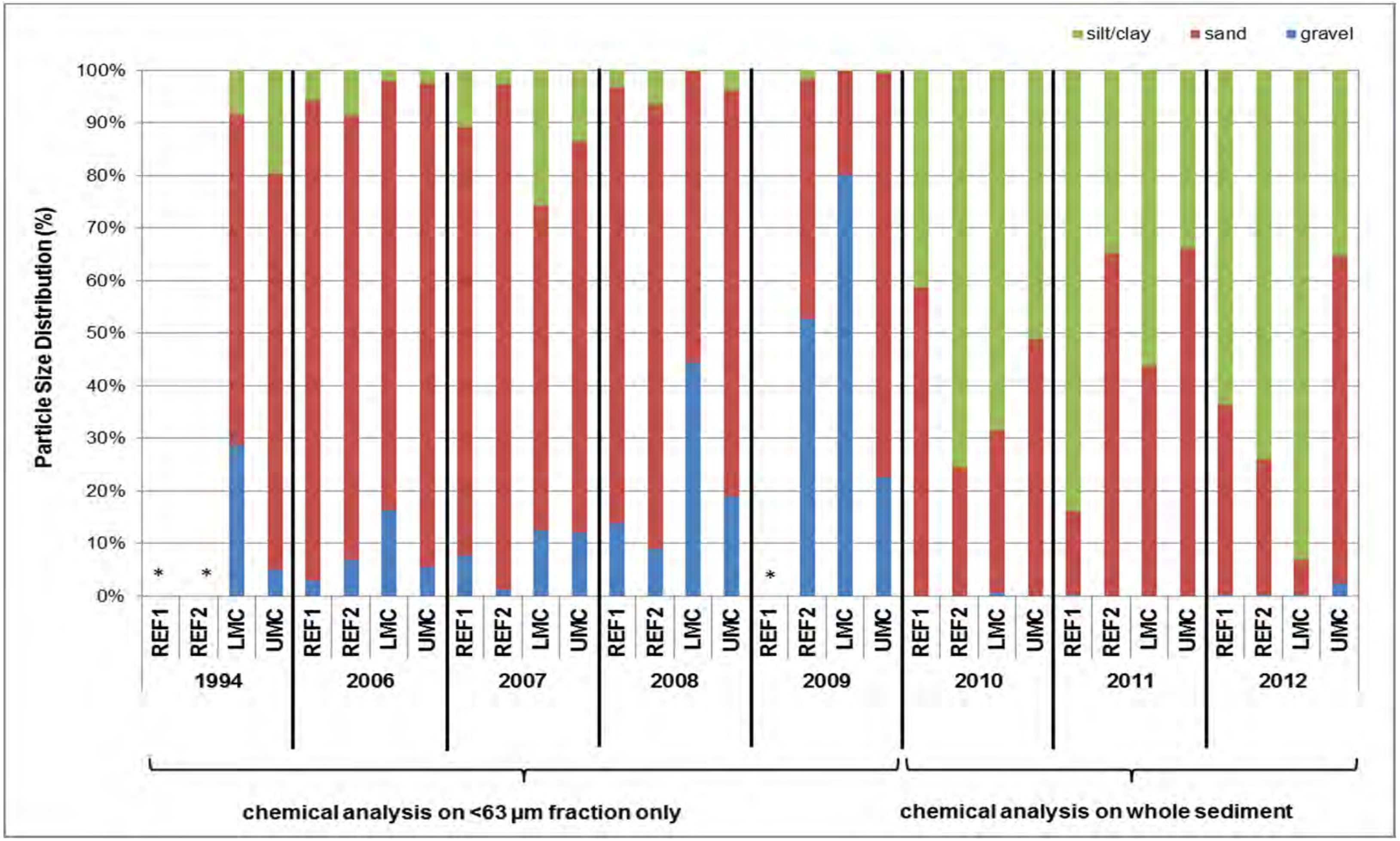

Figure 4-2: Particle Size Distribution of Sediment Collected in Minto Creek and Reference Locations, 1994–2012. ***(Source: Minnow, 2013)***

*Note: UMC = Upper Minto Creek; LMC = Lower Minto Creek; REF1 = Station W6 (south-flowing tributary) in 2006 to 2008 and McGinty Creek in 2010 to 2012; REF2 = Station W7 (north-flowing tributary) in 2006 to 2009 and Wolverine Creek in 2010 to 2012; * = no data*

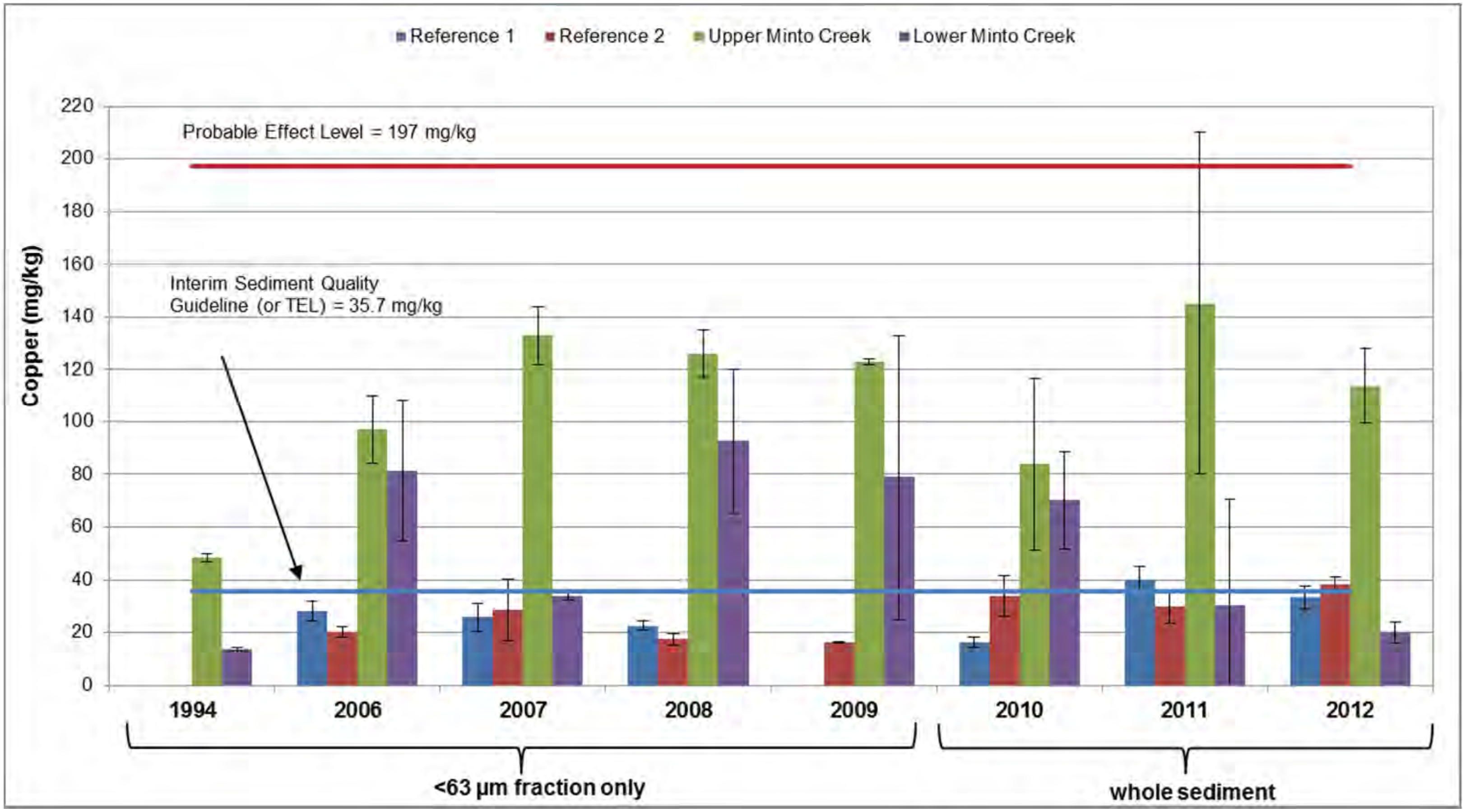

Figure 4-3: Mean Copper Concentrations in Sediment Collected in Minto Creek and Reference Locations, 1994–2012 (Mean ± Standard Deviation). ***(Source: Minnow, 2013)***

*Note: Reference 1 = Station W6 (south-flowing tributary) in 2006 to 2008 and McGinty Creek in 2010 to 2012; Reference 2 = Station W7 (north-flowing tributary) in 2006 to 2009 and Wolverine Creek in 2010 to 2012; * = no data; TEL= threshold effect levels*

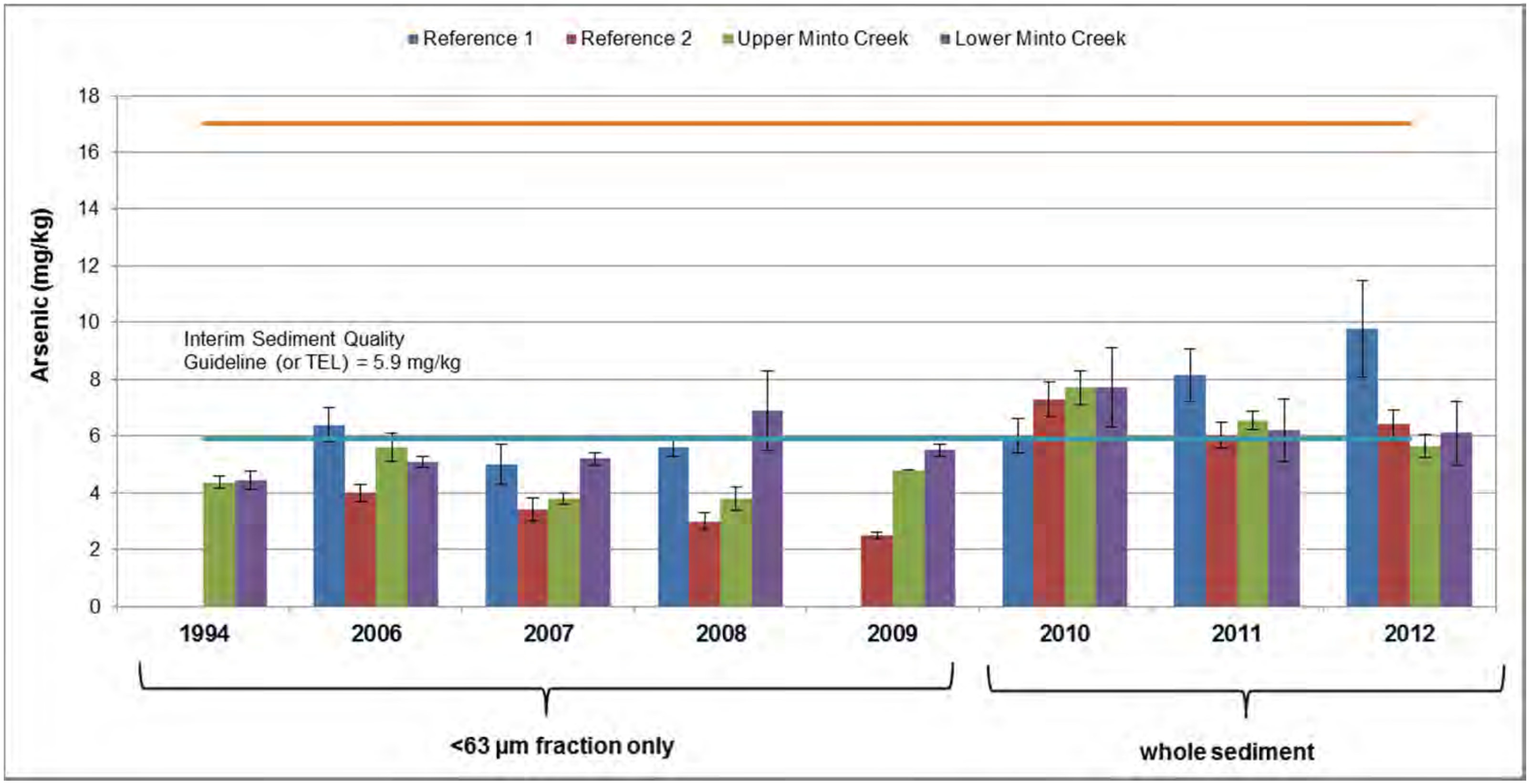

Figure 4-4: Mean Arsenic Concentrations in Sediment Collected in Minto Creek and Reference Locations, 1994–2012 (Mean ± Standard Deviation). ***(Source: Minnow, 2013)***

*Note: Reference 1 = Station W6 (south-flowing tributary) in 2006 to 2008 and McGinty Creek in 2010 to 2012; Reference 2 = Station W7 (north-flowing tributary) in 2006 to 2009 and Wolverine Creek in 2010 to 2012; * = no data; TEL= threshold effect levels*

Therefore, elevated sediment copper in the upper reaches of Minto Creek may be of limited importance in terms of exposure and potential toxicity to biota. However, continued sampling in this area is relevant from a monitoring perspective (Minnow 2012). In 2011, sediment was collected to conduct two sediment toxicity tests. A 14-day *Hyalella azteca* and a 10-day *Chironomus dilutes* survival and growth tests were conducted at Nautilus Environmental (Burnaby, BC). Even though copper and arsenic were elevated above ISQGs the toxicity tests indicated that sediment from Minto Creek was non-toxic. There were no significant reductions in survival and growth for either *H. azteca* or *C. dilutus* relative to laboratory controls. A detailed report on Minto Creek sediment, periphyton, and benthic invertebrate community was prepared by Minnow (2012 and 2013) and is presented in Appendix F.

4.2 BENTHIC MACROINVERTEBRATE MONITORING PROGRAM

Benthic macroinvertebrates are non-backboned animals inhabiting the bottom substrates of aquatic habitats. Along with being the most important primary consumers in stream ecosystems, they are a key source of food for fish and a key energy link between trophic levels. The abundance, diversity, and taxonomic composition of benthos can be used as indicators of changing environmental conditions because their distribution and abundance can be influenced by a wide variety of physical parameters such as hydrology, substrate composition, metal concentrations, water temperatures, dissolved oxygen, pH, salinity, and sediment C/N ratios. The benthic communities that develop are an indication of the ability of the various species to adapt to particular environments.

4.2.1 Chronology of Key Efforts

Baseline and numerous other benthic invertebrate studies have been undertaken in the Minto Mine area from 2006–2012 (Table 4-3). Sampling methods and locations changed over the years; in 1994 baseline data were collected near the mouth of Minto Creek, and in 2006 samples were collected at Station W2 as three single-grab samples. In 2008 and 2010, samples were collected at Station W2 as three-grab composites. During 2011 and 2012, data were collected as five replicate three-grab composite samples from a large area upstream of W2; this method represents the only years that an area rather than a station was sampled.

Table 4-3: Summary of Key Benthic Macroinvertebrate Monitoring Studies, Minto Mine.

Year	Firm and Study	Scope of Studies
1994	Hallam Knight Piesold – IEE for Minto Creek (HKP 1994)	Collection of benthic samples at 6 sites in Minto Creek in conjunction with baseline studies.
2006	Access Consulting Group (Access 2007)	Collection of benthic invertebrate samples under the terms of the water use license.
2008	Minnow Environmental (Minnow 2009b)	Collection of benthic invertebrate samples under the terms of the water use license.
2008	Minnow Environmental & Access Consulting Group (Minnow/Access 2009)	Collection of benthic samples as part of the EEM, Cycle 1 program

Year	Firm and Study	Scope of Studies
2010–2012	Minnow Environmental (Minnow 2011, 2012 and 2013)	Collection of benthic invertebrate samples under the terms of the water use license.
2010	Minnow Environmental	Collection of invertebrate samples in McGinty Creek
2011	Minnow Environmental & Access Consulting Group (Minnow/Access 2012)	Collection of benthic samples as part of the EEM, Cycle 2 program

4.2.2 1994 Baseline Study Program

4.2.2.1 Methods

As part of the original baseline studies at the Minto Mine site in 1994, triplicate benthic macroinvertebrate samples were collected at six sites in the Minto Creek watershed in late August. Samples were collected using a modified Hess sampler (42 cm high x 35 cm diameter, 250 µm mesh). Samples were preserved in 10% formalin with Rose Bengal stain and shipped to Dr. Charles Low in Victoria, BC, for taxonomic analysis and identification. Three of the six sites sampled in this program have been incorporated into the ongoing Minto WUL (water use licence) benthic invertebrate community monitoring program (described below).

4.2.2.2 Results

Data from the 1994 sampling efforts in Minto Creek were tabulated and are presented below in Table 4-4. A representative list of all benthic invertebrates captured during the 1994 sampling event can be found in Appendix G.

Table 4-4: Summary of Benthic Invertebrate Data Collected in 1994.

	W2	W3	W7
Density (m2)	9,327	2,637	20,140
Diversity	43	38	34
EPT Index	7	6	6
Richness Index	5.3	5.6	3.8
% sensitive	37.4	49.4	71.8
% facultative	62.2	44.5	23.2
% tolerant	0.4	6.1	5

4.2.3 Benthic Invertebrate Sampling under MMER

Minto's EEM programs under MMER were run concurrent with WUL Macroinvertebrate sampling programs in both 2008 and 2011. This rigorously designed sampling program was conducted to determine potential effects of the mine operations. The interpretive report for Cycle 1 and Cycle 2 were completed and submitted to Environment Canada in January 2009 and January 2012, respectively (Minnow/Access 2009, 2012). The collections in 2008 occurred approximately two weeks into an emergency water release that was being conducted by the mine following an exceptionally wet summer and rainfall event that occurred in late August 2008.

4.2.3.1 Methods

The 2008 EEM sampling program used a comparative approach between Minto Creek (exposure) and McGinty Creek (reference). Samples were collected on September 9 and 10, 2008, using a 0.1 m^2 Hess Sampler with 250 µm mesh. At each (exposed and reference) area, five individual samples were collected, and targeted cobble substrates with a target of three bankfull widths of distance between samples. Each sample consisted of three composite sub-samples (0.3 m^2 total area). Substrate penetration with the Hess sampler was targeted at 10–15 cm, and samples were preserved within six hours in a 10% buffered formalin solution. Invertebrate taxonomic analysis was conducted by Zaranko Environmental Assessment Services, and quality control re-identification for QA/QC purposes was conducted by Bill Mortoon of Invertebrate Taxonomic Services.

The 2011 EEM sampling program used a multiple control/impact design between Minto Creek, McGinty Creek (RefA) and a tributary off of Wolverine Creek (RefB). The sampling protocol had few changes from the 2008 EEM sampling program. Samples were collected on September 7–9, 2011, and used the same type of Hess sampler at a substrate penetration depth of 10 cm. Five individual samples were collected at each site, with each sample being made up of a composite of three grabs. Samples were preserved in a 10% buffered formalin solution and sent to Cordillera Consulting for invertebrate taxonomic analysis. In the laboratory samples were split using sieves, to evaluate 250 µm and 500 µm fractions.

4.2.3.2 Results

Basic results of the 2008 EEM benthic analyses indicated that Minto Creek (treatment) had a significantly higher benthic invertebrate density and slightly lower number of taxa (not significant) compared to McGinty Creek. The mean abundance of oligochaetes was higher in Minto Creek, while the mean abundance of ephemeroptera, plecoptera, and trichoptera (EPT), and chironomids were lower in Minto Creek. Basic metrics are provided in Table 4-5, while raw invertebrate data are provided in Appendix G.

Overall, the analysis of benthic metrics and supporting measures (by ANOVA and correlation) showed that there were clear differences between the Minto Creek exposure area and the McGinty Creek reference area. These differences appeared to be related to a combination of subtle habitat differences (water depth at sampling stations) and effluent exposure (as evident in higher temperature, conductivity, and principal component-1 [PC-1] water quality parameters). Principal component analysis (PCA) was used to assist with the interpretation of general trends and to collapse the large dataset for correlation with benthic community conditions. Water quality data was used in conducting the PCA. The first PC accounts for as much variability in the data as possible. Detailed information regarding the sampling program or other results are available in the First Interpretive Report for Cycle 1 (Minnow/Access 2009).

Table 4-5: Basic Metrics and Supporting Data Summaries from 2008 and 2011 EEM Program Benthic Data.

Parameter	2008				2011			
	Reference Area (McGinty Creek)	Exposure Area (Minto Creek)	Significant Difference Among Areas? (p-value)[a]		Reference Area (McGinty Creek)	Exposure Area (Minto Creek)	Significant Difference Among Areas? (p-value)[a]	
Density (Ind./m2)	1,010.7 ± 184.8	6,750.0 ± 824.7	Yes	0.001	3,884 ± 746	38,278 ± 22,128	Yes	0.074
Number of taxa	20.6 ± 1.4	18.6 ± 1.3	Yes	0.000	19.6 ± 2.4	22.6 ± 2.4	No	0.141
Oligochaetes (%)	6.9 ± 0.9	34.6 ± 10.9	No	0.558	-	-	-	-
EPT (%)	32.1 ± 3.6	9.0 ± 1.5	No	0.103	-	-	-	-
Chironomids (%)	44.8 ± 2.7	38.1 ± 9.5	Yes	0.014	-	-	-	-
Simpson's D	0.85 ± 0.01	0.82 ± 0.04	Yes	0.050	0.78 ± 0.03	0.58 ± 0.13	Yes	0.068
Simpson's E (Smith & Wilson 1996)	0.34 ± 0.03	0.34 ± 0.04	No	0.981	0.24 ± 0.05	0.12 ± 0.04	Yes	0.013
Field DO (% Sat)	88.0 ± 1.9	77.2 ± 1.0	-	-	86.2 ± 1.3	-	-	-
Field conductivity (µs/cm)	75.0 ± 1.8	243.8 ± 0.4	-	-	57.2 ± 5.0	276.0 ± 2.4	-	-
Field pH	6.3 ± 0.2	7.7 ± 0.2	-	-	7.3 ± 0.3	8.1 ± 0.3	-	-
Avg. Velocity at Sample (m/s)	0.59 ± 0.01	0.57 ± 0.03	-	-	0.43 ± 0.18	0.17 ± 0.08	-	-
Avg. Depth at Sample (cm)	19.2 ± 0.6	27.8 ± 1.2	-	-	18.2 ± 3.1	12.8 ± 6.5	-	-
Bedrock (%)	0.0 ± 0.0	0.0 ± 0.0	-	-	-	-	-	-
Boulder (%)	0.0 ± 0.0	0.0 ± 0.0	-	-	-	-	-	-
Cobble (%)	78.0 ± 2.0	82.0 ± 2.0	-	-	66.0 ± 8.9	56.0 ± 20.7	-	-
Gravel (%)	12.0 ± 2.0	9.0 ± 1.0	-	-	22.0 ± 4.5	23.0 ± 12.0	-	-
Sand (%)	10.0 ± 0.0	9.0 ± 1.0	-	-	12.0 ± 4.5	21.0 ± 13.4	-	-

[a] *p-value obtained from 1-way ANOVA, $p < 0.1$*

The 2011 EEM benthic results show that Minto Creek had significantly higher number of taxa and higher density compared to both reference sites. Density was not significant but this can be attributed to the high variability between the exposure sites. Relative abundance of EPT was significantly higher at Minto. The more tolerant chironomids were significantly higher at Minto Creek compared to the reference sites. Basic metrics are provided in Table 4-5, while raw invertebrate data are provided in Appendix G.

Increased taxa, higher density, and lower evenness is indicative of an site that is experiencing nutrient enrichment. The invertebrate community composition in Minto Creek suggests that the mine-related effluent is causing it to flourish. When investigated further, it was observed that the density of orthoclad chironomids were higher at Minto Creek; these are generally associated with areas of high nutrient enrichment. Comparing the Cycle 1 and Cycle 2 reports shows differences in community structures. More details and other results are available in the Cycle 2 report (Minnow/Access 2012).

4.2.4 Water Use License Sampling Program 2006, 2008, 2010–2012

4.2.4.1 Methods

Under the terms of Minto's Water Use License #QZ06-006, benthic macroinvertebrate communities were required to be monitored annually in Minto Creek. In 2006, data were collected at station W2 as three single grab samples; 2008 and 2010 data were collected at Station W2 as three-grab composites. Data in 2011 and 2012 were collected as five replicate three-grab samples from a large area upstream of Station W2. Samples were also collected from reference sites (not influenced by mine effluent discharge) each time; namely W6 and W7 in 2006 and 2008, and lower Wolverine Creek in 2010 to 2012.

4.2.4.2 Results

Tables 4-6 and 4-7 summarize benthic macroinvertebrate results obtained under the terms of Minto's Water Use License #QZ06-006. Complete tables of results are presented in Appendix G.

Mean number of taxa in lower Minto Creek in 2011 (18.6 taxa) was lower than the 1994 baseline (HKP 1994), and the reference area in lower Wolverine Creek (both 24 taxa); but greater than in 2006 (15 taxa), which was also a year that the mine did not discharge (Figure 4-5). Number of taxa documented in 2011 fell within the range of taxa observed in previous studies (Figure 4-5). Although benthic invertebrate density in lower Minto Creek was lowest in 2011 (Figure 4-5), density was still greater than the lower Wolverine Creek reference (4,258 versus 1,554 individuals/m^2; Appendix G). In 2011, evenness in lower Minto Creek was comparable to 2006 (when the mine was not discharging) and was lower than that of lower Wolverine Creek (Appendix G). Changes in density and evenness over time likely reflected high temporal variability of benthic invertebrate communities in the region, also evident at reference areas (Minnow 2009b, 2011). High inter-annual variability in environmental conditions such as flow and deep freezing can, in turn, influence benthic invertebrate community composition features among years. (Minnow 2012) A detailed report on Minto Creek sediment, periphyton, and benthic invertebrate community was prepared by Minnow (2012) and is presented in Appendix G.

Table 4-6: Summary of Benthic Invertebrate Data Collected at Erosional Habitat in 2006, 2008, and 2010–2012.

	2006				2008			2010		
	W2	W3	W6	W7	W2	W6	W7	W2	W6	W7
	Exposure	Exposure	Reference	Reference	Exposure	Reference	Reference	Exposure	Reference	Reference
Total Number of Organisms	10,018	2,070	8,159	2,379	5,445	350	1,610	5,500	12,019	4,737
Total Number of Taxa	32	33	41	19	17	12	15	21	14	18
EPT Index	4	6	5	3	-	-	-	-	-	-
Richness Index	3.9	5	5.2	3.3	-	-	-	-	-	-
Simpson's Diversity (1-D)	0.506	-	0.177	0.277	0.154	0.367	0.198	0.137	0.535	0.203
Simpson's Diversity (D)	0.494	-	0.823	0.723	0.846	0.633	0.802	0.863	0.465	0.797
Simpson's Evenness	0.532	-	0.867	0.779	0.899	0.691	0.859	0.906	0.501	0.844
Key Taxa Groups (% composition)										
Nemata	0%	-	6%	0%	11%	3%	14%	18%	9%	3%
Oligochaeta	7%	-	23%	35%	27%	56%	50%	8%	7%	8%
Mayflies/ Stoneflies	4%	-	27%	48%	5%	29%	5%	35%	4%	40%
Chironomids	88%	-	36%	12%	51%	7%	22%	37%	79%	48%

Table 4-7: Summary of Benthic Invertebrate Data Collected at Depositional Habitat in 2010 and 2011.

	2010		2011		2012	
	Lower Wolverine Creek (Mean) Reference	Lower Minto Creek (Mean) Exposure	Lower Wolverine Creek (Mean) Reference	Lower Minto Creek (Mean) Exposure	Lower Wolverine Creek (Mean) Reference	Lower Minto Creek (Mean) Exposure
Density	495	5,284	1,554	4,259	7,579	856
Number of Taxa	6.2	14	24	18.6	12.6	20.4
Simpson's Diversity (1-D)	0.310	0.329	0.173	0.351	0.488	0.260
Simpson's Diversity (D)	0.690	0.671	0.827	0.649	0.512	0.740
Simpson's Evenness (E)[a]	0.649	0.239	0.263	0.161	0.202	0.203
Simpson's Evenness (E)[b]	0.86	0.723	0.864	0.687	-	-
Percent Nematoda (roundworms)	3%	4%	4%	25%	1%	5%
Percent Oligochaeta (worms)	9%	9%	15%	5%	11%	8%
Percent Ostracoda (seed shrimp)	0%	12%	-	-	-	-
Percent EPT (mayflies, stoneflies, and caddisflies)	0%	0%	29%	7%	11%	24%
Percent Ceratopogonidae (biting midges)	0%	1%	-	-	-	-
Percent Empididae (dagger flies)	11%	1%	-	-	-	-
Percent Tipulids (crane flies)	12%	5%	-	-	-	-
Percent Chironomids (non-biting flies)	63%	68%	44%	51%	75%	51%

[a] *calculated per Environment Canada 2002*
[b] *calculated per Krebs 1989*

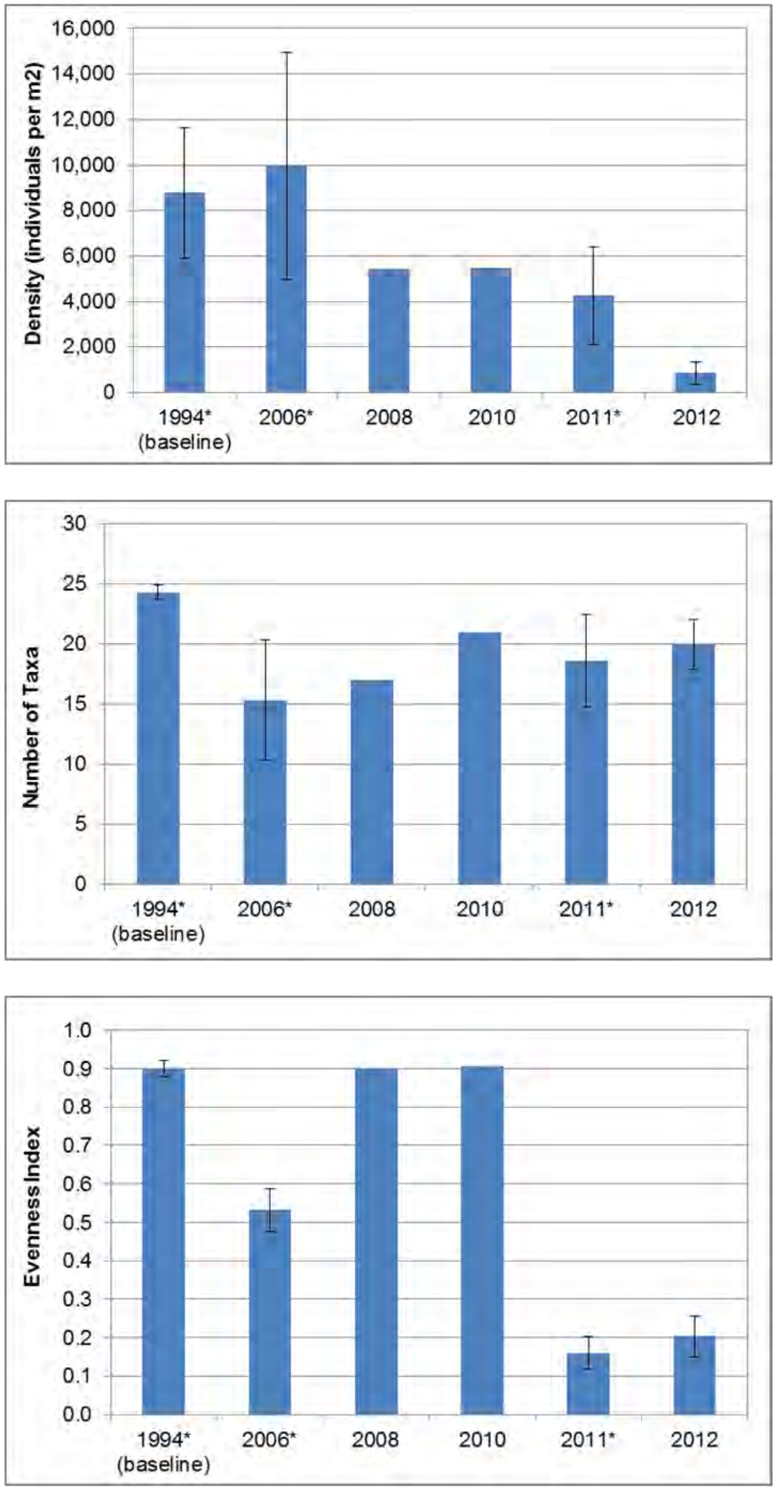

Figure 4-5: Primary Benthic Invertebrate Community Metrics at Lower Minto Creek, 1994–2012.

Note: Data presented as mean ± standard deviation where replicated. Asterisk (*) indicates a year the mine was not discharging.

4.2.5 Benthic Invertebrate Sampling in McGinty Creek

4.2.5.1 Methods

As part of an environmental baseline assessment, benthic invertebrate sampling was conducted in McGinty Creek in September 2010 by Minnow Environmental. Samples were collected from two locations in McGinty Creek as there was no sediment in the main branch downstream of MN0.5. A 100-pebble count was conducted at MN0.5. Five samples were collected at each site. Supporting data, including habitat characterization, were also collected.

4.2.5.2 Results

The mean results and standard deviation are presented in Table 4-8 below. Habitat characterization data as well as complete benthic data tables are presented in Appendix H.

Table 4-8: Summary of Benthic Invertebrate Data, McGinty Creek, 2010.

	Mid McGinty Creek		Upper McGinty Creek	
	Total	**S.D.**	**Total**	**S.D.**
Mean Number of Organisms	2939	1027	2812	590
Total Number of Taxa	40	-	29	-
Mean Number of Taxa	19	4	15.6	3
Simpson's Diversity (1-D)	0.771	0.041	0.778	0.022
Simpson's Diversity (D)	0.229	0.041	0.222	0.022
Simpson's Evenness (E) EEM	0.247	0.079	0.296	0.046
Simpson's Evenness (E) Krebs	0.815	0.049	0.832	0.021
Percent Composition				
% Nematodes	17%	12%	1%	1%
% Oligochaetes	17%	13%	23%	14%
% Chironomids	47%	12%	50%	12%
% Tipulids	0%	0%	0%	0%
% ETP	13%	3%	23%	10%

Note: S.D. = standard deviation

4.3 PERIPHYTON SAMPLING

Periphytic algae are simple aquatic plants which inhabit the substrate of water bodies. As photosynthesizers, algae form the base of the aquatic food web. Algal concentrations and population composition vary seasonally with changing photoperiod, temperature, nutrient levels, and flow regimes. Periphyton can provide a valuable biological monitoring tool to assess potential impacts of nutrient enrichment and metal toxicity.

Disturbance of igneous and metamorphic rocks from mining and subsequent runoff potentially can have effects on water quality. Excessive nitrogen has the potential to impair water quality for drinking, aquatic life and recreation because of the toxicity of nitrates, nitrites and ammonia and their role as a limiting nutrient in promoting algal growth. Biologically available phosphorous or ortho-phosphate is more readily accumulated by living organisms and can contribute to accelerated algae growth. Excessive algal growth can in turn result in lake eutrophication and the choking of streams.

Chlorophyll a is the primary photosynthetic pigment and is common to all algae. Determining chlorophyll a concentrations provides a measure of algae biomass and thus, the primary productivity of a given location. Previous to 2012, chlorophyll a samples were measured in water but in 2012 chlorophyll a was measured in periphyton. Since Minto Creek is a lotic system, measuring chlorophyll a in periphyton is more representative of productivity. Measuring this environmental parameter provides baseline data for monitoring possible future impacts to downstream water quality. Taxonomic identification and relative abundance ranking of the algae samples provides information on community complexity and composition. Species presence information allows comparison to known community associations from the literature and regional studies, and permits increased prediction capabilities. This qualitative sampling should be able to detect gross changes in the dominant species.

4.3.1 Periphyton Sampling during 1994 Baseline Studies

4.3.1.1 Methods

Periphyton sampling was conducted as part of the original baseline study program by HKP in August 1994, concurrent with benthic invertebrate collection. These collections were intended to provide a temporal and spatial baseline database of relative productivity and typical algal community composition. Five samples sites (P1 through P5) were sampled, with locations upstream and downstream of expected potential impact areas at that time. These sites correspond to current water quality sampling locations as outlined in Figure 4-1 according to reference Table 4-9.

At each site, six replicate samples were taken for taxonomic analysis and chlorophyll a analysis. Samples at each location were normalized to areas of similar depth and velocity. Representative samples of algae were taken from 5.3 cm^2 areas of cobble-sized substrate at each site using a 50 mL Stockner sampler and transferred to plastic 50 mL sample containers.

Samples for chlorophyll a concentration determination were individually filtered through 0.45 μm cellulose acetate filters, buffered with $MgCO_3$, stored on silicate crystals and submitted to ASL Laboratories Ltd. for analysis.

Table 4-9: Correspondence Between Periphyton and Water Quality Sampling Sites.

1994 Sample Site	Water Quality Station
P1	W1
P2	W2
P3	W3
P4	W7
P5	W8
P6	W9

Samples for community composition studies were preserved with Lugol's iodine solution and sent to Munroe Environmental Consulting for taxonomic analysis. Sub-samples were settled in 2.5 mL settling chambers, and then examined to identify species and estimate abundance by percentage of green, blue-green, and other common algal species. Diatoms were identified and assigned the relative abundance rankings of predominant, common and present.

4.3.1.2 Chlorophyll a Results

Mean chlorophyll a values ranged from 0.079 µg/cm2 at station P3 to 0.392 µg/cm^2 at station P5 (Table 4-10). The highest mean concentration of chlorophyll a was detected at P5 in the upper reaches of the Minto Creek watershed in an area of disturbance. Very little cover vegetation exists in this region due to mining exploration activities and forest fire. Therefore, an abundance of sunlight is allowed into the water column. A thick algal mat was observed on the creek substrate. The lowest value was detected in an area with thick overgrowth consisting of willows and alder. High variability was observed between replicates at sites P3 and P5.

Table 4-10: Chlorophyll a Content of Periphyton (µg/cm^2).

Replicate	Site P1	Site P2	Site P3	Site P4	Site P5
1	0.187	0.059	0.094	0.352	0.375
2	0.208	0.112	0.141	<0.01	0.181
3	0.132	0.637	0.098	0.153	1.104
4	0.059	0.077	0.073	0.092	0.189
5	0.941	0.473	0.022	0.081	0.167
6	0.061	0.312	0.047	0.077	0.334
Mean	**0.265**	**0.278**	**0.079**	**0.126**	**0.392**
S.D.	**0.045**	**0.053**	**0.206**	**0.109**	**0.142**

Note: Adapted from Table 8.1 in HKP 1994

4.3.1.3 Species Composition Results

A comparison of species presence between sampling areas is included as Table 4-11. A summary of dominant and common species is also presented in Appendix I.

In general, samples from most sites contained very little periphyton material, which likely indicates a relatively unproductive stream or a stream subject to scouring from high flows during freshet. Species composition was similar to other creeks observed in southwest Yukon. High proportions of the diatoms *Nitzschia spp*. were found at sites P2 and P3. *Nitzschia* species, in abundance, are often associated with organic or nutrient enrichment. Although periphyton abundance was low, *Nitzschia* predominance at sites P2 and P3 may indicate locations with a potential sensitivity to enrichment.

Table 4-11: Stream Periphyton Results from Minto Creek as Described by HKP, 1994.

Site	Results
Site P1 (W1)	Three samples from site B1 contained very little visible sediment and three contained a moderate amount, which consisted mostly of detritus, silt, and small amounts of algae. Diatoms comprised 50 to 95% of the periphyton. *Navicula spp*. were predominant. The red alga *Audouinella violacea* was predominant in some samples, comprising 5 to 50% of the alga.
Site P2 (W2)	Four samples contained very little visible sediment and two contained a moderate amount (silt, detritus, and algae). Diatoms comprised 59 to 99% of the periphyton; *Nitzschian spp*. were predominant. The blue-green algae *Chamaesiphon incrustans*, *Lyngbya diguetii*, and *Plectonema notatum* were common in two samples and comprised up to 25% of the sample.
Site P3 (W3)	All samples contained very little visible sediment or algae. Only two samples contained enough algae to estimate percent abundance. Diatoms comprised 30 and 90% of the periphyton in these two samples. Common diatoms in all six samples included *Nitzschia spp*., *Navicula spp*., *Synedra cf. incisa,* and *Synedra rumpens*. *Audouinella violacea* and *Phormidium sp*. were common (5 to 35%) in the two samples where abundance was estimated.
Site P4 (W7)	Samples from P4 were not collected quantitatively because of limited substrate, but were analyzed in the usual manner for periphyton composition. Three samples contained coarse sand and were comprised almost completely of diatoms. *Nitzschia spp*. were predominant and *Navicula spp*. were common. Two samples contained large amounts of moss (*Fontinalis sp*.) and were covered by the epiphytic blue-green alga *Lyngbya nordgaardii*. One sample was composed of filamentous algae and contained the chrysophyte *Hydrurus foetidus* (50%), *Nitzschia spp*. and *Navicula spp*.
Site P5 (W8)	Samples from P5 contained very small amounts of fine sediment and very little algae. Two samples contained too little periphyton to estimate percent abundance. Diatoms comprised 90 to 99% of the periphyton in the other four samples. The most common diatom species were *Navicula spp*., *Synedra rumpens*, and *Nitzschia spp*. The blue-green alga *Nostoc sp*. was common in one sample. *Audouinella violacea* was common in another.
Site P6 (W9)	Samples from P6 contained very small amounts of sediment. Diatoms comprised 45 to 93% of the periphyton. *Gomphonema spp*. were predominant. *Meridion circulaire*, *Navicula spp.* and *Synedra rumpens* were common. The chrysophyte *Hydrurus foetidus* was predominant in two samples (25 to 40%) and common (5%) in three others. The crustose blue-green alga *Chamaesiphon incrustans* was predominant in two samples and common in two others. Other common species included *Lyngbya diguetii* and an unidentified filamentous blue-green algae.

4.3.2 Periphyton Monitoring under WUL, 2011 and 2012

4.3.2.1 Methods

"The productivity of lower Minto Creek and lower Wolverine Creek was assessed through collection of periphyton (e.g., algae attached to rocks) and measurements of chlorophyll a (used as a surrogate for the productivity of photosynthetic organisms)." (Minto, 2012) "Periphyton was collected from up to five randomly selected rocks at each station with the use of a rubber GEMS-type sampler having a 33 cm2 sample area." (Minnow, 2012)

4.3.2.2 Results

"Overall, the periphyton community of lower Minto Creek relative to lower Wolverine Creek had lower density and taxon richness". (Minnow, 2012) Periphyton community metric means are presented in Table 4-12 below. "Periphyton communities of lower Minto Creek and lower Wolverine Creek in 2011 both differed from the community documented at lower Minto Creek in 1994 (Figure 4-6), suggesting high natural temporal variability in community structure." (Minnow, 2012) Results from the 2012 studies are currently pending. Detailed results and analysis are presented in Minnow's assessment report found in Appendix F. *Source: Minto, 2012 (Table 5-33)*

Table 4-12: Periphyton Community Metric Means, 2011.

Metric	Lower Wolverine Creek (Reference)	Lower Minto Creek (Exposure)	Significant Difference Among Areas? (p-value)[a]	
Density (individuals/cm2)	2,273,337	326,318	Yes	0.002
Number of Taxa (presence/absence)	40.6	34.2	Yes	0.030
Number of Taxa (quantitative)	30.4	26.8	Yes	0.052
Simpson's Evenness (Environment Canada 2011)	0.06	0.119	Yes	0.087
Bray Curtis Distance to lower Wolverine Creek Median	0.192	0.784	Yes	0.0001

[a] *p-value obtained from t-test, p < 0.1*
Source: Adapted from Minnow 2012 (Table D.4)

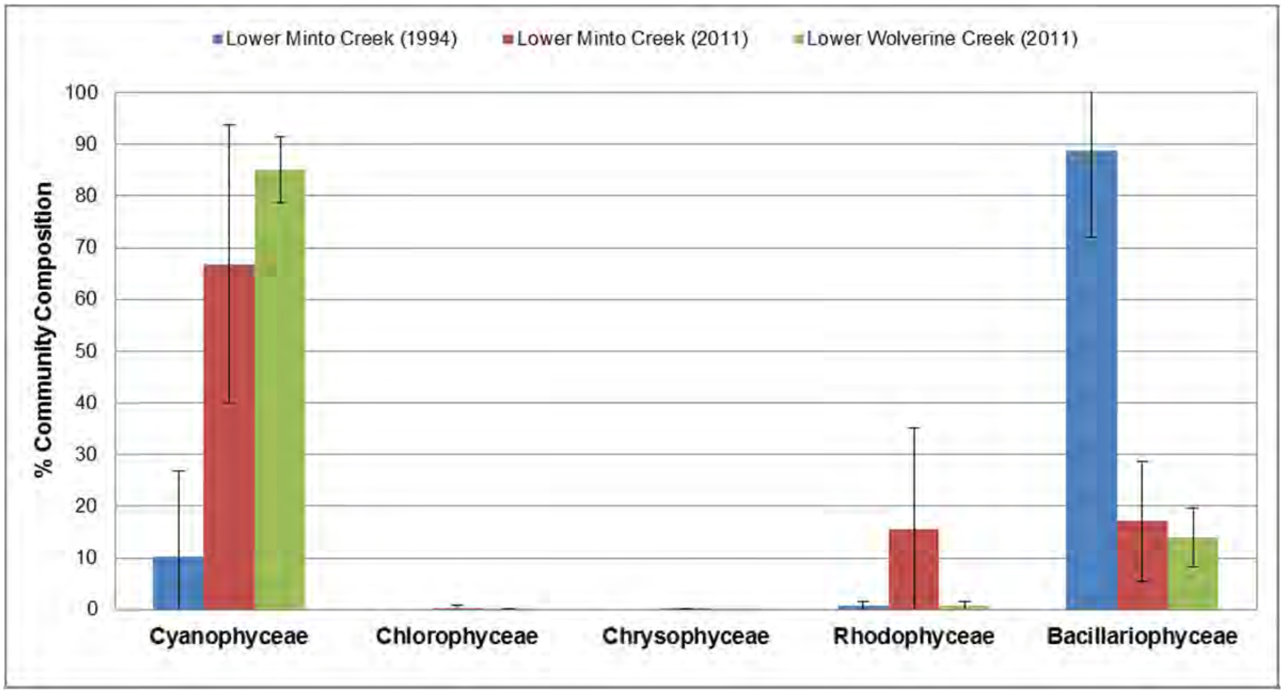

Figure 4-6: Periphyton Community Composition in Lower Minto Creek (1994 and 2011) and Lower Wolverine Creek, 2011. ***(Source: Minnow, 2012)***

Data presented as mean ± standard deviation.

5 CONCLUSION

This report was prepared based on data and information available as of November 2011, in support of Minto's Phase V/VI project proposal to YESAB. It is based on a number of different reports, some of which are presented in Appendices to this report.

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Appendix A

General Life History Characteristics of Yukon River Fish Species

The following life history summaries have been modified from HKP (1994) using information from sources including the Yukon Territorial Government's website (2009).

Coho salmon *Onocorhynchus kisutch*

Starting in October, Coho salmon spawn in swift flowing tributaries with gravel substrate as far inland as Dawson. They are brood hiders and, although they do not guard the deposited eggs, females often guard the redd throughout the spawning period. Exogenous feeding starts at the alevin phase and prey includes insects and other invertebrates. As the smolt phase is reached, fish become an important food source. While in the Yukon River system, the juveniles inhabit shallow gravel areas and in late summer or fall, move to deeper pools. The majority of juvenile Coho salmon reach the ocean as smolts by the end of their first year and return to spawn after a further year and some months in the ocean. The presence of Coho salmon in the Minto region has not yet been documented.

Chum salmon *Oncorhynchus keta*

Two chum salmon spawning runs take place in the Yukon River: one in late summer and one in late fall. Their range extends into the major tributaries of the Yukon River (White, Stewart, Pelly, and Teslin Rivers) and into the Minto region. Chum salmon are brood hiders and the female partially covers the redd after spawning. Hatching occurs in winter and free embryos remain in the gravel until they are able to migrate to the sea. The freshwater rearing period for chum salmon alevins and juveniles has been reduced and migration to the sea may take only a few days to a few weeks. Alevins and juveniles may or may not feed during their migration. Chum salmon return to spawn their third or fourth year.

Chinook salmon *Oncorhynchus tshawytacha*

Chinook salmon migrate up the Yukon River at a rate greater than 30 km per day and reach their spawning areas by July or August. They are brood hiders and the redds are covered with gravel after spawning. Females may dig several redds and spawn with more than one male; and guard the nest as long as possible before dying. Hatching occurs in the following spring and free embryos remain in the gravel until the yolk is absorbed. Alevins and juveniles prey on various invertebrate organisms during their first year in freshwater and then migrate downstream as smolts, becoming primarily piscivorous at sea. While in freshwater, alevins will school but juveniles soon become defensive of territories. Adults return to spawn in the Yukon River usually after 4 to 7 years in the ocean. The presence of JCS was detected in the lower section of the Minto Creek (near its confluence with the Yukon River) during the 2007 and 2009 surveys conducted for Minto Explorations.

Burbot *Lota lota*

Burbot spawn in mid-winter, usually between January and March. They are bottom-dwellers, open substrate spawners, and produce pelagic larvae. At night during spawning, several individuals roll together in a constantly moving ball over sand or gravel substrate. Larger females may produce over a million small eggs (approximately 1 mm in diameter) which are not guarded. Eggs are semi-pelagic and are easily transported by water movement. Free embryos lack embryonic respiratory organs, similar to those belonging to the pelagic spawning guild. Feeding actively at night, small burbot prey on aquatic insects, crustaceans, plankton, and fish eggs, whereas larger individuals prey predominantly on fish. The adult stage is reached at 3 or 4 years of age.

Arctic grayling *Thymallus Arcticus*

Arctic grayling spawn in small streams as soon as ice break up has commenced. Males defend territories while on the spawning ground. Arctic grayling spawn over unprepared cobble or gravel and produce benthic embryos and larvae. Hatching occurs fairly quickly and exogenous feeding starts while the yolk is still present. At this phase, prey consists largely of zooplankton, while bottom nymphs, snails, small fish and eggs, and a high percentage of terrestrial insects make up the diet of older juveniles and adults. Spawning populations consist of individuals four years of age and older. A small number of juvenile Arctic grayling were detected in the lower section of the Minto Creek (near its confluence with the Yukon River) during the 1994 and 2007 surveys conducted for Minto Explorations.

Inconnu *Stenodus leucichthys*

Inconnu are relatively abundant in the Yukon, Pelly, Stewart, and Porcupine River systems. They are rock and gravel spawners and brood hiders, and no protection is given to the embryos once spawning is completed. Spawning takes place between late summer and early winter in tributary streams, producing free embryos that remain in the spawning substrate until they emerge as fully formed alevins. Young inconnu prey on various invertebrates such as insect larvae and planktonic crustaceans, whereas fish, including the Chinook salmon, comprise much of the diet of larger individuals.

Bering cisco *Coregonus laurettae*

In Canada, Bering cisco are only found in the Yukon River. They spawn in fast-flowing water on open rock and gravel substrates and do not attempt to hide their brood. Hatching occurs in the spring and the free embryos are photophobic and retreat into the substrate. Being an anadramous species, juvenile Bering cisco do not appear to spend much time rearing in freshwater and migrate out of the river as fry. Their diet likely consists of a variety of benthic and planktonic foods and adults return to spawn probably in early fall. Bering cisco reach sexual maturity between 4 and 9 years of age.

Least cisco *Coregonus sardinella*

Least cisco are rock and gravel, open substrate spawners. Spawning usually occurs in September and adults abandon the eggs after spawning has been completed. Hatching occurs the following spring and free embryos move into the substrate. The least cisco diet consists of aquatic insects, mollusks, crustaceans, aquatic worms, and small fish. There are both anadramous and freshwater populations.

Lake whitefish *Coregonus clupeaformis*

Lake whitefish spawn on rock and gravel substrates in the shallow water of lakes and rivers. Embryos are benthic and are not guarded by the spawning adults. The diet of adult lake whitefish includes aquatic insects, mollusks, crustaceans, fish eggs, and small fish. Spawning occurs in fall or early winter.

Round whitefish *Prosopium cylindraceum*

Round whitefish, like many other coregonids, are rock and gravel, open substrate spawners. Round whitefish do not guard their broods and embryos are benthic. Their diet consists of benthic invertebrates including mayfly larvae and pupae, chironomid and caddisfly larvae, amphipods, mollusks, crustaceans, fish eggs, and small fish. Spawning occurs during the fall in both lakes and rivers.

Northern pike *Esox lucius*

Northern pike are spring, obligatory plant spawners and do not guard their young. Spawning occurs in shallow weedy areas close to shore or calm rivers over a two to five-day period. During this time, females release a small number of eggs in many spawning acts. After each episode, the highly adhesive eggs are scattered by a tail thrust and attach to macrophytes. Eggs hatch in approximately two weeks and the non-photophobic, free embryos are shaped so that they swim upwards. Cement glands are present on the heads of free embryos. These strategies have evolved so that embryos are not subject to the often hypoxic conditions of the spawning ground bottom. Small juveniles feed on zooplankton and sub-adult aquatic insects, while larger juveniles and adults prey on various larger organisms such as fish and amphibians as well as small mammals and aquatic birds. In northern areas, males and females usually mature at five and six years of age, respectively. Northern pike typically winter in deeper rivers and lakes.

Slimy sculpin *Cottus cognatus*

Slimy sculpin are spring, nest spawners and guard their young. Eggs are deposited in natural rock cavities or clean, constructed burrows where the male guards the embryos. These areas are generally well oxygenated and therefore, respiratory organs of the embryos are only partially developed. The adult diet consists of aquatic insects, crustaceans, fish eggs, and small fish. Throughout the year, the slimy sculpin lives in rock- or cobble-bottomed streams and lakes and sometimes in brackish waters.

Longnose sucker *Catostomus catostomus*

Longnose suckers are rock and gravel spawners and produce benthic larvae. Their spring spawning runs commence when stream water temperatures reach 5°C. Spawning usually occurs in streams at an approximate mean depth of 20 cm with a 30 to 45 cm/s flow rate and a gravel and cobble substrate size range from 5 to 10 cm. Longnose suckers will spawn in shoal areas of lakes if streams are not present. Hatching occurs in approximately two weeks and photophobic, free embryos remain in the substrate for one to two weeks. Prey for the longnose sucker is almost exclusively benthic invertebrates including amphipods, caddisfly, midge, mayfly, ostracods, gastropods, beetles, pelecypods, as well as copepods and cladocerans. They will also occasionally feed on fish eggs and vegetation. Longnose suckers reach sexual maturity at varying ages, the youngest possibly at five years.

APPENDIX B

REACH DESCRIPTION FROM HKP 1994 BASELINE STUDIES

Minto Creek	
Reach 1, site 1 (Plate 1):	The stream gradient is 1.5%. Bed material consists of clays, silts and small gravel. This section of the creek is in an area of backwater from the Yukon River, and therefore, the water is relatively static. The stream cover was approximated at 45% and was comprised of large organic debris (LOD), undercut banks and deep pools. In addition, the water was extremely turbid. The average depth of the creek was 1.3 m. The average wetted width was 4.5 m. The creek banks are very unstable.
Reach 1, site 2 (Plate 2):	The stream gradient is 2.5%. Bed material consists of mostly fines (40%), gravel (35%) and small cobble (30%). The stream is composed mostly of run (45%), with areas of riffle (35%), and several pools (20%). Cover was provided by cutbanks, deep pools and LOD. The average wetted width was 2.5 m. Flows were estimated at 0.612 m3/s. The water was clearer than site #1, but was dark brown in colour.
Reach 1, site 3 (Plate 3):	Due to Limited access a new site was established approximately 1.5 km downstream of site 1. Unlike site 1, site 2 did not appear to be in the burn zone which covers the majority of the Minto Creek watershed. The stream gradient at site 2 is 6% and the average wetted width is 3 m. Bed material consists of mostly large cobble with some boulders. The creek is primarily composed of pools and chutes. Stream cover was approximated at 20% and was comprised of overvegetation and large boulders.
Reach 3, site 1 (Plate 4):	The stream gradient is 3.0% and the average wetted width is 3.0 m. Bed material consists of mostly fines (85%) with some small gravel (15%). The creek is primarily composed of run with some pools. Stream cover was approximated at 65% and was comprised of LOD, deep pools, overstream vegetation and cutbanks.
Reach 5, site 1 (Plate 5):	The stream gradient is 4% and the average wetted width is 3.0 m. Bed material consists mostly of fines (60%) with some gravel and small cobble. The stream is composed of mostly riffle (45%), with some areas of pool and run. Substantial cover (50%) is provided by LOD, overstream vegetation, cutbanks and deep pools.
Reach 5, site 2 (Plate 6):	An alternate site was also designated for reach 5 so that it could be accessed by vehicle. The stream gradient is 4% and the average wetted width is 3.0 m. Bed material consists mostly of fines (60%) with some gravel and small cobble. The stream is composed of mostly riffle (45%), with some areas of pool and run. Substantial cover (50%) is provided by LOD, overstream vegetation, cutbanks and deep pools.

Creek A	
Reach 1, site 1 (Plate 7):	The creek has an approximate gradient of 0.5% and an average wetted width of 0.5 m. The stream is composed mainly of run (88%) and the stream bed consists exclusively of fines. The Stream cover is provided mostly by cutbanks, with some areas of deep pools, and occasional in-stream and over-stream vegetation.
Reach 1, site 2 (Plate 8):	An alternate site adjacent to the road was chosen so the site could be accessed by truck. The creek has an average wetted width of 0.50 m. The stream is composed mainly of run (88%) and the stream bed consists exclusively of fines. The stream cover is provided mostly by cutbanks, with some areas of deep pools, and occasional in-stream and over-stream vegetation. The creek meanders throughout an area which consists mostly of sedge. Many small ponds exist in the area.

McGinty Creek (referred to as Unnamed Creek B)	
Reach 1, site 1 (Plate 9):	The average wetted width was 2.5 m and the gradient was 3%. The bed material consisted of mostly fines, gravels and small cobble with some large cobble and boulders. The stream was composed mostly of run with equal amounts of riffle and pool. Stream cover (30%) was comprised of cutbank, deep pool and LOD.
Reach 2, site 1 (Plate 10):	The average wetted width of the creek was 2.0 m and the stream gradient was 4.5%. the stream was Composed mostly of run (60%) with areas of riffle and few pools. The creek bed was comprised mostly of fines, gravels and small cobbles. Stream cover was extensive (80%) and was comprised of over-stream vegetation, cutbanks, LOD and deep pools.

Plates 1-13: Fisheries Sample Sites in Minto Creek and Tributaries (HKP 1994)

Plate 1: Minto Creek, Reach 1, Site 1 (at Yukon River)

Plate 2: Minto Creek, Reach 1, Site 2.

Plate 3: Minto Creek, Reach 1, Site 3.

Plate 4: Minto Creek, Reach 3, Site 1.

Plate 5: Minto Creek, Reach 5, Site 1.

Plate 6: Minto Creek, Reach 5, Site 2 (at H3/W3).

Plate 7: Creek A, Reach 1, Site 1.

Plate 8: Creek A, Reach 1, Site 2.

Plate 9: Creek B, Reach 1, Site 1.

Plate 10: Creek B, Reach 2, Site 1.

Plate 11: Dark Creek Tributary, Site 1

Plate 12: Dark Creek, Site 1.

Plate 13: Fish Barrier in Minto Creek, Reach 2

Appendix C

2009 Fish Relocation Summary Report by Access Consulting Group

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Letter Report

MINTO CREEK FISH RELOCATION PROJECT
September 29 – October 2, 2009
October 12 – 14, 2009

Background

There was some expectation that, due to increased flows occurring in the lower Minto Creek system (from the emergency discharge program), Chinook salmon young of the year (YOY), as well as other naturally occurring species (Slimy Sculpins), might have been attracted into lower Minto Creek from the Yukon River. The Department of Fisheries and Oceans Canada (DFO) submitted a letter to the Yukon Water Board dated June 23, 2009 in response to an application Minto Explorations Ltd. made requesting permission to discharge water. DFO's letter recommended installation of a temporary fish barrier to prevent fish from entering Minto Creek during elevated discharge periods. In addition a fish relocation program was conducted to prevent fish from being trapped in the system at freeze-up and/or following a substantial reduction in flow.

Accordingly, the Minto Creek Fish Relocation Project was conceived, organized and executed as described below.

Authority

DFO Permit #CL-09-45

Relocation Project

Physical Layout

The Lower Minto Creek System (project area) was arbitrarily divided into two parts for the purpose of this project. The division was set at the culvert crossing of Minto Creek at km 11 of the Minto Mine Road. The area upstream of that point, Minto Creek upstream (upstream aspect), constituted a potential linear Creek distance of approximately 1.5 km. The area downstream from the road crossing (downstream aspect) incorporated a linear Creek distance of approximately 500 m, terminating at its confluence with the Yukon River.

The section of lower Minto Creek where fish have been captured in the past is a small, low gradient stream, averaging approximately 2 m in width. Access to the Creek is substantially compromised due to the very dense bush and abundant deadfall bordering the lower Creek on both sides, for much of its length. There is an existing, minimally maintained walking trail along about 600 m of the eastern upstream aspect of the project area. No such access existed along the downstream aspect, which is even more heavily inundated with vegetation and deadfall than the upstream aspect.

Approval had been given (Selkirk First Nation Access and Land Use Permit #09-03/Sept. 24, 2009) to construct a basic ATV accessible trail into the downstream portion, in order to accommodate some access to the Creek, and also to allow for the transport of sandbags and related equipment and materials for the purpose of constructing a temporary fish barrier near the Minto Creek confluence with the Yukon River. This barrier was conceived, designed and installed to prevent the migration of additional fish into Minto Creek during the emergency discharge and fish re-location program

Methodology

Minnow trapping with Gee's minnow traps had been determined to be the primary method for fish capture, with the possibility for electrofishing as applicable, although actual access to, and subsequent use within, the Creek with an electrofishing unit was generally considered to entail a substantial safety risk.

All minnow traps were baited with Yukon River origin Chinook salmon roe. All captured fish during Phase I were released into Big Creek, approximately 150 m upstream of the confluence of Big Creek with the Yukon River. Big Creek is a substantial tributary to the Yukon River, located eight road kilometres upstream on the Yukon River from Minto Creek. All captured fish during Phase II were released directly into the Yukon River at a point approximately 1.5 road kilometers upstream from its confluence with Minto Creek.

PHASE I

September 29

The actual hands-on project was initiated on September 29, 2009. The route of the proposed ATV access trail, having been evaluated a substantial time previously, was identified and flagged that morning. Cutting of the trail was intended to have begun at the same time, but circumstances delayed the trail clearing crew until the following day.

Trapping began on the upstream aspect of the project area on September 29. An extensive reconnaissance had already been conducted on this portion of the Creek, and a rough walking trail had been identified and flagged. The Creek was followed on foot to a point approximately 600 m upstream from the culvert crossing at km 11. At this point, due to the enclosing canyon wall on the east, it was necessary to cross the Creek. The Creek was followed for another approximate 400 m until another crossing would have been required due to the impending canyon wall to the west.

In between the first and second Creek crossings, three natural in-stream barriers were encountered. The first two were considered substantial but likely only partial fish barriers; the third was considered to be a complete fish barrier.

Plate 1. Natural existing fish barrier approximately 900 m upstream of km 11.

The barrier was approximately 0.6 m high and spanned the entire width of the Creek.

Three traps were set upstream of the natural barrier, and the installation of an additional 29 traps was undertaken, spaced somewhat evenly (allowing for stream configuration and access) over the entire distance all the way back downstream to the Minto Mine Road.

All traps were flagged in a specific and highly visible manner so that none would be missed during re-setting and/or recovery.

After the setting of the upstream traps was completed, a temporary fish barrier was constructed at the outlet of each of the two culverts (Minto Creek) at the road crossing at km 11. A total of 20 sandbags were used for the two barriers.

Plate 2. Temporary fish barriers placed at the outlets of Road crossing culverts – Km. 11, Minto Mine Road.

A layer of plastic Vexar® screening (1/4 ") was added and extended downstream from the barrier, aiding in the prevention of upstream fish migration. This allowed for isolation of the upstream section of the project area in terms of trapping and monitoring Catch per Unit Effort (CPUE)

September 30

Checking of the upstream traps began at approximately 11:30, starting with the upstream extent of the sets. The results from the first set of upstream traps are presented in Table 1. Traps were not set in the downstream aspect on September 29 as the access trail had not been completed at that time.

TABLE 1: Overnight Minnow Trapping Results – September 30.

Location	Date of Catch	Set Duration	Fish Captured	# Traps	Average Catch per Trap (ch)
Upstream of Culvert	September 30	Overnight	292 Ch; 1 SS	32	9.13
Downstream of Culvert	N/A	N/A	N/A	N/A	N/A

Ch = Chinook salmon fry; SS = Slimy Sculpin

No fish were captured in the traps set upstream of the suspected natural barrier, confirming it as a barrier to fish migration. Each of the 29 remaining traps, with the exception of three, contained at least one salmon fry. One trap contained 80 salmon fry.

One trap contained a single dead salmon fry. That trap was pulled and placed at another location. All traps, with the exception of the three upstream of the complete fish barrier, were re-set. No other mortalities were encountered.

During the afternoon, a fish barrier was constructed in Minto Creek in the downstream aspect of the project, near its confluence with the Yukon River. A total of 29 sandbags were used for this barrier.

Plate 3. Temporary fish barrier placed in Minto Creek near its confluence with the Yukon River.

Plate 4. Different view of the same temporary fish barrier as in Plate 3.

Location of terminal downstream Minto Creek fish barrier: 0392846 6948664

A layer of plastic Vexar® screening extended downstream from the barrier, aiding in the prevention of upstream fish migration.

This downstream barrier measured 251 cm in width and spanned the entirety of Minto Creek while providing a minimum drop of 50 cm from the surface of the water to the bottom of the sandbags.

The site for the barrier was chosen due to its relative closeness to the Yukon River, and a manageable width and depth for the purpose of installing an artificial barrier. From this point downstream to the Yukon River, Minto Creek was extremely heavily inundated with deadfall and large woody debris, to the extent that any reasonable access to and within the Creek was not available.

Immediately after the construction of the downstream barrier, a total of 16 minnow traps were set in the downstream aspect (from km 11 downstream to the barrier) of the project area. The first nine set sites were accessible by walking within the Creek, downstream from the Minto Mine Road. The remaining seven were set upstream from the barrier with the assistance of ATV access on the newly cut trail.

October 1

On the morning of October 1, all minnow traps throughout the entire project area were checked, and most were re-set with fresh bait.

At approximately 6:00 am that morning, the flow into Minto Creek had been reduced by approximately 60%, according to the pre-determined procedure for this project. A significant reduction in flow was not noticeable at this time.

The results of the overnight trapping on October 1 are presented in Table 2.

TABLE 2: Overnight Minnow Trapping Results – October 1.

Location	Date of Catch	Set Duration	Fish Captured	# Traps	Average Catch per Trap (ch)
Upstream of Culvert	October 1	Overnight	69 Ch	25	2.76
Downstream of Culvert			142 Ch	16	8.875

Ch = Chinook salmon fry

All artificial fish barriers were inspected for soundness and function.

All minnow traps were supplied with fresh bait and re-set.

October 2

All minnow traps were checked and then removed from Minto Creek, and the relocation project was suspended, pending additional supplies and personnel.

The results of the overnight trapping on October 2 are presented in Table 3.

TABLE 3: Overnight Minnow Trapping Results – October 2.

Location	Date of Catch	Set Duration	Fish Captured	# Traps	Average Catch per Trap (ch)
Upstream of Culvert	October 2	Overnight	175 Ch; 1 BB	25	7.0
Downstream of Culvert			144 Ch	16	9.0

Ch = Chinook salmon fry; BB = Burbot

A summary of effort and results from Phase I is presented in Table 4.

TABLE 4: Summary of Minnow Trapping Effort and Results – Phase I

Minto Creek Total	Trapping Period	Set Duration	Fish Captured	# Traps Set	Average Catch per Trap (ch)

Upstream @ natural fish barrier ► downstream to artificial fish barrier near Yukon River	Sept. 29 – Oct. 2	Three nights upstream; two nights downstream	822 Ch (1 found dead)	114	7.21

Ch = Chinook salmon fry

During this phase of the relocation project, a total of 822 Chinook salmon fry were captured. Eight hundred and twenty-one (821) Chinook salmon fry were released unharmed into Big Creek, a tributary of the Yukon River in the same general area as Minto Creek. One slimy sculpin and one juvenile burbot were also captured and released unharmed. Two sub-samples of Chinook fry were measured for fork length (mm). The sample sizes were 36 and 25. The respective averages of the two sub-samples (fork length) were 73.1 mm and 70.8 mm.

Nineteen Chinook salmon fry were retained for metals analyses (DFO permit #CL-09-54), but were included in the total count of 822.

Plate 5. Salmon fry about to be sampled for fork length prior to release.

Plate 6. Salmon fry captured in Minto Creek being relocated into Big Creek.

PHASE II

For a variety of reasons, including availability of necessary resources, both personnel and material, the fish relocation project was suspended for one week. Water flow in Minto Creek from the discharge continued during this interval ensuring survival of any remaining fish. The barriers only prevented fish from migrating upstream and did not prevent them from migrating downstream past the barriers and out of Minto Creek.

October 12

Phase II was initiated on the morning of October 12, employing the same basic methodology that was used during Phase I.

A total of 24 minnow traps were set in the area upstream of the culvert at km 11 on the Minto Mine Road.

A total of 17 minnow traps were set in the area downstream of the culvert at km 11. These traps were somewhat evenly distributed from the culvert to the previously installed downstream barrier.

All traps were baited with Yukon River Chinook salmon roe. All captured fish were released unharmed into the Yukon River. During Phase I, fish were released into Big Creek. This was done at the time in order to prevent the possibility of fish moving a short distance downstream from the release site on the Yukon River and being attracted back up into Minto Creek. During Phase II, the downstream barrier on Minto Creek had proven to hold fast, and all indications were that it provided a complete and formidable barrier to upstream migration. The Yukon River release site was a much closer and more conveniently accessible release site than Big Creek.

October 13

The morning of October 13 was clear and cold. The ambient temperature was approximately – 12 °C. Ice had formed overnight along the edges of Minto Creek, and the water level had risen noticeably due to downstream ice blockages. Ice had to be chipped away at almost every minnow trap site in order to retrieve them. As the water was super-chilled (below freezing), a substantial amount of crystallized, or frazzle, ice immediately formed on each minnow trap as it was removed from the water. While this caused no apparent damage to any fish trapped inside, it made the entire process of checking and re-setting traps more difficult and time consuming.

The cold ambient temperature also presented another problem. When the plastic containers used to transport captured fish out to the Mine Road were filled with Creek water, the super-chilled water immediately began to freeze when exposed to the sub-freezing air temperature. Captured fish would not be able to survive for long, as the container water immediately began to form ice crystals as it progressed to a solid block of ice. In order to circumvent this problem, several containers were filled with water taken from the Yukon River, which was still well above 0 °C. Then the containers were driven back to the culvert at km 11, and left in the vehicle with the heater on for approximately 20 minutes. This process warmed the water sufficiently to allow for the walk to the upstream terminus and back to the road without the water forming any substantial amount of ice. Also, as the day progressed, the air temperature began to rise, and eventually the sun broke into the canyon and provided moderate warmth to the opaque fish containers. The project crew made it a point to place the containers in the sun whenever they stopped to check traps. This method proved to be successful and was employed both mornings that the traps were checked (Oct. 13 and 14).

The results of the overnight trapping as collected on October 13 are listed in Table 5.

TABLE 5: Overnight Minnow Trapping Results – October 13.

Location	Date of Catch	Set Duration	Fish Captured	# Traps	Average Catch per Trap (ch)
Upstream of Culvert	October 13	Overnight	102 Ch	24	4.25
Downstream of Culvert			52 Ch	17	3.06

Ch = Chinook salmon fry

All artificial fish barriers were inspected for soundness and function. Minto Creek was just at about the same level as the top of the barrier on the morning of October 13, in the higher flow culvert. As previously mentioned, the Creek had risen overnight due to ice dam blockages downstream. The extreme downstream barrier was evaluated and determined to still be functioning as a complete fish barrier.

All minnow traps were supplied with fresh bait. Due to a very low catch rate in the upstream aspect of the upstream area of the project, eleven traps were removed from that area. The upper 2/3 of the upstream area yielded a very small number of fish, therefore emphasis was placed on the first 200 metres or so upstream of the culvert at km 11. A total of 13 traps were set overnight in the overall upstream aspect.

Due to the substantial rise in the level of Minto Creek, four traps were removed from the downstream aspect of the project area, out of concern for having safe access to them should the Creek continue to rise. As it turned out, this concern was justified. An additional trap was removed from the vicinity of the terminal downstream barrier, as it was damaged while attempting to remove it through the surface ice. A total of 12 traps were set overnight in the downstream aspect.

October 14

All minnow traps were removed from Minto Creek, and due to the significant reduction in the number of fish captured as compared to the previous day, the relocation project was considered successful, and therefore terminated at that point.

The ambient air temperature was -15 °C that morning, and the same precautions regarding water freezing in the fish containers were taken as were the previous morning.

Minto Creek had risen again overnight. The water level in the high flow culvert was measured, and found to be 28 cm above the uppermost aspect of the barrier.

The results of the overnight trapping as collected on October 14 are listed in Table 6.

TABLE 6: Overnight Minnow Trapping Results – October 14.

Location	Date of Catch	Set Duration	Fish Captured	# Traps	Average Catch per Trap (ch)	Catch Compared to previous day
Upstream of Culvert	October 14	Overnight	10 Ch	13	0.77	9.8%
Downstream of Culvert			1 Ch	12	0.08	1.9%

Ch = Chinook salmon fry

A summary of effort and results from Phase II is presented in Table 7.

Table 7: Summary of Minnow Trapping Effort and Results – Phase II

Minto Creek Total	Trapping Period	Set Duration	Fish Captured	# Traps Set	Average Catch per Trap (ch)
Upstream @ natural fish barrier ► downstream to artificial fish barrier near	Oct. 12 – Oct. 14	Two nights upstream; two nights downstream	165 Ch	66	2.5

Yukon River					

Ch = Chinook salmon fry

During this phase of the relocation project, a total of 165 Chinook salmon fry were captured. All captured fish were released unharmed into the Yukon River just upstream of the Minto Creek confluence.

Summary

During both phases of the relocation project, a collective total of 987 Chinook salmon fry were captured from Minto Creek. Accounting for one salmon mortality in the trap, and 19 retained for “metals in tissue” analysis, 967 Chinook salmon fry were removed from Minto Creek and relocated unharmed into either Big Creek or the Yukon River. In addition, one slimy sculpin and one juvenile burbot were captured and released unharmed.

During the entire relocation project, a total of 180 overnight minnow trap sets was accomplished. The last collection day yielded a total of 11 fish constituting about 1% of the number captured overall, providing confidence that well over 90% of the fish occurring in lower Minto Creek, between the natural and man-made barrier, at the time of this project had been captured and re-located

The man-made fish barriers located at the culverts at km 11, installed on September 29, were removed at approximately 2:00 pm on October 14. The barrier near the Yukon River was left in place and was to be removed following cessation of discharge of water from the mine site.

APPENDIX D

2010 MINTO CREEK MARK-RECAPTURE STUDY PRELIMINARY REPORT

BY ACCESS CONSULTING GROUP

ACCESS CONSULTING GROUP

JUVENILE CHINOOK SALMON MARK/RECAPTURE STUDY

MINTO CREEK 2010

Prepared for:

MINTO EXPLORATIONS LTD.

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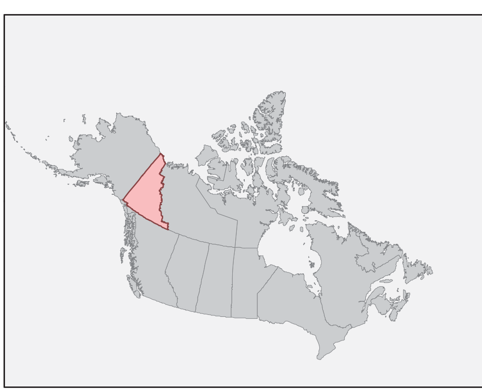
1 INTRODUCTION

Minto Explorations Ltd. (Minto), a wholly owned subsidiary of Capstone Mining Corp. (Capstone), owns and operates a high-grade copper mine (the Minto Mine), located approximately 240 km northwest of Whitehorse, Yukon(Figure 1). The project is located within Selkirk First Nation (Selkirk) Category A Settlement Land Parcel R-6A, and is centered at approximately 62°37'N latitude and 137°15'W longitude. The Minto Mine commenced commercial operation in October 2007 and is permitted to conduct mining and milling operations at a rate of 3,600 tonnes of ore per day (tpd). Minto is currently mining the Minto "Main" deposit as an open pit, which is expected to produce a total of 6.1 million tonnes (Mt) of ore and 30.5 Mt of waste during its operating life to 2011. The operating life of the mine will total 3.5 years of operation and another seven months of processing low grade ore stockpiles. The Minto orebody (copper/gold/silver) currently being mined is located in the upper reaches of the Minto Creek watershed approximately 12 km to the west of the Minto Creek confluence with the Yukon River (Figure 2).



MINTO MINE

Minto Explorations Ltd.

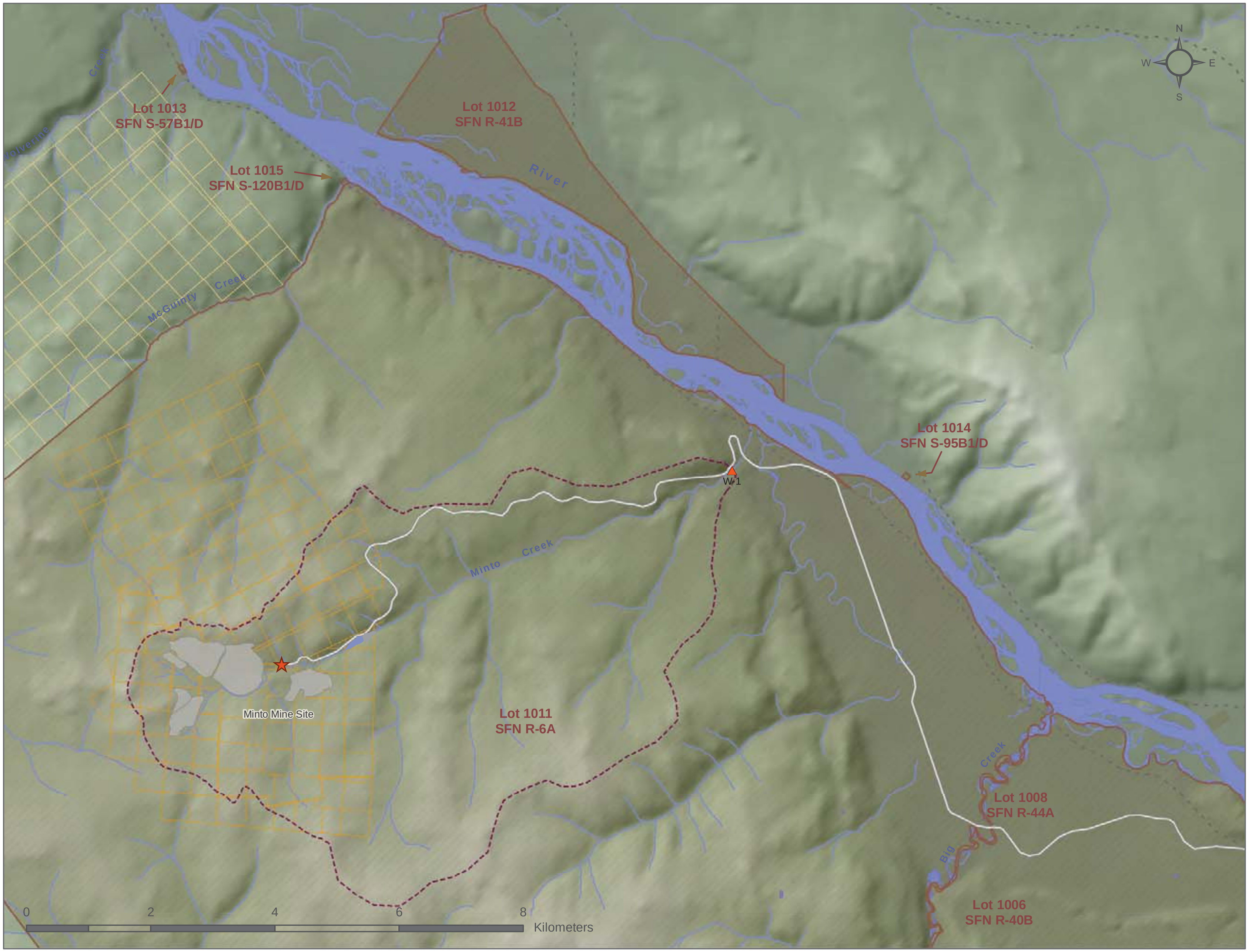
ACCESS

JUVENILE CHINOOK SALMON MARK/RECAPTURE PROGRAM MINTO CREEK 2010

FIGURE 1

PROPERTY LOCATION

YWB - July 16, 2014 - QZ14-031



MINTO MINE

JUVENILE CHINOOK SALMON MARK/RECAPTURE PROGRAM MINTO CREEK 2010

Minto Explorations Ltd.

- Minto Mine Site
- Water Quality Station
- Mine Access Road
- Road
- Trail
- Watercourse
- Contour
- Minto Creek Catchment
- First Nation Settlement Land
- Minto Explorations Ltd. Claims
- Other Claims
- Waterbody

National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Cadastral datacompiled by Natural Resources Canada. Reproduced underlicense from © Her Majesty the Queen in Right of Canada,Department of Natural Resources Canada. All rights reserved. Quartz claims data obtained from Energy, Mines and Ressources, YTG. Data currrent as of December 4th 2009. First Nation Settlement Land obtained from Geomatics Yukon, December 2010.

NAD 83 UTM Zone 8N

FIGURE 2
PROPERTY OVERVIEW

ACCESS

DRAWN BY MD	NOV 2010	VERIFIED BY DP

YWB - July 16, 2014 - QZ14-031

2 BACKGROUND

Based on fish studies conducted in Minto Creek over previous years it was determined that the system is used by several species of fish during the open-water season including juvenile chinook salmon (JCS). These studies have been intermittent throughout the open water season over several years and although they give a good indication of fish usage and presence in the system they do not indicate how that usage varies throughout the season and how dynamic the JCS population, the most prominent group, is in terms of its migratory pattern in and out of the creek.

In order to better understand the dynamics of the JCS population using Minto Creek, a mark/recapture study was undertaken in the summer/fall of 2010. The study was developed to determine how use of the system by JCS changes throughout the open-water season and to determine how long individual fish may stay in the creek system (i.e. residency time).

2.1 FISH COMMUNITY

Attempts to collect fish in lower Minto Creek while conducting the Phase 1 Metal Mining Effluent Regulation, Environmental Effects Monitoring (EEM) study in 2008 resulted in the capture of no fish during the month of June and very few fish during the month of September. This is consistent with the findings of previous fish investigations conducted in the creek (HKP 1994; R&D 2006, 2007). Fish use of Minto Creek is transient and likely short-lived as has been found in other non-natal Chinook rearing creeks (Walker 1976; Scrivener et al. 1994). Minto Creek does not provide preferred spawning habitat for fish and the fact that it completely freezes during winter months, with no winter flow in lower Minto Creek, negates its suitability for spawning by Chinook salmon. Accordingly, there is no evidence of spawning in Minto Creek (HKP 1994; R&D 2006, 2007), nor is there traditional knowledge indicating spawning occurring in the system (HKP 1994).

Although water flows are adequate to support fish during the spring it appears that fish do not enter Minto Creek until early summer (late June/early July), once water temperatures in the creek rise and equilibrate with that of the Yukon River. Lower Minto Creek is also subject to low or zero flow conditions during periods in the summer when a portion (or all) of the flow sometimes infiltrates the ground following passage through a canyon located approximately 2.0 km upstream of the Yukon River.

When fish have been captured in the creek, the majority of them tend to be juvenile chinook salmon (Onchoryhnchus tshawytscha). Other species that have been found in the creek in low numbers include round whitefish (Prosopium cylindraceum), arctic grayling (Thymallus arcticus), slimy sculpin (Cottus cognatus) and burbot (Lota lota). Fish sampling events conducted in 1994, 2006, 2007 (summarized in the Phase 1 EEM study design; Minnow/Access 2007) and as part of the Phase I EEM study in 2008 (Minnow/Access 2009; Table 2.6) yielded both low numbers of fish and catch-per-unit-effort (CPUE).

During the summer of 2009, the Minto Mine was given authorization to discharge effluent from the site under an amendment to its Water Use License. This resulted in a substantial increase in water flow-rate in Minto Creek for a sustained period from June 26th through October 30th. Fish sampling conducted during this discharge period indicated that fish (juvenile Chinook salmon in particular), were possibly being attracted by the higher flow in Minto Creek and/or the temperature differential between Minto Creek and the Yukon River resulting from the discharge. This was apparent in a marked increase in CPUE using minnow traps. The numbers of fish entering Minto Creek as a result of the discharge were substantial enough for Fisheries and Oceans Canada (DFO), Whitehorse Office, to direct the company to undertake a fish re-location program on lower Minto Creek and establish a fish barrier near the Yukon River confluence in order to prevent additional fish from moving into Minto Creek. DFO was concerned that the fish could become stranded in Minto Creek following cessation of the discharge. The fish re-location project was undertaken from late September through early October and resulted in the capture of 987 juvenile Chinook salmon. At the beginning of the re-location, some minnow traps were yielding catches as high as 80 individuals per minnow trap in an overnight set. Prior to this, the most salmon captured in a sampling event (excluding those captured at the Yukon River confluence), including the application of both electrofishing and multiple minnow trapping effort was 17 (Minnow/Access 2009).

2.2 RECEIVING ENVIRONMENT (LOWER MINTO CREEK)

Minto Creek is an ephemeral watercourse with a mainstem length of approximately 17 km, flowing northeast to its confluence with the Yukon River (Figure 2). Flows in Minto Creek are generally characterized by peaks in the spring during freshet and lows in the summer. Minto Creek freezes and glaciates in the winter and has been observed to be entirely dry in the lower reaches in the mid-late summer. Sizeable floods may also occur in the summer as a result of significant precipitation events. Minto Creek has five main tributaries, four of which join the Minto Creek mainstem upstream of the canyon (Figure 2).

Using the Cowardin et al. (1979) classification system, Minto Creek is an upper perennial riverine system with a sand-gravel-cobble substrate. The topography of the area is dominated by rounded hills, with discontinuous permafrost areas on most of the north-facing slopes in the upper watershed. In-stream aquatic vegetation is sparse, likely due to seasonal scouring and glaciation.

The creek ranges from 2-3 m in wetted width and 0.5-1.5 m in depth. Minto Creek has two distinct reaches – upper and lower – which are divided by a steep canyon of gradient 21%. The upper reach ranges in gradient from 6% at the headwaters to 1.5% just above the canyon. The history of forest fires in the vicinity has contributed significant large organic debris (LOD) loading to this reach, and vegetative cover is still recovering from the last burn in 1995. The substrate is primarily fine (silt/sand) with some cobble/gravel sections in this area of primarily riffle/run morphology with few pools. Recent investigations have also documented areas where creek flows in whole or in part migrate below the surface (hyporheic flow) and re-emerge downstream. This has been observed at low-flow conditions. The lower reach is approximately 2 km long, with substantial large organic debris (LOD) and vegetative cover, with mostly silt/sand substrate, with few cobbles and gravels. The lower section of this reach contains backwater from the Yukon River, and the access road to the Mine site crosses the creek which flows through a double culvert. Cut-banks and riffle/run morphology, with some pools, dominate the habitat of this reach. Gradient in this section ranges from 1.5% to 6% at the base of the canyon, where the substrate changes to mostly cobbles and boulders and the habitat is erosional. Elevations of the lower reach drop from 493 m at the base of the canyon to 448 m at the mouth of the creek at the Yukon River confluence.

During fish studies conducted in 2009 a natural barrier to fish passage was located approximately 1.2 km up from the Yukon River confluence. This barrier consists of a buildup of organic debris resulting in a small waterfall > 40 cm in height. This barrier may not be permanent and subject to change in future years due to erosion and/or high water events.

3 2010 FISH MARK-RECAPTURE PROJECT – MINTO CREEK

The mark-recapture study was conducted during the summer/fall of 2010 between June 28 to November 3, 2010. During this time frame the study involved 9 site visits and trapping events. Of these the first six events, up until September 9 involved marking of fish at approximately two week intervals. No further marking was done after the September 9 marking, however three further trapping events were conducted in order to re-capture marked fish. Procedures used for the mark/recapture program are presented below.

3.1 MARK-RECAPTURE PROCEDURE

During each trapping event, minnow traps baited with Yukon River salmon roe were placed in 16 suitable trapping locations in lower Minto Creek, from immediately upstream of the natural fish barrier (site 024), to about 400m downstream of the culvert at km 11 of the Minto Mine Road (site 013), and left overnight (soak time ranging from 18 to 26 hours). The same sites (Figure 3) were used throughout the duration of the project.

The general procedure for checking the traps and subsequent fish marking is outlined below:

- Due to the time and effort required to set up a "marking" site, and the actual fish marking procedure, all fish were transported to one of the two designated fish marking sites at a) the culvert at km 11 and b) site 019, as indicated above.

- Fish captured in the downstream portion below the culvert (4 traps), and two traps immediately upstream of and in the vicinity of the culvert (2 traps), were collected and transported by bucket to the culvert at km 11, where they were distributed into two – three minnow traps and placed back into the Creek in a calm, shady backwater area. They were held in this location until the marking procedure was initiated, which occurred later in the day.

- Fish captured at sites 017, MIN-W1, and 018 were transported via bucket upstream to 019 where they were distributed among minnow traps and left in a large pool, along with the fish already captured at 019.

- Fish captured from the upstream extent of the sampling area (sites 020 – 024 and MCb1) and transported back downstream to site 019.

- The marker dye used was the commercially available fluorescent Visible Implant Elastomer (VIE – Northwest Marine Technologies®), and had been previously used and approved by DFO Canada. The marker was prepared by mixing two components together. This was done immediately prior to marking in order to obtain the maximum amount of use before the polymer began to harden. Throughout the course of the marking events, it was determined that the useful life of the polymer was approximately 1.5 hours, depending on ambient temperatures. Higher temperatures caused the polymer to harden more quickly, and rendered unsuitable for injection.

- The fish that had been left in the traps in the Creek for holding were moved to a holding bucket in appropriate numbers.

- Approximately 10 - 15 fish were moved to a pre-anesthetic bucket containing a measured amount of an approved fish anesthetic, MS-222 (Tricaine Methanesulfonate).

- A small number of fish were moved from the pre-anesthetic bucket to the anesthetic bucket, which contained a higher concentration of MS-222.

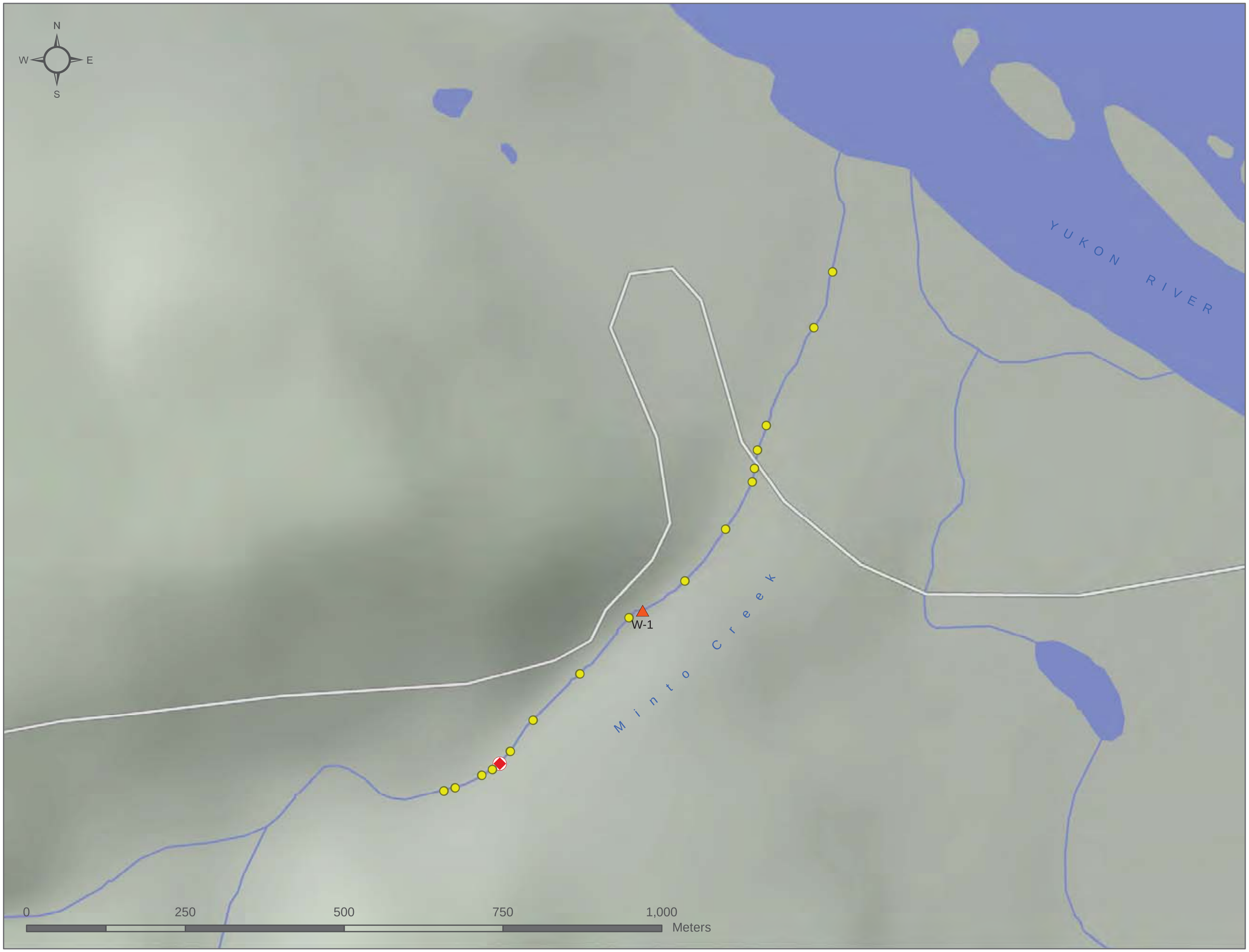
- As the fish began to experience advanced Stage II level of anesthesia, they were removed from the anesthesia bucket individually and the marker was injected just under the outer epidermal layer. The marking procedure involved injecting a miniscule amount of a fluorescent marker dye just under the skin.

- Each marked fish was then passed to a second operator and measured for fork length.

- The fish were then placed into the recovery bucket.

- The recovery bucket, as well as the anesthetic and holding buckets, were monitored constantly by a third operator. Once the fish had recovered adequately, they were released back into the Creek.

- Care was taken at all times to ensure that the level of anesthesia, the progression of recovery, the temperature, and oxygen levels of the water in all holding containers were optimum.



MINTO MINE

JUVENILE CHINOOK SALMON MARK/RECAPTURE PROGRAM MINTO CREEK 2010

Minto Explorations Ltd.

- Capture Location
- Fish Barrier
- Water Quality Station
- Mine Access Road
- Watercourse
- Waterbody

NAD 83 UTM Zone 8N

FIGURE 3
CAPTURE LOCATIONS

ACCESS

DRAWN BY MD	NOV 2010	VERIFIED BY DP

4 RESULTS AND DISCUSSION

The colors used for marking (fluorescent pink and fluorescent orange) and locations of the marker varied at each event, allowing for the identification of the marking date in the event that fish were recaptured. Only one combination of marker color and location was used on two different marking events, i.e. pink marker behind the left eye. Table 1 below summarizes the number of fish caught and marked and the specific marking designation during each event.

Table 1 Fish Marking Summary

Date	Marker Color	Mark Location	# chinook caught	# caught cumulative	# marked	% marked	# marked cumulative
29-Jun	n/a	n/a	0	0	0	0.0	0
14-Jul	Orange	Right Eye	65	65	61	93.8	61
28-Jul	Pink	Left Eye	428	493	254	59.3	315
11-Aug	Pink	Right Eye	498	991	284	57.0	599
24-Aug	Pink	Left Eye	403	1394	270	67.0	869
9-Sep	Pink or Orange	Dorsal fin - right side	241	1635	199	82.6	1068
21-Sep	n/a	n/a	192	1827	0	0.0	1068

Right eye = immediately posterior to the eye on the right side
Left eye = immediately posterior to the eye on the left side
Dorsal fin = adjacent to the base of the dorsal fin on the indicated side

All 16 trapping sites, with their general characteristics, are listed in Table 2. Note that the water depth indicated was measured on September 30, and that it varied somewhat throughout the duration of the project, primarily due to precipitation events.

Table 2 - Trapping Site Locations and General Characteristics

Site	Latitude	Longitude	Depth (cm)	Substrate	Cover	Flow
013	62.65420477	-137.09300992	41	sand (75%), silt (25%)	sparse/open	pool
014	62.65340874	-137.09371467	63	gravel (10%), sand (75%), silt (15%)	sparse/open	pool
015	62.65201760	-137.09498713	59	gravel (50%), sand (50%)	sparse/open	pool
016	62.65168064	-137.09540446	29	gravel, sand	open	pool
025	62.65154402	-137.09554612	33	cobble, gravel	open	pool
026	62.65139088	-137.09560764	33	cobble, gravel, sand	sparse/open	pool/slight flow
017	62.65049737	-137.09603688	30	boulder, cobble, gravel, sand	moderate	pool
018	62.64954946	-137.09681036	25	fine gravel, sand	open	pool
Minto W1	62.64909759	-137.09856184	30	sand, silt	open	pool
019	62.64834833	-137.10028114	44	sand, silt	open	slight
020	62.64768155	-137.10165116	28	fine gravel, sand	moderate/sparse	pool
021	62.64720546	-137.10215835	52	gravel, sand	sparse	pool/slight flow
022	62.64693883	-137.10293116	28	cobble, gravel, sand	sparse/open	slight/ moderate flow

Site	Latitude	Longitude	Depth (cm)	Substrate	Cover	Flow
023	62.64707990	-137.10340457	43	sand	moderate	pool
MCb1	62.64699390	-137.10436120	39	gravel, sand	moderate	slight
024	62.64722717	-137.10454049	n/a	n/a	moderate	pool

4.1 FISH CAPTURE

In 2010, Minto Mine conducted a controlled discharge of treated water into Minto Creek from July 15 until November 2. This resulted in a more consistent flow regime throughout this period with a mean daily average discharge of 0.114 m3/s in lower Minto Creek (W1). Minimum daily average discharge during this period was 0.052 m3/s. It appears – as during a controlled discharge in 2009 – that more fish (JCS in particular) may have been attracted into the system than under a normal natural flow regime. Thus the numbers of fish captured over the course of the study were much higher than in previous years (except for 2009).

A total of 1,635 chinook salmon were captured throughout the mark/recapture study over 7 trapping events from June 29 to September 9. Of these, 1,068 received a mark representing approximately 65.3% of the number of fish captured during the marking portion of the study. An additional 671 fish were captured during three subsequent trapping sessions (September 21, October 1 and November 3.) Fish captured during these sessions were observed for marks.

No fish were captured during the first sampling event on June 29. The maximum number captured was 498 on August 11. Numbers captured after this date dropped up until the October 1 sampling event (Figure 1). The last sampling event (November 1 to 3) was conducted in order to re-locate fish from Minto Creek to the Yukon River and thus more traps were set, and left soaking over a longer period, than during the mark/recapture program. Expectedly, this returned a higher catch (371 JCS) relative to the previous trapping events throughout the season.

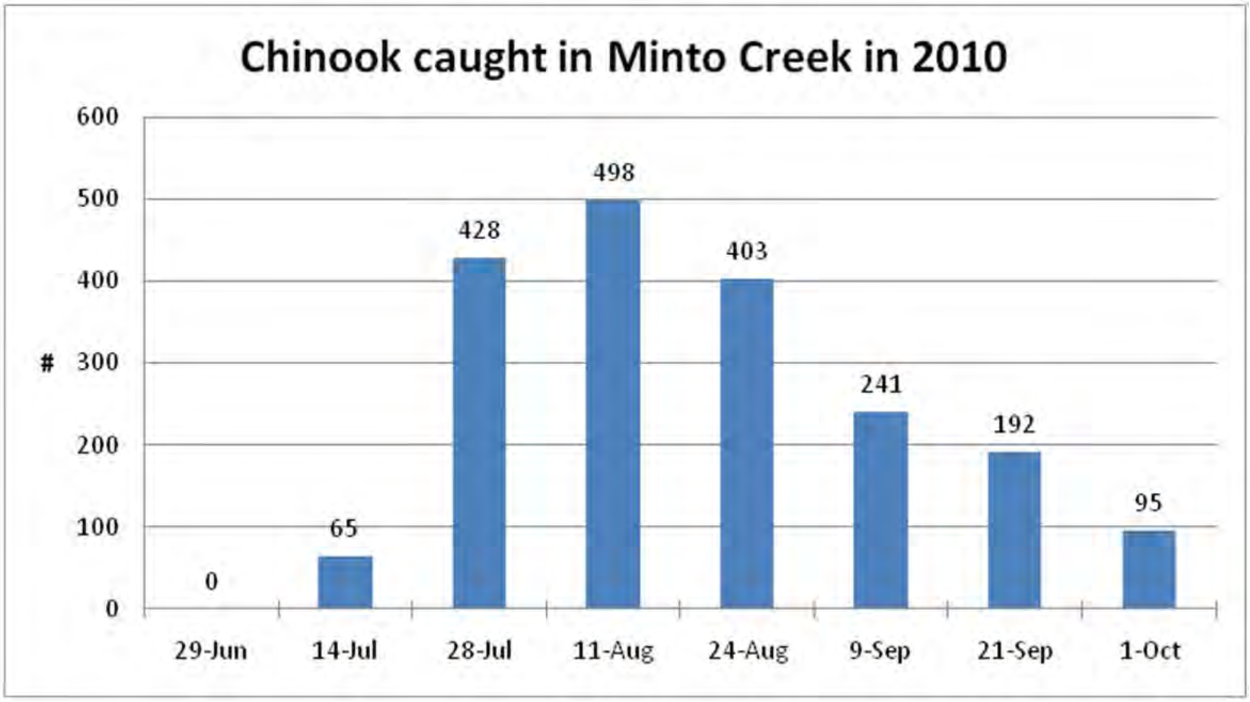


Figure 4 Actual number of juvenile chinook salmon captured during the 2010 mark/recapture study. Catch based on consistent catch per unit effort

During a fish re-location program conducted in 2009 a fish barrier was identified on Minto Creek approximately 1.2 km up from the haul road (see Figure 2) . Traps were set above this barrier during each of the trapping sessions in 2010, and as in 2009 no fish were captured upstream of this barrier.

In 2009 a fish re-location program was undertaken in order to avoid potential stranding of fish in Minto Creek subsequent to cessation of flow from a controlled discharge from the mine site. This re-location program involved constructing a barrier on Minto Creek near the Yukon River which prevented fish from migrating upstream. Following establishment of the barrier, most fish (estimated > 95%) were captured and released in a new location. The capture data from the first 24 hours of this program was used to develop a 24 hour Catch per Unit Effort Index for estimating total population of JCS in Minto Creek during the 2010 program as the total population (within 5%) was determined in 2009.

Fish re-location program 2009:

Total Overnight Capture (First Set):	434
Total Number Captured:	987
CPUE Ratio:	2.3

For the purpose of this population estimate the ratio has been adjusted to 3:1 (est. population: # captured in first overnight set) to account for the fact that more traps were set during 2009 fish re-location program first overnight set. Trap sites selected during the 2010 mark/recapture program however were biased towards the best capture locations and therefore the adjusted ratio is not a direct multiple of the number of traps used between years.

Using the population estimate ratio the maximum population estimated for Minto Creek during 2010 is approximately 1500 JCS on August 11 (Figure 5).

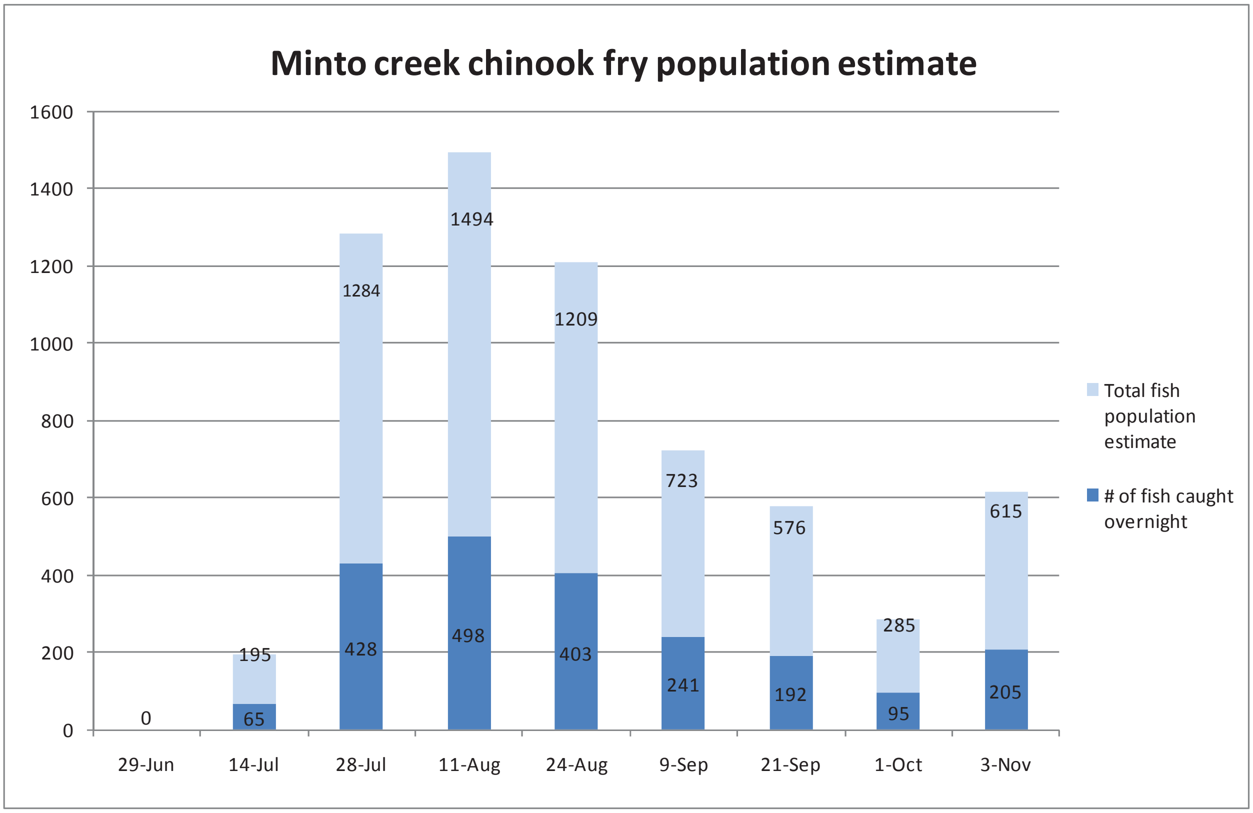


Figure 5 Juvenile Chinook salmon fry population estimate in Minto Creek 2010

After the first event when fish were marked (July 14) each fish captured was observed for presence of mark on all subsequent capture events. A total of 109 previously marked fish over seven sampling events (after July 14) were captured (Table 1). Of these nine fish had been marked twice (i.e. recaptured on two events subsequent to being marked).

The 100 unique individuals that were recaptured were considered in terms of the length of time, at a minimum, they were resident in Minto Creek. Taking into account that a duplicate tag (colour and mark location) were used on 28th of July and 24th of August a range of residency as a percentage of total estimated population is presented in Figure 6. This data indicates that most individuals do not spend an extended amount of time in Minto creek. Less than 10% of the population remained in Minto Creek for more than two weeks after being marked. Less than 1% remained for 10 weeks or more. Conversely this suggests that 90% of the population left the creek after two weeks and 99% were gone after 10 weeks. A few of the marked individuals (3) were still present in the creek after 12 weeks. It is important to note a number of assumptions that have been made when reviewing the data. These assumptions include:

- No lost marks
- All re-captured marked fish were noted
- No increase in mortality associated with marking the fish
- The population estimate is reasonably accurate

It is also important to note that the residence time is based on the length of time between when the fish was marked and recaptured. The amount of time the fish had been in the creek prior to being marked is unknown. However it is known that any fish marked were not likely in the creek prior to June 30 as no fish were captured during the June 29th sampling event.

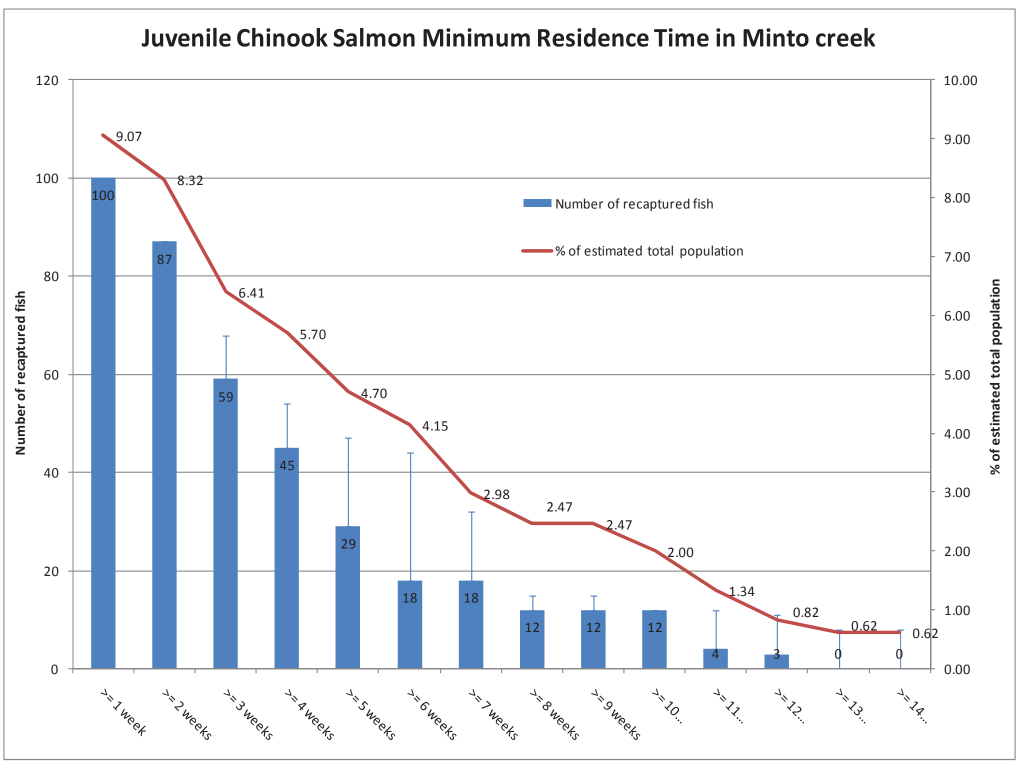


Figure 6 Minimum residence time of recaptured juvenile Chinook salmon in Minto Creek, 2010

This is consistent with research done on other groups of JCS using non-natal streams for rearing. Scrivener et al. determined the average residency time for JCS rearing in a non-natal stream in the upper Fraser River watershed to be 9 days.

4.2 FISH GROWTH

During the mark/recapture study a subsample of fish captured were measured for fork-length (FL) in order to monitor their growth over the course of the study. Average FL at the beginning of the study (July 14) when JCS were first captured was 64.2 mm (Figure 7). Growth rate leveled off towards the end of August, (likely a reflection of cooling water temperature) with a maximum FL noted on September 21 of 74.6 mm. Average FL was slightly lower in the sample measured on October 1 which may reflect the transient nature of the population. A study conducted in Croucher Creek Yukon in 1993 (Moodie et. Al.) determined a mean FL of 71 mm for JSC in that system at the end of October.

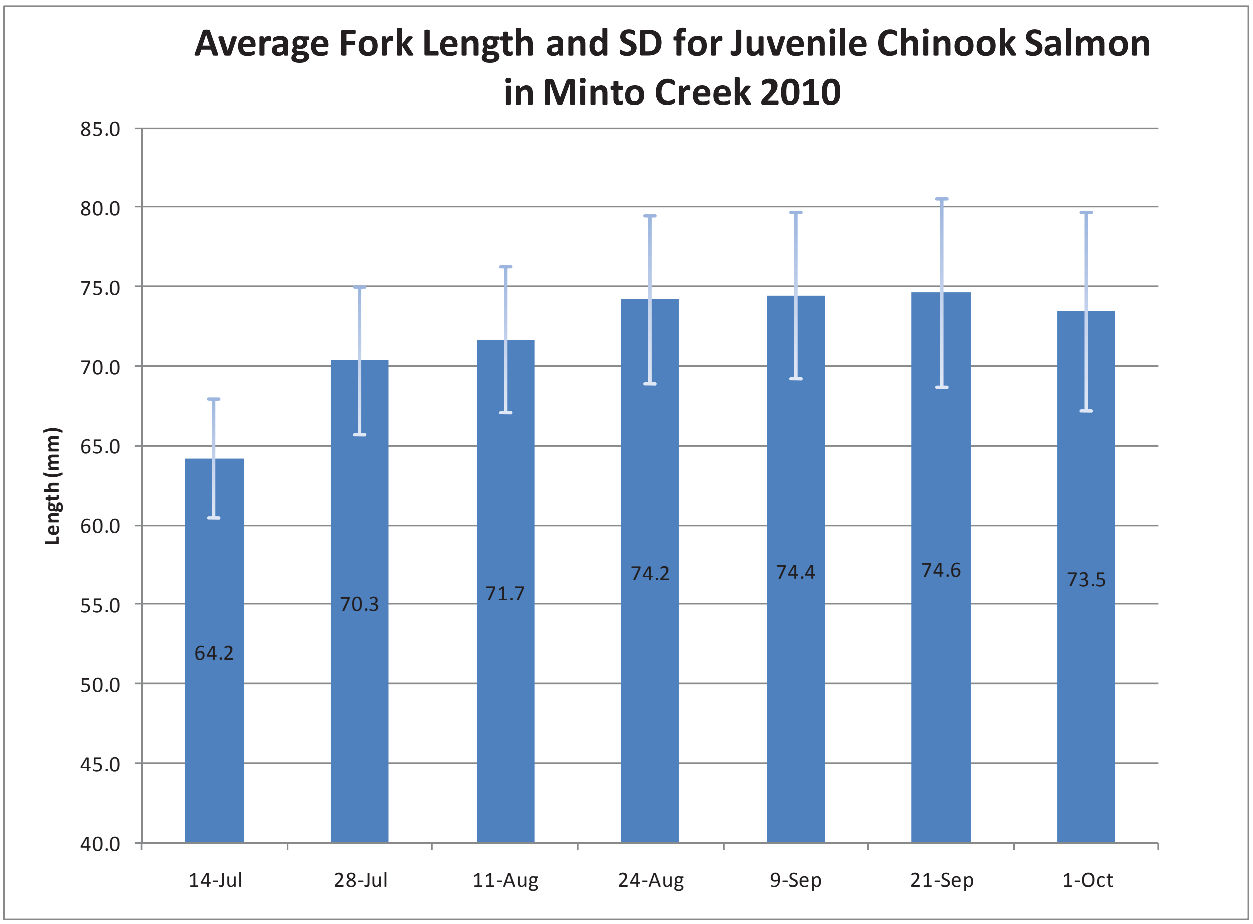


Figure 7 Average fork length (mm) and standard deviation for juvenile Chinook salmon captured in Minto Creek, 2010.

5 SUMMARY

No juvenile chinook salmon or other species were encountered in Minto Creek during a late June sampling event. This is consistent with previous studies in that few fish if any have been encountered in the creek prior to July. During this study fish were still present in the system in early November.

Numbers of chinook salmon increased on subsequent events from July 14 until August 11 when the peak number were captured. The estimated population of JCS in the creek at this time was about 1,500 after which the numbers declined. The number of fish captured in 2009 and 2010 were much higher on a "catch per unit effort" basis than in years previous to 2009. As in 2009 Minto Mine was influencing the flow regime in Minto Creek through a controlled water discharge from the mine site throughout much of the summer until early November 2010. This likely influenced an increased use of the system by juvenile chinook salmon.

Analysis of marked fish recaptured indicates that much of the population does not remain in the creek for an extended period of time and that there is a high degree of immigration and emigration of the population in the creek. The data suggests that 90% of the population may only spend up to approximately two weeks in the system. Only a few individuals (1%) spent an extended period of time (> 12 weeks) in the system.

JCS growth leveled off towards the end of August, likely a reflection of cooling water temperatures. Overall however, the growth of individuals in the system is consistent with JCS populations in other tributaries of the Yukon River.

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APPENDIX E

MINTO MINE DETAILED SEDIMENT QUALITY RESULTS, 1994

Results of Stream Sediment Survey+ Conducted for Minto Exploration Ltd.'s IEE (HKP, 1994), Adapted from Table 5.9 of MintoEx's IEE (HKP 1994)

Analysis	Sampling Station															
	S1 (W9)				S2 (W3)				S3 (~100 m d/s W6)				S4 (W2)			
	Replicate				Replicate				Replicate				Replicate			
	a	b	c	AVG	a	b	c	AVG	a	b	c	AVG	a	b	c	AVG
Physical Tests:																
Moisture %	24.50	27.50	23.70	**25.23**	25.30	20.40	19.40	**21.70**	23.00	24.30	25.00	**24.10**	21.00	18.10	16.30	**18.47**
Total Metals:*																
Antimony	0.45	0.31	0.33	0.36	0.46	0.36	0.44	0.42	0.38	0.49	0.45	0.44	0.32	0.29	0.25	0.29
Arsenic	4.59	4.62	3.01	4.07	4.16	4.59	4.17	4.37	4.25	3.85	4.56	4.22	4.57	4.66	4.09	4.44
Cadmium	0.11	0.11	<0.1	0.07	0.12	0.15	0.12	0.13	<0.1	<0.1	<0.1	0.00	<0.1	<0.1	<0.1	0.00
Chromium	17.40	19.30	14.90	17.20	25.30	19.70	21.40	22.13	24.00	21.50	24.40	23.30	13.40	15.00	13.70	14.03
Copper	113.0	104.0	91.40	102.8	46.70	49.00	49.10	48.27	41.50	39.00	40.90	40.47	14.20	14.20	13.00	13.80
Lead	3.10	4.00	3.00	3.37	3.90	4.10	3.80	3.93	3.90	3.70	3.90	3.83	2.60	2.20	<2.0	1.60
Mercury	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01
Molybdenum	<4.0	<4.0	<4.0	0.00	<4.0	<4.0	<4.0	0.00	<4.0	<4.0	<4.0	0.00	<4.0	<4.0	<4.0	0.00
Silver	<2.0	<2.0	<2.0	0.00	<2.0	<6.0	<2.0	0.00	<2.0	<2.0	<2.0	0.00	<2.0	<2.0	<2.0	0.00
Zinc	34.30	38.00	34.90	35.73	47.20	49.10	47.10	47.80	47.20	46.50	51.90	48.53	30.40	28.90	29.00	29.43
Particle Size:																
Gravel - % (>2.00 mm)	8.39	10.50	8.84	9.24	5.36	4.39	4.95	4.90	2.58	1.24	1.43	1.75	25.00	27.50	34.00	28.83
Sand - % (2.00–0.063 mm)	74.00	72.60	69.90	72.17	75.30	75.20	75.10	75.20	78.80	77.70	77.10	77.87	65.40	64.00	58.50	62.63
Silt - % (0.063 mm-4 µm)	13.10	12.80	16.30	14.07	13.60	14.20	14.00	13.93	12.30	14.80	15.20	14.10	7.59	6.56	5.74	6.63
Clay - % (<4 µm)	4.47	4.16	5.02	4.55	5.79	6.24	5.91	5.98	6.39	6.24	6.31	6.31	1.99	1.93	1.75	1.89

+Values expressed are means

+ Results are expressed as milligram per dry kilogram

Adapted from Table 5.9 in

APPENDIX F

MINTO CREEK SEDIMENT, PERIPHYTON AND BENTHIC INVERTEBRATE COMMUNITY ASSESSMENT, MINNOW ENVIRONMENTAL, 2012–2013

Minto Creek Sediment, Periphyton and Benthic Invertebrate Community Assessment - 2011

Report Prepared for:

Minto Explorations Limited
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Vancouver, BC
V6C 2W2

Report Prepared by:

Minnow Environmental Inc.
101-1025 Hillside Ave.
Victoria, BC
V8T 2A2

March 2012

Minto Creek Sediment, Periphyton and Benthic Invertebrate Community Assessment - 2011

Report Prepared for:

Minto Explorations Limited

Report Prepared by:

Minnow Environmental Inc.

Jocelyn Kelly, M.Sc.
Project Manager

Pierre Stecko, M.Sc., EP, RPBio
Project Principal

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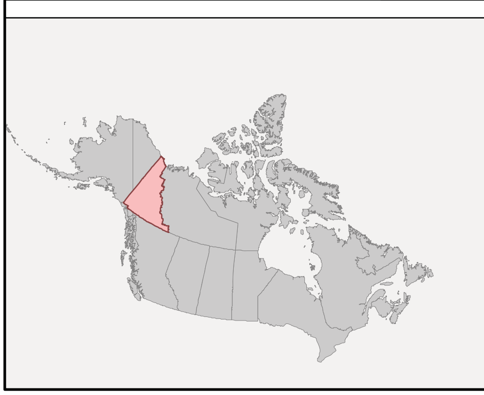
1.0 INTRODUCTION

1.1 Site Description

The Minto Mine is a high-grade copper mine located within Selkirk First Nation (SFN) Category A Settlement Land Parcel R-6A approximately 240 km northwest of Whitehorse, Yukon Territory (62°37'N latitude and 137°15'W longitude; Figure 1.1). It is owned and operated by Minto Explorations Ltd. (MintoEx), a wholly owned subsidiary of Capstone Mining Corporation (Capstone). Development of the mine was initiated in 1997, commercial operations started in October 2007 and the anticipated operating life is to the year 2020. The facility is permitted to conduct open pit mining and milling at a rate of 3,600 tonnes of copper/gold/silver ore per day, which is currently expected to produce a total of approximately 6.1 million tonnes (Mt) of ore and 30.5 Mt of waste (e.g., waste rock and tailings) during the mine's operating life. Precipitation and surface water runoff from the tailings deposit and mine operational area, as well as treated mine water, are collected in a Water Storage Pond (WSP; Figure 1.2). Effluent from the WSP is periodically discharged into Minto Creek under conditions specified in Water Use Licence (WUL) QZ96-006 (Amendment 7, March 2011). Minto Creek, in turn, discharges to the Yukon River approximately 12 km south-east of the mine site (Figure 1.2). Starting in 2012, mine-impacted water will be collected at the Minto Creek Detention Structure (Figure 1.2) and pumped to the water treatment plant or the open pit with the aim of eliminating its direct flow to the WSP.

1.2 Background

Under the WUL, the Minto Mine implements a routine water quality surveillance program within Minto Creek and reference tributaries at sampling frequencies that vary from weekly to monthly during the ice-free period (typically from April to October or November). In accordance with the WUL, the Minto Mine submits water quality data as original laboratory reports and monthly summary reports within 30-days of month-end. Water quality monitoring data have indicated that total suspended solids concentrations can rise dramatically during high flow events and concentrations of a number of metals (including aluminum, chromium, copper and iron) are concurrently higher than national water quality guidelines for the protection of aquatic life even under background and reference conditions (e.g., HKP 1994; Minnow 2009a, 2010a, 2010b). Recent analysis of routine water quality data and water quality data collected in September 2011 (Minnow/Access 2012) documented an influence of the Minto Mine on Minto Creek, even in the absence of mine effluent discharge, as evident in conductivity and in concentrations of nitrate,



MINTO PROJECT

Minto Explorations Ltd.
A SUBSIDIARY OF CAPSTONE MINING LTD.

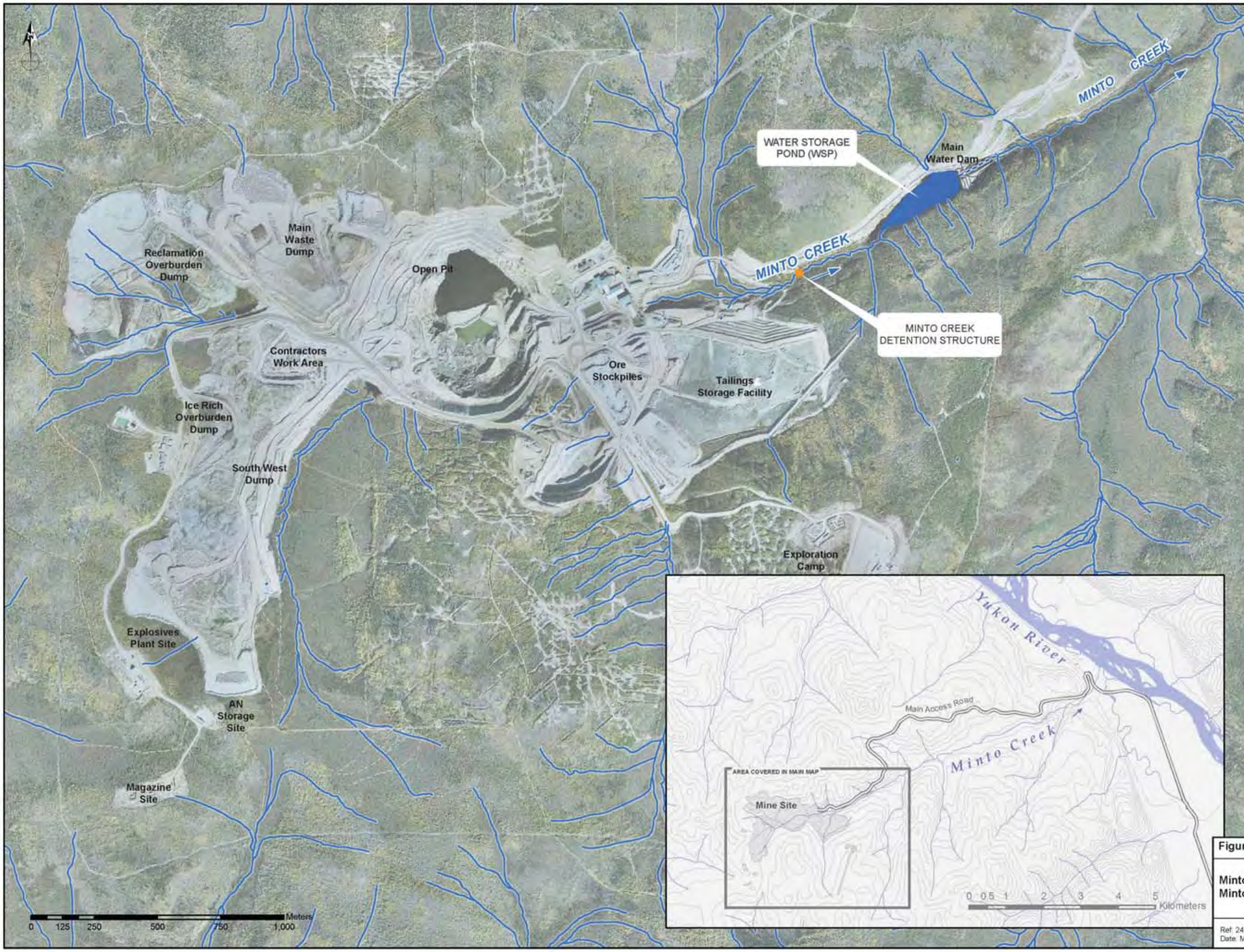
ACCESS
CONSULTING GROUP

Figure 1.1

minnow environmental inc.

Location of the Minto Mine

Ref: 2414YWB - July 16, 2014 - QZ14-031
Date: March 2012
Source: Access Consulting Group



MINTO MINE

Minto Explorations Ltd.

A SUBSIDIARY OF CAPSTONE MINING LTD

ACCESS

Aerial imagery obtained from Challenger Geomatics.
Imagery acquired September 9th 2011.
Hydrology data provided by Minto Explorations Ltd, May 2010.

Inset topography compiled by Natural Ressource Canada.

Projection : UTM Zone 8N
Datum: NAD 83

Figure 1.2

minnow

Minto Mine Site and Receiving Environment, Minto Mine WUL, 2011

Ref: 2414 YWB - July 16, 2014 - QZ14-031
Date: March 2012
Source: Access Consulting

sulphate, chloride, molybdenum and sodium that were greater in Minto Creek than at reference areas. During effluent discharge, concentrations of bromide and nitrite, and to a lesser extent, selenium and total Kjeldahl nitrogen (TKN), were also elevated in Minto Creek relative to reference concentrations. Although mean concentrations of a number of analytes were above water quality guidelines in Minto Creek over the 2009-2011 period, only nitrate and selenium were consistently greater than both guidelines and reference (Minnow/Access 2012).

The Minto Mine also implements annual biological monitoring under the WUL, which includes monitoring of sediment, periphyton, benthic invertebrates, fish and fish habitat. Biological monitoring programs have been modified over time, but data from 1994 (baseline) and 2006-2010 and have been reported previously. The most recent sediment and benthic program conducted in September 2010 demonstrated that sediments of Minto Creek had concentrations of several analytes that were greater than Interim Sediment Quality Guidelines (ISQGs) for the protection of aquatic life (or "Threshold Effect Levels"; Minnow 2011). However, only copper was elevated at effluent-exposed areas (in Minto Creek) to concentrations greater than ISQGs, baseline and reference. This indicated that the Minto Mine has caused an increase in sediment copper concentrations to a level that cannot be considered protective across all species and ecosystems. Subtle differences in depositional benthic invertebrate community composition between Minto Creek and the reference area (lower Wolverine Creek) were generally suggestive of slightly different habitat characteristics, with some evidence of stimulation potentially due to the higher temperature and nutrient concentrations of Minto Creek (Minnow 2011). Overall, most benthic invertebrate endpoints differed in a direction indicative of a healthy depositional benthic invertebrate community in Minto Creek (Minnow 2011).

1.3 Objectives

The objectives of this study and report are to characterize and interpret current sediment quality, periphyton community condition and benthic invertebrate community condition of Minto Creek relative to reference conditions and conditions documented in previous years.

1.4 Report Overview

This report is presented in eight sections, the first of which is this introduction (Section 1.0). Section 2.0 presents the methods used in sample collection, sample analysis and data analysis. Section 3.0 provides a description of the sampling areas and a summary of supporting physical and chemical data collected in the field. Section 4.0 provides the sediment quality results. Section 5.0 provides the periphyton community results. Benthic invertebrate community results are presented in Section 6.0. Conclusions and recommendations of the study are provided in Section 7.0. All the references cited throughout this report are listed in Section 8.0.

2.0 METHODS

Minnow Environmental Inc. implemented the Minto Creek sediment, periphyton and benthic invertebrate community assessment from September 10th to 14th, 2011 with the assistance of Minto Mine staff. The study design (Table 2.1; Figure 2.1) was submitted to the Yukon Water Board in June 2011 in accordance with the Minto Mine Water Use Licence (QZ06-006 - Amendment 7) and included some changes relative to previous WUL biological monitoring (2006-2010) as recommended in the most recent interpretive report (Minnow 2011). Sediment sampling was undertaken in upper Minto Creek, lower Minto Creek and corresponding reference areas (Table 2.1; Figure 2.1). Periphyton and benthic invertebrate community sampling were undertaken in erosional habitat of lower Minto Creek and a corresponding reference area (Table 2.1; Figure 2.1). Supporting measures (e.g., habitat characteristics, field meter measures, etc.) were collected at all sampling stations.

2.1 Supporting Measures

2.1.1 Field Collection

A number of environmental variables were measured to support the sediment quality, periphyton community, and benthic invertebrate community data collected for the Minto Creek assessment. The location of each station was recorded using a Geographic Positioning System (GPS) with coordinates recorded in latitudes and longitudes (degrees, minutes and decimal seconds using the North American Datum of 1983).

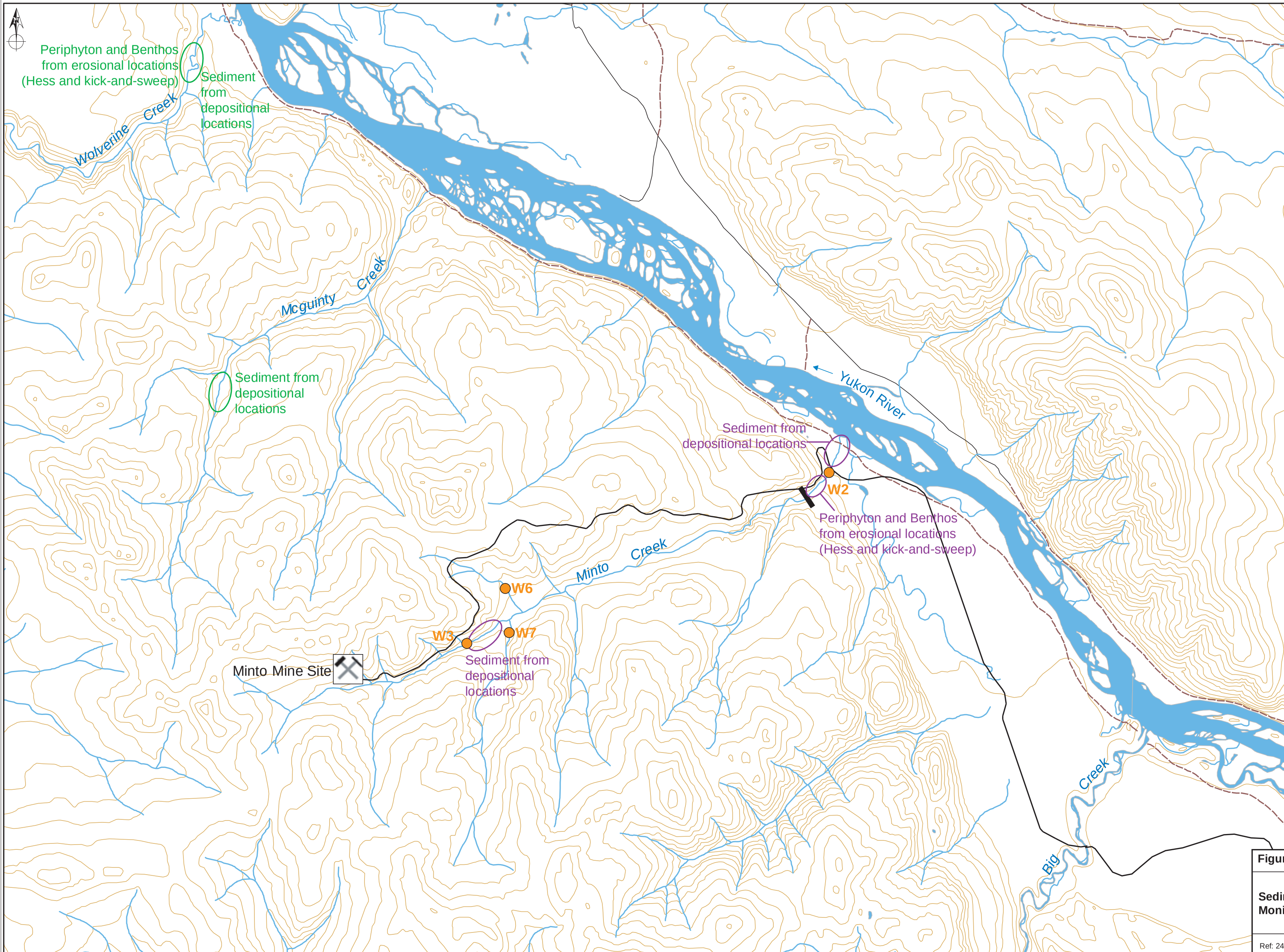
Additional supporting measures collected concurrent with sediment sampling (i.e., at depositional areas) included sediment redox potential, core penetration depth (lower creek areas only), sample texture, and the presence or absence of organic detritus. *In situ* measurements of temperature, dissolved oxygen, conductivity, and pH were also taken at each station using either a YSI 650 MDS (Multiparameter Display System) field meter equipped with a YSI 6600 Sonde (Yellow Springs Instruments, Yellow Springs, OH) or a Hanna 4M multiparameter meter (Woonsocket, RI). Due to the recent forest fire in the vicinity of lower Minto Creek and considerable loss of vegetation, topsoil may be eroding into the creek and depositing as sediments. Five soil samples were collected from locations a few meters from the banks of lower Minto Creek for analysis of metals by the mine for comparison against sediment metal concentrations.

At each periphyton and benthic invertebrate community station, *in situ* measurements were taken using a field meter (described above), water depth was measured using a

Table 2.1: Minto Mine Water Use License program summary, September, 2011.

Area Type	Area	Station	Water	Chlorophyll "a"	Sediment by Spoon [1]	Sediment by Hand Corer [2]	Sediment Toxicity Testing [3]	Periphyton Community	Benthic Community by Hess Sampler [4]	Benthic Community by Kick and Sweep [5]
Lower Creek Areas	Lower Minto Creek (Exposed)	LMC-1	X	X		X	X	X	X	X
		LMC-2		X		X		X	X	
		LMC-3		X		X		X	X	
		LMC-4		X		X		X	X	
		LMC-5		X		X		X	X	
	Lower Wolverine Creek (Reference)	LWC-1	X	X		X	X	X	X	X
		LWC-2		X		X		X	X	
		LWC-3		X		X		X	X	
		LWC-4		X		X		X	X	
		LWC-5		X		X		X	X	
Upper Creek Areas	Upper Minto Creek (Exposed)	UMC-1	X		X					
		UMC-2			X					
		UMC-3			X					
		UMC-4			X					
		UMC-5			X					
	Upper McGuinty Creek (Reference)	URC-1	X		X					
		URC-2			X					
		URC-3			X					
		URC-4			X					
		URC-5			X					

[1] top 2 centimeters collected; minimum 3-grab composite
[2] top 2 centimeters collected; 3-grab composite
[3] sediment toxicity testing with *Chironomus dilutus* and *Hyalella azteca*
[4] 250 um mesh; 3-grab composite
[5] 243 um mesh; 10 minutes



Legend

- Minto Mine Site
- Routine water quality station
- Reference area
- Exposure area
- Fish barrier
- Road
- Contour
- Water Course
- Water Body

Scale: 0 500 1,000 2,000 m

Figure 2.1

minnow

Sediment and Benthic Invertebrate Monitoring Areas

Ref: 241 YWB - July 16, 2014 - QZ14-031 ...ess Consulting
Date: March 2012

meter stick and water velocity was measured using a Marsh-McBirney Flo-Mate 2000 portable flow meter (Marsh-McBirney Ltd., Frederick, MD). Creek wetted and bankfull widths were measured at each sampling station using a tape measure. Additional data collected to characterize each periphyton and benthic invertebrate sampling station included: elevation, gradient, water appearance, creek morphology, bank condition, substrate texture, instream cover, residual pool depth, instream features, overhead canopy, aquatic vegetation, riparian vegetation, surrounding land use and anthropogenic disturbance. In addition, the intermediate axis length of 100 rocks that were washed in the Hess sampler at each station were measured and recorded, and the percent embeddedness of ten randomly selected rocks was also evaluated and recorded. This type of substrate characterization is similar to the Canadian Aquatic Biomonitoring Network (CABIN) protocol (CABIN 2010) for characterizing benthic invertebrate habitat and provided additional information to assess and standardize habitat conditions among sampling stations. Summary statistics of intermediate axis lengths were calculated for each station including the median and geometric mean as per CABIN protocol.

Water samples for chemical analysis were collected at each periphyton and benthic sampling area. Samples were collected into pre-labeled sample bottles that were triple rinsed with site water except for bottles containing a pre-measured amount of preservative, which were filled directly. Water samples for dissolved organic carbon (DOC) and for dissolved ICP-MS (Inductively Coupled Plasma-Mass Spectrometry) analytes were filtered in the field using a 0.45 µm polypropylene filter.

The productivity of lower Minto Creek and lower Wolverine Creek was evaluated through measurements of chlorophyll *a*, in addition to collection of periphyton (Section 2.3), at each periphyton and benthic station. Chlorophyll *a* is the primary photosynthetic pigment of all oxygen-evolving photosynthetic organisms (Wetzel 2001) and therefore provides an indicator of the standing stock of photosynthetic organisms representing the lowest trophic level. Water samples for chlorophyll *a* analysis were collected into a plastic filter funnel and filtered through a 0.45-micron cellulose acetate membrane filter (Whatman Inc., Florham Park, NJ) assisted by a vacuum pump in the field. Following filtration of a known (and recorded) volume of water, the membrane filter was wrapped in aluminum foil, inserted into a labeled envelope, placed on ice in a cooler and subsequently frozen on return from the field. All samples were maintained in coolers with ice packs during transportation or at 4°C in a refrigerator on site until submission to the ALS Group Environmental Laboratory (ALS; Whitehorse, Yukon).

2.1.2 Data Analysis

Water chemistry data quality was assessed prior to data analysis and interpretation, and was judged to be acceptable (Appendix A). Water quality of Minto Creek was evaluated relative to WUL standards, concentrations measured in reference areas, applicable water quality guidelines, and previous water quality (i.e., Minto Mine Annual Water Quality Report 2010; Minnow 2010a, 2010b). When applying guidelines, Canadian Water Quality Guidelines for the protection of aquatic life (CWQG; CCME 1999) were used or, in the absence of a CWQG, provincial guidelines [i.e., British Columbia Water Quality Guidelines (BCWQG; BCMOE 2006a and 2006b) or Ontario Provincial water Quality Objectives (PWQO; OMOEE 1994)] were used.

Chlorophyll *a* data were tested for differences among effluent-exposed and reference areas using ANOVA. Prior to ANOVA, data were transformed as necessary to meet assumptions of normality and homogeneity of variance. Statistical comparisons were conducted using SPSS software (SPSS 2003). The productivity of the creeks was assessed by comparing chlorophyll *a* concentration against the Dodds et al. (1998) classification system for temperate streams.

2.2 Sediment Quality

2.2.1 Sample Collection and Laboratory Analysis

Sediment samples were collected for analysis of particle size and for chemical analysis at depositional areas within Minto Creek and reference creeks (Table 2.1; Figure 2.1). At lower Minto Creek and lower Wolverine Creek, sediment samples for particle size analysis were collected using a 15.24 cm x 15.24 cm stainless steel ponar grab (0.023 m^2 sampling area). A composite sample was created by collecting the surficial two centimeters of sediment from each of three acceptable grabs (i.e., full to each edge of the sampler) using a stainless steel spoon. Sediment samples for physical characterization were then placed into pre-labeled 500 mL PET (polyethylene) jars. Sediment samples for chemical analyses were collected using a 4.7 cm (inside diameter) Lexan® core tube, which was carefully inserted into sediment deposits, capped using a fitted plastic cap and retrieved by hand. From each acceptable core (i.e., each core containing an intact, representative sediment-water interface), the surficial two centimeters of sediment was manually extruded upwards into a graded core collar, cut with a stainless steel core knife, and placed into a pre-labeled 250 mL glass jar. Samples from three cores treated in this manner were composited to form a single sample from each station. At upper Minto Creek and upper McGinty Creek, sediment deposits were rare and were typically very shallow (i.e., deposits were less than three centimeters in depth). Accordingly, collecting by ponar or by coring, as described above, was not effective in the upper creek areas and sediments were collected using a stainless steel spoon. Specifically, at locations of sediment deposition, surficial sediment was carefully collected by slowly spooning the sediment into a sample jar, with care taken to avoid the loss of fine material. In order to be as consistent as possible with the sediment collected in the lower Creek areas, samples included only the top 2 centimeters of deposited sediment. Immediately after collection, sediment samples were placed in a cooler, and later placed in a refrigerator at approximately 4°C until they were submitted to the ALS Group Environmental Laboratory in Burnaby, BC, for analysis of particle size, total organic carbon, elements including metals (by ICP-MS and ICP-OES (Inductively Coupled Plasma-Optical Emission Spectroscopy] scans) and mercury.

Sediment samples for toxicity testing were collected into four litre HDPE pails. Following collection, samples were placed on ice inside coolers and shipped to Nautilus Environmental (Burnaby, BC). Sample appearance, odour, and temperature were recorded at the laboratory. The sediment samples were evaluated for toxicity using a 14-day *Hyalella azteca* survival and growth test and a 10-day *Chironomus dilutus* survival and growth test following Environment Canada methods and protocols (Environment Canada 1997a and 1997b).

2.2.2 Data Analysis

Sediment data quality was assessed prior to data analysis and interpretation, and was judged to be acceptable (Appendix A). Sediment quality data were evaluated relative to sediment quality guidelines (SQGs) for the protection of aquatic life (e.g., CCME 1999) and reference concentrations to identify metals with the potential to adversely affect aquatic life and/or whose concentrations were elevated due to mine activity. Sediment quality data were also evaluated by comparison to results obtained in previous years of sampling (1994 and 2006-2010). However, interpretation was conducted with careful consideration of a significant methodological change made in 2010 and 2011 (sediments collected as described above) relative to previous years. Sediments collected in all previous years were collected within the active channel of the creek using an aluminum or Teflon scoop. Samples were submitted whole for analysis of particle size distribution, which generally included significant quantities of gravel and sand. Only material passing through a 230 mesh sieve (<63 um; silt and clay) was digested and analyzed for metals. While this approach does result in the analysis of geochemically-relevant fine sediment (e.g., Horowitz 1991), it represents an impediment to the interpretation of the biological significance of sediment chemistry as organisms are exposed to whole sediment, and sediment quality guidelines (SQGs) for the protection of aquatic life (e.g., CCME 1999) apply to whole sediment.

2.3 Periphyton Community

2.3.1 Sample Collection and Laboratory Analysis

Periphyton is the assemblage of algae, bacteria, fungi, and meiofauna attached to submerged substrate in freshwaters. However, periphyton communities are generally characterized on the basis of the attached algae community. Attached algal communities are representative of the lowest trophic level and are indicators of productivity. Periphyton was collected from up to five randomly selected rocks at each station with the use of a rubber GEMS-type sampler (Gadget for Epilithic Microalgal Sampling; Canani et al. 2010) having a 33 cm^2 sample area. Each rock was removed from the stream bed, the area within the sampler was brushed using a wire brush and a syringe was used to transfer the sample into a plastic jar. Samples were then preserved with Lugol's iodine solution and shipped to Fraser Environmental Services (Surrey, BC) for analysis to species/variant level.

2.3.2 Data Analysis

Periphyton communities were evaluated using summary metrics including number of organisms per cm^2, number of taxa, Simpson's Evenness and Bray-Curtis Index (Environment Canada 2011). Additional non-statistical comparisons were made using percent community composition of dominant taxa (calculated as the abundance of each respective taxon group relative to the total number of organisms in the sample).

For each periphyton sample, total organism density (individuals/cm^2) was calculated based on the known area sampled (e.g., 165 cm^2 if five rocks sampled). The diversity metric "number of taxa" (also known as taxon richness) included all separate taxa identified to the species/variant level, excluding any organisms that could not be conclusively identified as separate taxa. Simpson's Evenness ("E") index was computed according to formulae presented by Smith and Wilson (1996) and recommended by Environment Canada (2011). This index takes into account both the relative abundance of taxa, and the number of taxa, with values ranging from 0 (low diversity or evenness) to 1 (high diversity or evenness). Bray-Curtis (B-C) indices were also calculated according to Environment Canada (2011). This metric takes into account the abundance of each taxon at each station compared to the median abundance computed from the reference stations (LWC), to compute an index of the relative "dissimilarity" of each station from the hypothetical reference median station. Larger B-C index values indicate greater dissimilarity from reference.

Due to the nature of periphyton identification and quantification in the laboratory, some taxa were identified only as present/absent and could not be reliably quantified. Taxon richness was therefore calculated for both the qualitative and quantitative datasets whereas all other summary metrics and statistics were calculated using the quantitative dataset only. Periphyton community endpoints were summarized by separately reporting mean, median, minimum, maximum, and standard deviation for each study area. Differences among effluent-exposed and reference areas were tested using t-tests with significance set at alpha < 0.10. Prior to ANOVA, data were tested for the assumptions of normality and homogeneity of variance and transformed if necessary. All statistics were conducted using SPSS (SPSS 2003).

Historical periphyton data from the 1994 baseline report (HKP 1994) was compared to 2011 data. Due to differences in reporting of periphyton community in the 1994 report (e.g., taxa identified as present, common or dominant), a non-statistical comparison was performed using proportional abundances at the Phylum taxonomic level.

2.4 Benthic Invertebrate Community

2.4.1 Sample Collection and Laboratory Analysis

Benthic invertebrate community samples were collected in erosional habitat of lower Minto Creek and lower Wolverine Creek as required under the WUL. Benthic invertebrate community samples were collected from riffle/run habitat with cobble and gravel substrate using a Hess sampler (0.1 m^2) outfitted with 250 μm mesh (to maintain consistency with previous WUL sampling despite the general acceptance of 500 μm mesh for environmental monitoring; Environment Canada 2011). One sample was collected at each monitoring location and consisted of a three-grab composite (0.3 m^2 of bottom area in total). For each grab, the substrate within the sampler was disturbed and gently scrubbed (by hand and nail brush) with care taken to ensure that all dislodged organic material was swept into the sampler collection net. The substrate was disturbed to a depth of approximately 10 cm over a period of approximately 5 minutes. This procedure was repeated for the second and third grab, following which all of the material contained in the collection net was carefully transferred to a pre-labeled 2 litre wide-mouth plastic jar using a stainless steel spoon and a wash bottle while working over a plastic tub to avoid any potential loss of organisms. Any organisms that adhered to the sieve bag were removed by hand and added to the sample. All samples were labeled internally (using wooden sticks) and externally with the station number, area identifier, Minnow project number, date and field personnel in order to ensure correct identification at the laboratory. Samples were preserved within six hours of collection using buffered formalin solution to a nominal concentration of 10% in ambient water.

A kick-and-sweep technique was also used to collect benthic invertebrate community samples at one station in lower Minto Creek (LMC-4) and lower Wolverine Creek (LWC-1). In this technique, the sampler disturbed the substrate with his feet upstream of a D-net (243 µm mesh) that was placed on the streambed. The sampler started a few feet from the stream bank, disturbed the substrate, moved the collection net over the disturbed area with a sweeping motion to capture displaced benthic invertebrates, and repeated the process for 10 minutes to generate a single sample in each area. The sampler moved in a zigzag pattern while staying at a relatively constant depth. The number of transects, distance (m) and approximate water depth were recorded on field sheets. All organisms were collected and preserved as described above.

All benthic invertebrate samples were shipped to Cordillera Consulting in Summerland, BC. At the laboratory, each sample was elutriated to remove sand, gravel and clay and the remaining organic material was preserved in 70% ethanol. The elutriate was examined for any mollusc or trichopteran cases then each sample was examined to estimate the total number of invertebrates. If the estimated number was greater than 600 individuals and the sample was fine and non-clumping, a subsample was taken using a Folsom Plankton Splitter (Motodo 1959; Van Guelpen et al. 1982). Empty snail or bivalve shells, empty caddisfly cases, invertebrate fragments such as legs, gills, antennae etc. were not removed or counted. When organism fragments were encountered, only the heads were counted towards the total. Larval and pupa exuviae were not counted while terrestrial stages and terrestrial drop-ins were indicated as such and do not contribute to the total count. Benthic invertebrates were identified to the “lowest practicable taxonomic level” (which in most cases was genus) and counted. Following identification and counting, representative specimens of each taxon were preserved in a museum quality vial with a polyseal lid to create a voucher collection. The interior labels were used to identify the taxa, the client, date collected, site code and the project. Laboratory quality assurance/quality control (QA/QC) included an assessment of sub-sampling error and sorting efficiency on at least 10% of the samples.

2.4.2 Data Analysis - Hess sampling

Benthic invertebrate community data quality was assessed prior to data analysis and interpretation, and was judged to be acceptable (Appendix A). Benthic invertebrate communities were evaluated using summary metrics including invertebrate density (number of organisms per m^2 calculated based on a sample area of 0.3 m^2), number of taxa, Simpson's Evenness and Bray-Curtis Index (see Section 2.3.2 for detailed descriptions of metrics; Environment Canada 2011).

The relative proportions of the most abundant taxa were calculated relative to the total number of organisms in the sample. Dominant taxon groups were defined as those groups representing greater than 10% of total organism abundance in one or more areas or any groups considered to be important indicators of environmental stress. In this study, relative proportions of oligochaetes (worms), chironomids (non-biting midges), nematans (roundworms), and EPT taxa (Ephemeroptera [mayfly], Plecoptera [stonefly], Trichoptera [caddisfly] taxa) were examined. It is often possible to relate low relative abundance of sensitive taxonomic groups (e.g., EPT taxa) to environmental stress (e.g., Taylor and Bailey 1997). Similarly, high relative abundance of tolerant taxonomic groups (e.g., oligochaetes) may indicate higher environmental stress (Chapman et al. 1982a; 1982b).

All benthic invertebrate community endpoints were summarized by separately reporting mean, median, minimum, maximum, standard deviation, standard error and sample size for each study area. Differences among effluent-exposed and reference areas were tested using ANOVA. Prior to ANOVA, all data were transformed as necessary to meet assumptions of normality and homogeneity of variance. All statistical comparisons were conducted using SPSS software (SPSS 2002; 2011). Following the statistical comparisons, the magnitude of difference between effluent-exposed and reference area means was calculated for each benthic invertebrate community metric where a significant difference was detected. If a significant difference between areas was not detected, then the minimum effect size that could be detected was calculated.

Community structure was also assessed by examining the proportions of key taxonomic groups using a multivariate technique known as Correspondence Analysis (CA). CA is used to calculate axes, which can be thought of as new variables summarizing variation in the relative abundance of benthic taxa. When depicted in two-dimensional plots, taxa that tend to co-occur will have similar CA axis scores and will plot together, while those that rarely co-occur plot farther apart. Similarly, stations sharing many taxa plot closest to one another, while those with little in common plot farther apart. The greatest variation among either taxa or stations is explained by the first axis, with other axes accounting for progressively less variation. This type of multivariate analysis describes not only which stations have distinct benthic communities but also how these benthic communities differ among stations (i.e., which particular taxa differ). CA is influenced by rare species, so those taxa occurring at only one of the ten stations were removed. After screening and data reduction, abundances were log (x+1) transformed. Scores for both stations and taxa were calculated using the ADE-4 package (Thioulouse et al. 1997) to evaluate the associations of organisms and stations.

Benthic invertebrate community data were also evaluated by comparison to results obtained in previous years of sampling (1994, 2006, 2008 and 2010). Prior to making comparisons, summary metrics from earlier years were re-calculated (Minnow 2011) to ensure consistency and appropriate comparisons over time.

Samples collected by kick-and-sweep were analyzed using the Reference Condition Approach (RCA). A detailed description of the data analysis is provided in Appendix E. Results from the RCA model were compared to the more traditional control-impact (CI) approach applied to the Hess sampling data, which involved only one reference area for comparison against lower Minto Creek.

3.0 SUPPORTING MEASURES

3.1 Field Measures

Mean temperature in upper Minto Creek (1.59°C) was similar to upper McGinty Creek (1.21°C) and both were less than lower Minto Creek (5.01°C) and lower Wolverine Creek (4.02°C; Figure 3.1; Table 3.1). Specific conductance followed a concentration gradient from the mine to downstream (i.e., greatest in upper Minto Creek [497 µS/cm], followed by lower Minto Creek [242 µS/cm]) and was lowest in the reference areas (lower Wolverine Creek [198 µS/cm] and upper McGinty Creek [104 µS/cm]). Water in all areas was well oxygenated with a slightly alkaline pH; both variables were well within water quality guidelines as well as WUL standards for pH.

The intermediate axis lengths of cobble washed in the Hess sampler at each periphyton and benthic station were similar at lower Minto Creek and lower Wolverine Creek, with most cobble being between six and eight centimeters in length (Appendix Table B.2; Appendix Figures B.1a and B.1b). The medians (range 3.6 to 4.3 cm) and geometric means (range 3.9 to 4.6 cm) were similar among all stations and were within 0.7 cm, of each other.

Water temperatures in upper and lower Minto Creek in 2011 were lower than those during the 2010 survey, possibly due to the absence of discharge from the WSP in 2011 (Figure 3.1). In 2010, holding, and presumably warming, of water in the WSP that was then discharged into Minto Creek may have contributed to higher water temperatures. Specific conductance was also lower in 2011 than in 2010, again likely due to the absence of discharge from the WSP in 2011. Mean dissolved oxygen and pH were similar in 2010 and 2011 (Figure 3.1).

3.2 Water Chemistry and Chlorophyll *a*

Ten water analytes including alkalinity, dissolved organic carbon (DOC), fluoride, phosphorus, total organic carbon (TOC), total suspended solids (TSS), turbidity, aluminum, chromium, and iron did not meet a guideline or WUL standard or both at upper and/or lower Minto Creek exposure areas (Table 3.2). The only analytes greater than WUL standards were phosphorus, aluminum and iron in lower Minto Creek which were slightly higher than the applicable standard; however, concentrations of these analytes in the reference area of lower Wolverine Creek were also higher than standards suggesting naturally elevated concentrations. These analytes also tend to be positively correlated with TSS (Minnow 2012) which was relatively elevated in lower Minto Creek. Of the

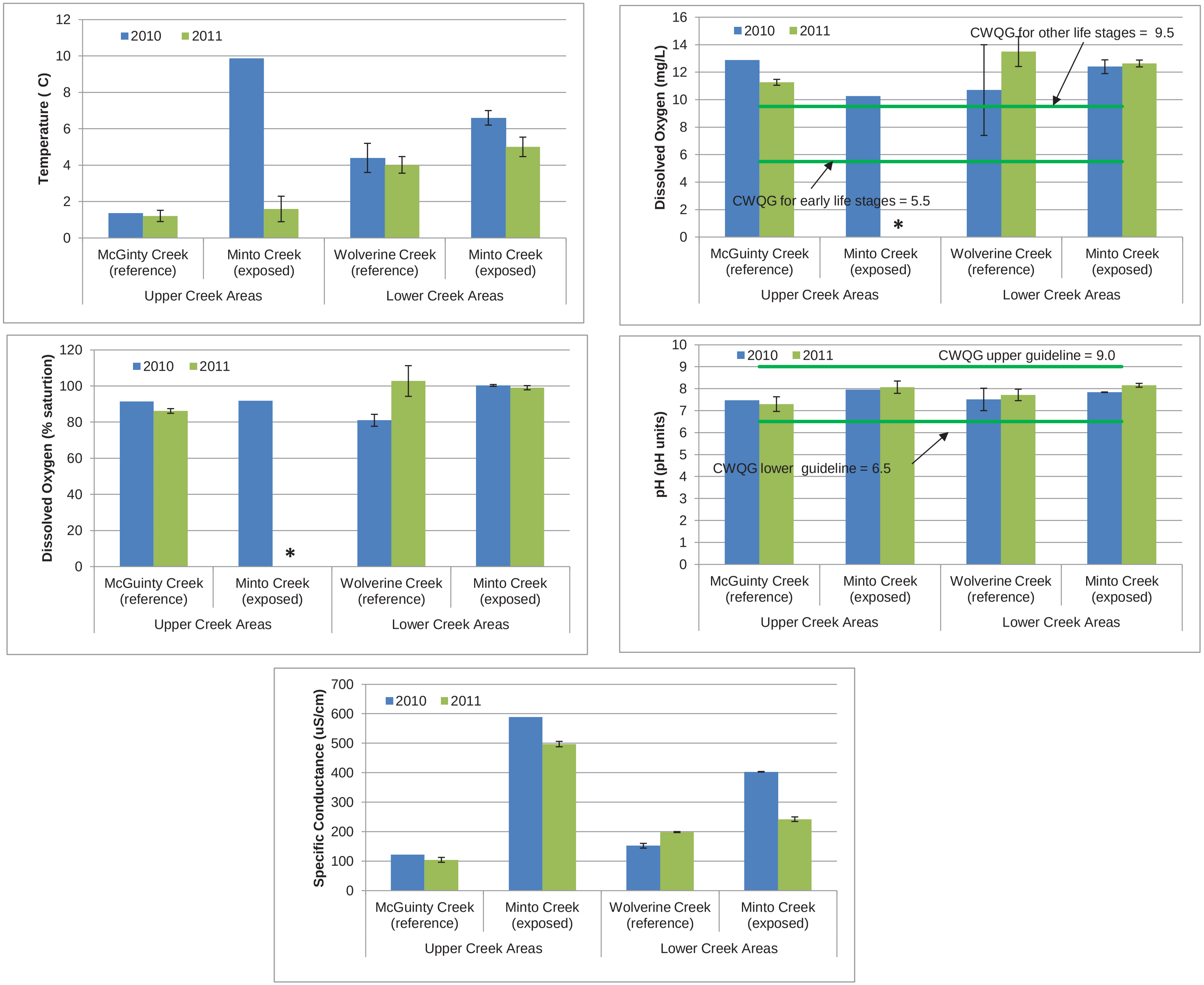


Figure 3.1: Physico-chemical measurements in depositional areas of upper and lower Minto Creek relative to reference areas. Data presented as mean ± standard deviation. Asterisk indicates measurement not obtained. Sample sizes were n=5 in all areas in 2011 and lower areas in 2010 and n=1 in upper areas in 2010.

Table 3.1: *In situ* measures at benthic invertebrate stations, Minto Mine WUL, September 2011. Shade indicates value does not meet WUL standard or water quality guideline.

Area	Variable	Temperature	Specific Conductance	Dissolved Oxygen	Dissolved Oxygen	pH	Mean Depth	Mean Velocity
	Unit	°C	µS/cm	mg/L	%	pH units	m	m/s
	Water Quality Guidelines	-	-	7	54	6.5-9.0[b]	-	-
Upper McGinty Creek (Reference)	UMC-1	1.62	115	10.99	84.6	7.87	0.14	0.32
	UMC-2	1.40	109	11.17	85.7	7.01	0.10	0.21
	UMC-3	1.21	102	11.34	86.8	7.14	0.13	0.33
	UMC-4	0.95	102	11.25	85.7	7.21	0.11	0.21
	UMC-5	0.88	93	11.57	88.0	7.26	0.08	0.45
	Mean	1.21	104	11.26	86.2	7.30	0.11	0.30
	Standard Deviation	0.308	8	0.214	1.290	0.333	0.022	0.100
Upper Minto Creek (Exposure)	UMC-1	2.38	486	-	-	8.26	0.05	0.21
	UMC-2	2.11	489	-	-	8.44	0.08	0.10
	UMC-3	1.68	501	-	-	8.02	0.10	0.35
	UMC-4	0.67	508	-	-	7.76	0.13	0.23
	UMC-5	1.13	501	-	-	7.86	0.11	0.25
	Mean	1.59	497	-	-	8.07	0.09	0.23
	Standard Deviation	0.700	9	-	-	0.281	0.030	0.089
Lower Wolverine Creek (Reference)	LWC-1	4.17	197	15.04	115.4	8.00	0.17	0.43
	LWC-2	4.54	197	13.37a	105.5a	7.72	0.12	0.42
	LWC-3	3.40	201	14.01	105.3	7.95	0.11	0.42
	LWC-4	3.71	199	12.52	94.5	7.48	0.12	0.40
	LWC-5	4.26	198	12.44	95.8	7.43	0.13	0.41
	Mean	4.02	198	13.50	102.8	7.72	0.13	0.42
	Standard Deviation	0.46	2	1.09	8.5	0.26	0.023	0.011
Lower Minto Creek (Exposure)	LMC-1	5.30	238	12.68	100.1	8.26	0.11	0.44
	LMC-2	5.00	238	12.72	99.6	8.23	0.14	0.42
	LMC-3	4.40	240	12.70	98.1	8.06	0.11	0.43
	LMC-4	4.60	239	12.87	99.9	8.09	0.18	0.42
	LMC-5	5.73	256	12.21	97.5	8.13	0.12	0.44
	Mean	5.01	242	12.64	99.0	8.15	0.13	0.43
	Standard Deviation	0.53	8	0.25	1.2	0.087	0.029	0.010

[a] Hanna meter value shown
[b] Range for the Water Use Licence is 6.0 - 9.0
[c] see Appendix Table B.4 for explanatory notes on selected water quality guidelines.
Note: data for dissolved oxygen at upper Minto Creek was accidentally lost; however, observed percent saturation at the time of the survey was >80% at each station.

Table 3.2: Water quality results at reference and exposure areas, WUL standards and applicable guidelines, Minto Mine WUL, September 2011.

Analyte		Units	Water Quality Guidelines[a]	WUL Limits at W2	Upper McGinty Creek (reference)	Upper Minto Creek (exposure)	Lower Wolverine Creek (reference)	Lower Minto Creek (exposure)
Ions, nutrients, physical analytes and cyanide	Alkalinity, Total (as CaCO3)	mg/L	43 - 109		56.8	212	87.2	126
	Ammonia (as N)	mg/L	1.27	0.35	0.0060	<0.0050	0.0120	0.0172
	Bromide (Br)	mg/L	-		<0.050	<0.050	<0.050	<0.050
	Chloride (Cl)	mg/L	150		<0.50	3.52	<0.50	0.83
	Conductivity	µS/cm	-		121	482	193	249
	Cyanide, Total	mg/L	0.005		<0.0050	<0.0050	<0.0050	<0.0050
	Dissolved Organic Carbon	mg/L	13 - 19		17.2	6.80	15.2	14.8
	Fluoride (F)	mg/L	0.12		0.197	0.490	0.127	0.230
	Hardness (as CaCO3)	mg/L	-		65.2	247	96.2	136
	Nitrate and Nitrite (as N)	mg/L	-		0.0381	1.05	0.0539	0.116
	Nitrate (as N)	mg/L	2.9	2.9	0.0381	1.05	0.0539	0.115
	Nitrite (as N)	mg/L	0.06	0.06	<0.0010	<0.0010	<0.0010	0.0013
	pH	pH units	6.5 - 9.0	6.0 - 9.0	7.91	8.31	8.09	8.16
	Phosphorus (P)-Total	mg/L	0.03	0.02	0.0254	0.0050	0.0359	0.0499
	Phosphorus (P)-Total Dissolved	mg/L	0.03		0.0135	0.0034	0.0095	0.0183
	Sulfate (SO4)	mg/L	100		6.35	52.8	15.3	9.51
	Total Dissolved Solids	mg/L	-		117	323	159	191
	Total Inorganic Carbon	mg/L	-		6.12	25.1	10.1	14.4
	Total Organic Carbon	mg/L	13 - 20		17.3	6.27	16.1	14.9
	Total Suspended Solids	mg/L	21.1		7.7	<3.0	24.5	24.5
	Turbidity	NTU	9.5		4.94	0.21	10.1	16.9
Total ICP-MS Scan	Aluminum (Al)-Total	mg/L	0.100	0.62	0.284	0.0103	0.818	0.717
	Antimony (Sb)-Total	mg/L	0.02		<0.00010	<0.00010	<0.00010	<0.00010
	Arsenic (As)-Total	mg/L	0.005	0.005	0.00076	0.00028	0.00077	0.00128
	Barium (Ba)-Total	mg/L	1		0.0467	0.0833	0.0520	0.0747
	Beryllium (Be)-Total	mg/L	0.0053		<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total	mg/L	-		<0.00050	<0.00050	<0.00050	<0.00050
	Boron (B)-Total	mg/L	1.5		<0.010	0.022	0.010	<0.010
	Cadmium (Cd)-Total	mg/L	0.00004 or 0.00007[b]	0.00004	<0.000010	<0.000010	0.000017	0.000014
	Calcium (Ca)-Total	mg/L	-		17.5	59.6	21.3	37.0
	Chromium (Cr)-Total	mg/L	0.001	0.002	0.00109	0.00048	0.00236	0.00167
	Cobalt (Co)-Total	mg/L	0.004		0.00052	<0.00010	0.00067	0.00073
	Copper (Cu)-Total	mg/L	0.003 or 0.004[b]	0.013	0.00254	0.00192	0.00363	0.00278
	Iron (Fe)-Total	mg/L	0.3	1.1	1.16	<0.030	1.39	1.95
	Lead (Pb)-Total	mg/L	0.004 or 0.007[b]	0.004	0.000110	<0.000050	0.000330	0.000303
	Lithium (Li)-Total	mg/L	0.014		0.00073	0.00224	0.00158	0.00128
	Magnesium (Mg)-Total	mg/L	-		5.20	23.8	11.1	10.7
	Manganese (Mn)-Total	mg/L	1.2 or 1.7[b]		0.0910	0.0174	0.0591	0.163
	Mercury (Hg)-Total	mg/L	0.000026		<0.000010	<0.000010	-	-
	Molybdenum (Mo)-Total	mg/L	0.073	0.073	0.000789	0.00340	0.000558	0.00113
	Nickel (Ni)-Total	mg/L	0.11 or 0.15[b]	0.11	0.00188	0.00075	0.00353	0.00276
	Potassium (K)-Total	mg/L	373		0.404	2.13	0.637	0.936
	Selenium (Se)-Total	mg/L	0.001	0.001	0.00021	0.00034	0.00020	0.00013
	Silicon (Si)-Total	mg/L	-		7.61	5.58	7.82	8.66
	Silver (Ag)-Total	mg/L	0.0001		<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total	mg/L	-		3.57	16.5	6.48	6.25
	Strontium (Sr)-Total	mg/L	-		0.109	0.636	0.199	0.269
	Thallium (Tl)-Total	mg/L	0.0008		<0.000010	<0.000010	<0.000010	<0.000010
	Tin (Sn)-Total	mg/L	-		<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total	mg/L	2		0.017	0.011	0.040	0.032
	Uranium (U)-Total	mg/L	0.015		0.000258	0.00292	0.000912	0.000785
	Vanadium (V)-Total	mg/L	0.006		0.0020	<0.0010	0.0042	0.0032
	Zinc (Zn)-Total	mg/L	0.03	0.03	<0.0030	<0.0030	0.0035	0.0035

Water use licence standard not met

Water quality guideline not met

[a] see Appendix Table B.4 for explanatory notes on selected water quality guidelines.

[b] higher guideline for comparison against upper McGinty Creek and upper Minto Creek and lower guideline for comparing lower Wolverine Creek and lower Minto Creek.

analytes that did not meet water quality guidelines, only alkalinity, DOC and TOC failed to meet guidelines in the receiving environment (upper Minto Creek only) but not in the reference area (upper McGinty Creek), suggesting a possible mine influence, presumably due to vegetation clearing at the mine site. Organic carbon concentrations are known to limit the bioavailability of divalent metals (e.g., Winner 1985; Meador 1991; Welsh et al. 1993; McIntyre 2008).

All other analytes had concentrations in one or both reference areas that were similar to exposure concentrations in upper or lower Minto Creek indicating that they may be naturally elevated. Since concentrations of total metals were not indicative of mine influence, it would follow that dissolved metals would not be either barring any analytical or sampling errors (Appendix Table B.3). Comparisons of analyte concentrations that were higher than WUL standards and/or guidelines in the receiving environment against 2010 data (Minnow 2010a, 2010b) indicate that mean TSS concentration was slightly higher in 2011 in lower Minto Creek whereas mean aluminum, chromium, and iron were very similar between years. Other analytes greater than WUL standard or guideline in 2010 in lower Minto Creek (cadmium, copper) or upper Minto Creek (copper, manganese) had mean concentrations in 2011 that were several times lower than in 2010, presumably owing to the absence of WSP discharge in 2011.

Mean chlorophyll *a* concentration in water, an indicator of phytoplankton productivity, was not statistically different (p=0.08) between lower Minto Creek (0.275 µg/L) and lower Wolverine Creek (0.186 µg/L; Figure 3.2; Appendix Table B.5). The productivity of both creeks could be considered very low (i.e., oligotrophic) based on the classification by Dodds et al. (1998) which sets the oligo-mesotrophic boundary as 10 µg/L for temperate streams. This differs substantially from classification based on phosphorus alone, which would define both lower Wolverine Creek and lower Minto Creek as mesotrophic (Dodds et al. 1998). The lower concentration of chlorophyll *a* despite relatively high phosphorus may be due to environmental factors associated with a subarctic system such as a shorter growing season.

3.3 Summary

Field water quality measures (temperature, specific conductance, dissolved oxygen and pH) and intermediate axis length of washed cobble were similar between lower Minto Creek and lower Wolverine Creek. Upper Minto Creek and upper McGinty Creek had pH and dissolved oxygen similar to the lower creek areas whereas temperature was lower in the upper creek areas and specific conductance was greatest in upper Minto Creek

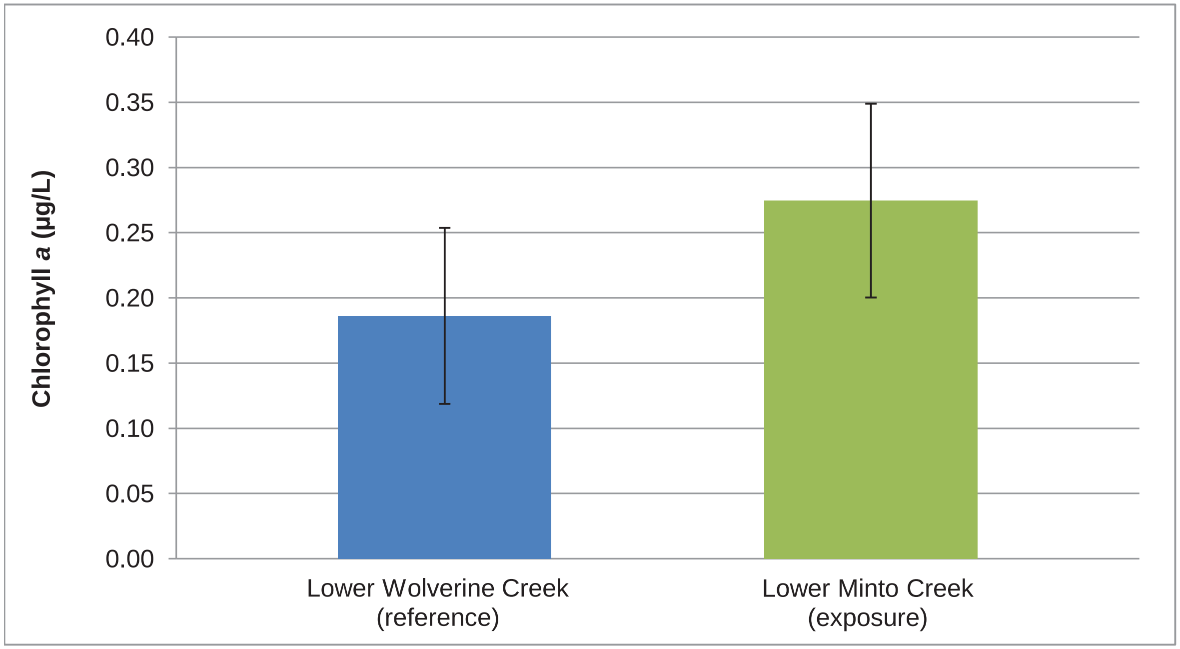


Figure 3.2: Concentrations of chlorophyll *a* in lower Wolverine Creek and lower Minto Creek, September 2011. Data presented as mean ± standard deviation.

followed by lower Minto Creek and the two reference areas. Temperature and specific conductance were lower in 2011 than in 2010, presumably due to the absence of WSP discharge in 2011.

Overall, water quality results demonstrated that ten analytes (alkalinity, DOC, fluoride, phosphorus, TOC, TSS, turbidity, aluminum, chromium, and iron) that did not meet WUL standards or water quality guidelines in at least one exposure area. Phosphorus, aluminum and iron were higher than WUL standards in both lower Minto Creek and reference areas suggesting naturally elevated concentrations and indicating that the WUL standards are not appropriate. Organic carbon was lower than the guideline and reference at upper Minto Creek) indicating a possible mine influence. Mean concentrations of most analytes tended to be similar or lower in 2011 than 2010. Chlorophyll *a* concentrations in lower Minto Creek and lower Wolverine Creek were similar and indicated low productivity (i.e., oligotrophic) according to the classification system of Dodds et al. (1998).

4.0 SEDIMENT QUALITY

4.1 Sediment Particle Size and Chemistry

Sediments collected in 2011 were largely composed of fine particles in the silt/clay and sand size categories (Figure 4.1; Appendix Table C.1). Mean concentrations of arsenic and copper, and one sample for zinc were greater than the Interim Sediment Quality Guideline (ISQG; CCME 1999) in the exposure areas (upper and lower Minto Creek; Table 4.1; Appendix Table C.1). The only concentration greater than a Probable Effect Level (PEL; CCME 1999) occurred for copper at one station in upper Minto Creek (UMC-3; Table 4.1; Appendix Table C.1). Mean chromium concentration was also higher than the ISQG but only in the reference area of lower Wolverine Creek. Concentrations of arsenic were comparable in all areas indicating elevations relative to ISQG may be natural. Mean concentrations above reference by at least two times were only detected in upper Minto Creek and included copper, manganese, and molybdenum. Since concentrations of metals in lower Minto Creek were generally lower than reference and/or ISQG, the potential contribution of eroded topsoil (Appendix Table C.2) was not examined.

4.2 Temporal Comparisons

Sediment particle size distribution in 2011 was similar to 2010 but was notably different from earlier sample year data (Figure 4.1). The disparity between 2010-2011 and 1994-2009 data reflects the change in sediment sampling methodology initiated in 2010 (Minnow 2011). Mean analyte concentrations higher than guideline in Minto Creek were compared to earlier data to detect any increasing or decreasing trends in sediment quality. Concentrations of arsenic were elevated above guideline during baseline data collection (1994), lending further support that it may be naturally elevated (Table 4.1; Appendix Table C.1). Similarly, copper was greater than guideline in 1994 while mean copper concentration in 2011 in upper Minto Creek was the highest of all years (Figure 4.2; Table 4.1; Appendix Table C.1). Due to the predominantly erosional habitat in upper Minto Creek, there are relatively few areas where sediment is deposited and this only in small quantities that likely wash away each year during freshet. Therefore, elevated sediment copper in the upper reaches of Minto Creek may be of limited importance in terms of exposure and potential toxicity to biota. However, continued sampling in this area is relevant from a monitoring perspective.

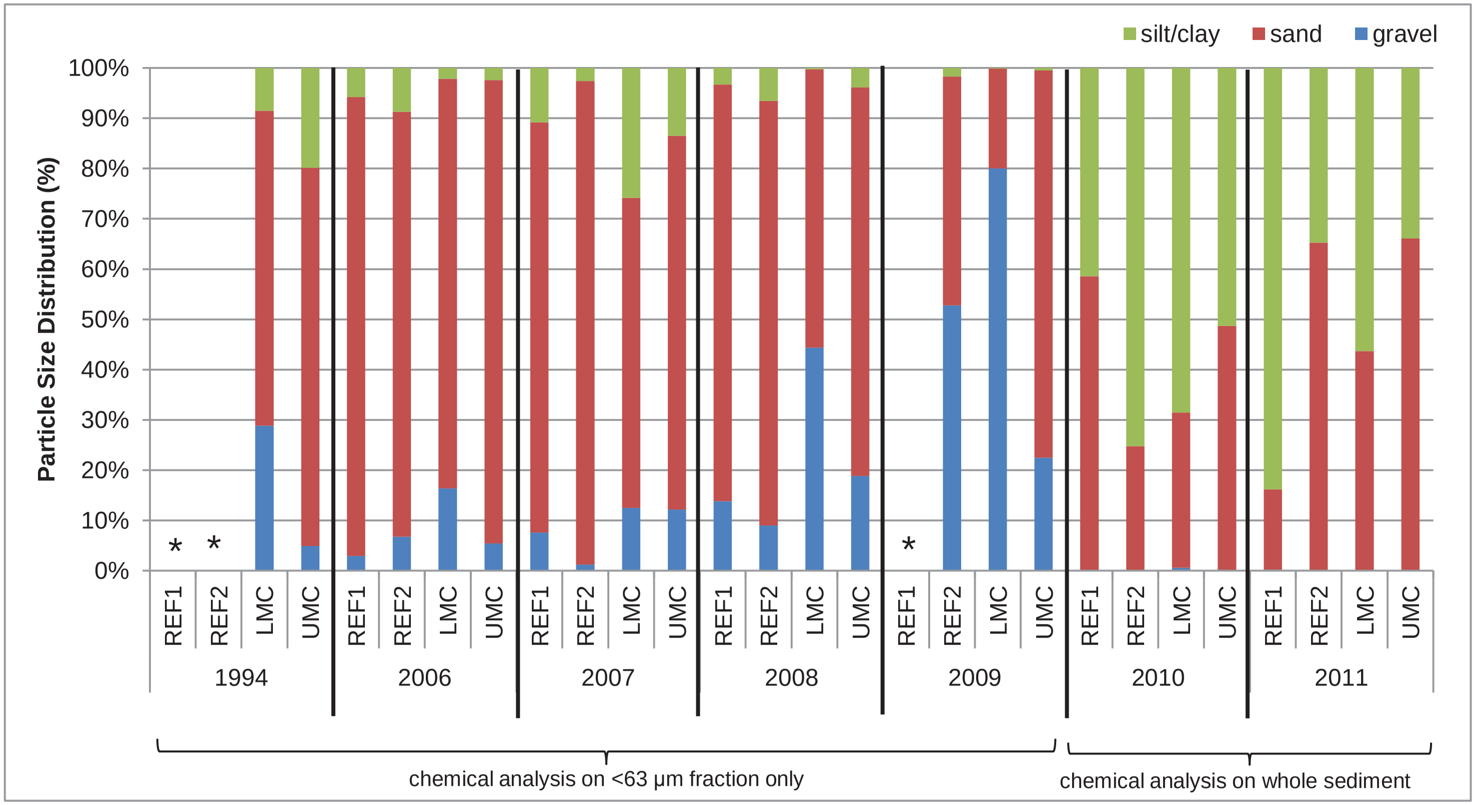


Figure 4.1: Particle size distribution of sediment collected in Minto Creek and reference locations, 1994-2011 [1]

[1] UMC = Upper Minto Creek; LMC = Lower Minto Creek; REF1 = Station W6 (south-flowing tributary) in 2006 to 2008 and McGuinty Creek in 2010 and 2011; REF2 = Station W7 (north- flowing tributary) in 2006 to 2009 and Wolverine Creek in 2010 and 2011; * - no data

Table 4.1: Sediment chemistry at reference and exposure areas, Minto Mine WUL, September 2011.

	Analytes	Units	CSQG [a]		Upper McGinty Creek (Reference)				Lower Wolverine Creek (Reference)				Upper Minto Creek (Exposure)				Lower Minto Creek (Exposure)			
			ISQG	PEL	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum
Particle size, TKN, carbon analytes and pH	% Gravel (>2mm)	%			<0.10	-	<0.10	<0.10	<0.10	0	<0.10	<0.10	<0.10	-	<0.10	<0.10	<0.10	0	<0.10	<0.10
	% Sand (2.0mm - 0.063mm)	%			8.72	-	8.72	8.72	48.4	6.6	41.1	53.6	49.3	-	49.3	49.3	27.9	6.1	19.1	35.6
	% Silt (0.063mm - 4um)	%			69.1	-	69.1	69.1	42.7	5.1	38	49.5	41.5	-	41.5	41.5	61.9	3.7	58.1	67.9
	% Clay (<4um)	%			22.2	-	22.2	22.2	8.97	2.12	6.88	12.2	9.21	-	9.21	9.21	10.3	2.72	6.32	13
	Total Kjeldahl Nitrogen (TKN)	%			0.769	0.157	0.565	0.944	0.279	0.106	0.174	0.421	0.200	0.029	0.169	0.242	0.200	0.08	0.063	0.251
	CaCO3 Equivalent	%			1.78	0.35	1.54	2.39	2.28	0.49	1.76	2.96	1.06	0.20	0.89	1.4	2.16	0.63	1.45	2.88
	Inorganic Carbon	%			0.21	0.04	0.18	0.29	0.27	0.061	0.21	0.36	0.13	0.02	0.11	0.17	0.26	0.08	0.17	0.35
	Total Carbon by Combustion	%			15.3	3.6	11.2	19.4	5.0	2.5	2.5	8.8	3.0	0.6	2.3	3.7	3.9	1.6	1	4.8
	Total Organic Carbon	%			15.1	3.5	11	19.1	4.75	2.49	2.25	8.48	2.85	0.63	2.2	3.54	3.66	1.58	0.85	4.59
	pH (1:2 soil:water)	pH units			7.03	0.17	6.86	7.3	7.20	0.21	6.96	7.52	7.90	0.09	7.77	8	7.75	0.11	7.65	7.9
Total ICP-MS Scan	Aluminum (Al)	mg/kg			15,860	808	15,100	17,200	13,520	1,494	11,700	15,300	13,920	926	12,700	14,900	11,082	1,144	9,410	12,600
	Antimony (Sb)	mg/kg			0.65	0.08	0.57	0.77	0.47	0.07	0.41	0.58	0.54	0.05	0.51	0.62	0.49	0.08	0.4	0.61
	Arsenic (As)	mg/kg	5.9	17	8.15	0.93	6.86	9.43	6.03	0.46	5.34	6.46	6.55	0.34	5.97	6.83	6.21	1.08	4.59	7.47
	Barium (Ba)	mg/kg			362	37	327	417	217	38	171	263	238	19	208	257	209	34.9	154	250
	Beryllium (Be)	mg/kg			0.54	0.07	0.48	0.64	0.72	0.12	0.57	0.83	0.55	0.05	0.49	0.6	0.43	0.07	0.32	0.52
	Bismuth (Bi)	mg/kg			<0.20	0	<0.20	<0.20	<0.20	0	<0.20	<0.20	<0.20	0	<0.20	<0.20	<0.20	0	<0.20	<0.20
	Cadmium (Cd)	mg/kg	0.6	3.5	0.314	0.076	0.254	0.443	0.246	0.074	0.175	0.348	0.237	0.045	0.16	0.273	0.180	0.055	0.12	0.265
	Calcium (Ca)	mg/kg			13,160	2,322	11,100	17,000	10,772	2,015	8,670	13,200	9,560	917	8,450	11,000	10,536	1,979	8,230	13,600
	Chromium (Cr)	mg/kg	37.3	90	35.8	1.7	34.2	37.7	42.6	4.5	38.1	48.4	33.3	3.2	28.1	36.8	26.8	2.3	23.4	29.5
	Cobalt (Co)	mg/kg			13.0	1.1	11.5	14.5	13.6	1.1	11.9	14.7	12.9	0.8	11.7	13.9	9.9	1.3	7.89	11.1
	Copper (Cu)	mg/kg	35.7	197	40.1	5.0	35.5	47.6	29.8	6.3	22.7	37.9	**145**	65	43.8	**206**	30.4	5.1	23.4	37.1
	Iron (Fe)	mg/kg			28,640	1,884	25,600	30,600	27,140	1,262	25,800	28,500	25,920	1,522	23,300	27,000	22,100	2,393	18,300	24,600
	Lead (Pb)	mg/kg	35	91.3	6.68	0.33	6.36	7.15	6.00	0.58	5.28	6.69	6.47	0.48	5.69	6.94	5.55	0.70	4.38	6.18
	Lithium (Li)	mg/kg			8.5	0.68	7.9	9.3	8.8	0.7	7.9	9.5	9.8	0.6	9.2	10.5	8.4	1.1	6.9	9.9
	Magnesium (Mg)	mg/kg			5,442	318	5,050	5,800	8,908	599	8,120	9,580	9,476	1,079	8,030	10,800	6,154	582	5,440	6,990
	Manganese (Mn)	mg/kg			979	214	746	1,290	586	104	477	755	**2,158**	748	1,040	**3,070**	714	145	506	908
	Mercury (Hg)	mg/kg	0.17	0.49	0.090	0.016	0.0726	0.112	0.0444	0.012	0.0318	0.0605	0.0288	0.0025	0.0251	0.0313	0.0382	0.0116	0.0226	0.0544
	Molybdenum (Mo)	mg/kg			0.81	0.2	0.67	1.01	0.58	0.04	0.53	0.64	**1.93**	0.67	0.92	**2.51**	0.59	0.06	0.5	0.67
	Nickel (Ni)	mg/kg			23.8	1.3	21.6	24.9	38.5	4.2	32.6	42.9	48.7	7.9	36.6	58.1	26.0	2.9	21.5	29
	Phosphorus (P)	mg/kg			951	84	821	1,050	1,001	33	951	1,030	946	59	850	986	815	33	760	842
	Potassium (K)	mg/kg			712	63	660	820	904	82	780	990	1,386	264	980	1,640	818	90	710	960
	Selenium (Se)	mg/kg			0.78	0.15	0.63	1.02	0.43	0.14	0.29	0.62	0.55	0.09	0.41	0.62	0.35	0.10	0.23	0.51
	Silver (Ag)	mg/kg			0.16	0.02	0.13	0.19	0.11	0.017	0.1	0.14	0.13	0.02	0.1	0.16	0.10	0.004	<0.10	0.11
	Sodium (Na)	mg/kg			182	13	170	200	392	37	350	440	464	91	340	570	244	22	210	270
	Strontium (Sr)	mg/kg			99.6	14.9	85.3	123	103	20	79.9	125	98.5	10.6	88	116	82.9	16.9	60.9	108
	Thallium (Tl)	mg/kg			0.095	0.005	0.091	0.104	0.079	0.010	0.069	0.092	0.098	0.009	0.085	0.108	0.077	0.011	0.061	0.09
	Tin (Sn)	mg/kg			<2.0	0	<2.0	<2.0	<2.0	0	<2.0	<2.0	<2.0	0	<2.0	<2.0	<2.0	0	<2.0	<2.0
	Titanium (Ti)	mg/kg			667	47	640	751	799	87	656	893	723	64	617	783	575	63	507	656
	Uranium (U)	mg/kg			1.86	0.31	1.5	2.33	2.20	0.50	1.7	2.9	0.926	0.071	0.813	0.996	1.09	0.32	0.731	1.59
	Vanadium (V)	mg/kg			68.6	6.1	62	77.4	70.7	4.6	66.2	76.6	57.4	2.8	54.1	61.2	47.6	4.3	41	51.7
	Zinc (Zn)	mg/kg	123	315	52.4	3.7	49.1	57.1	55.8	2.7	52.3	58.6	91.5	32.0	52	**139**	51.2	6.5	41.9	59.7

[a] Canadian Sediment Quality Guidelines - ISQG = interim sediment quality guideline; PEL = probable effect level (CCME 1999).

(blue) Indicates sediment concentration exceeding CSQG ISQG.

(green) Indicates sediment concentration exceeding CSQG PEL.

bold Indicates sediment concentration exceeding the higher reference mean by more than 2-times

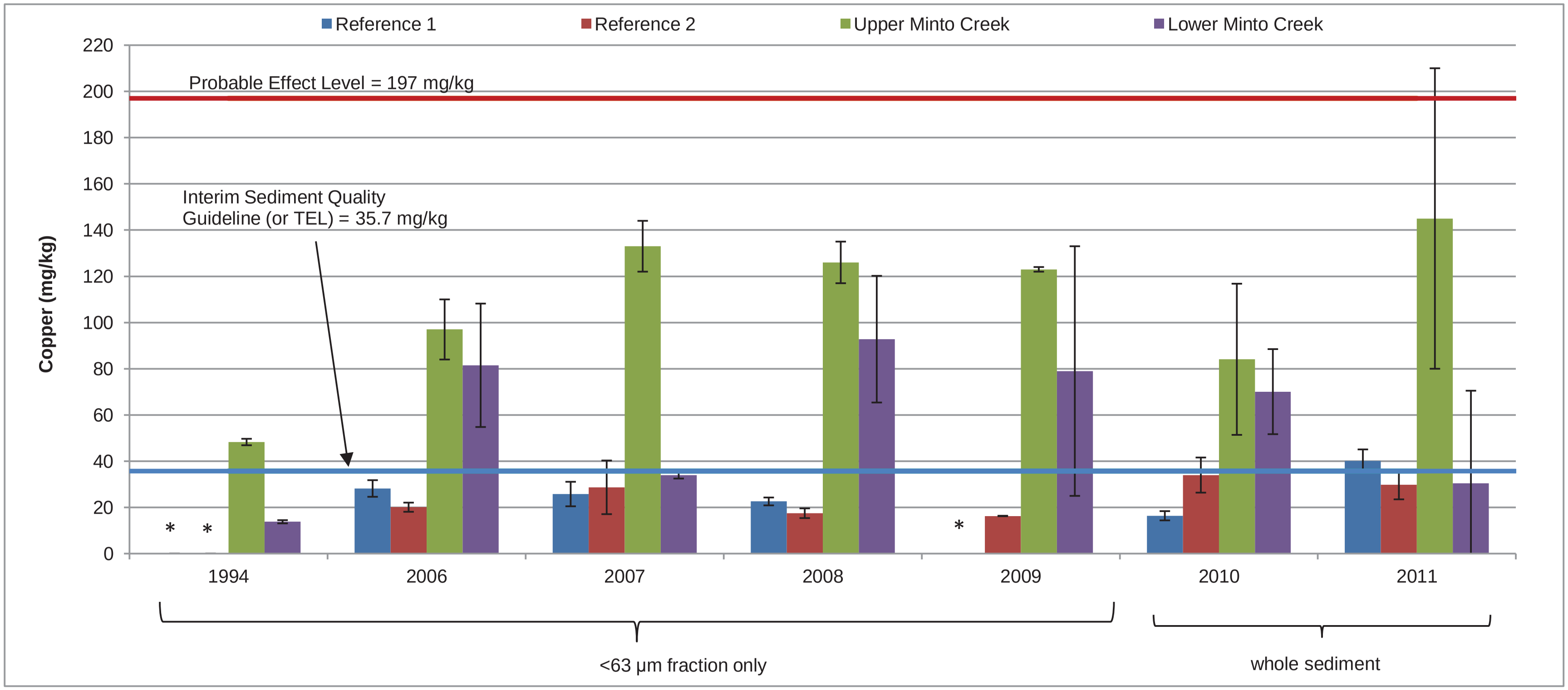


Figure 4.2: Mean copper concentrations in sediment collected in Minto Creek and reference locations, 1994-2011 (mean ± standard deviation) [1].

[1] Reference 1 = Station W6 (south-flowing tributary) in 2006 to 2008 and McGuinty Creek in 2010 and 2011; Reference 2 = Station W7 (north-flowing tributary) in 2006 to 2009 and Wolverine Creek in 2010 and 2011; * = no data. TEL: Threshold Effect Levels

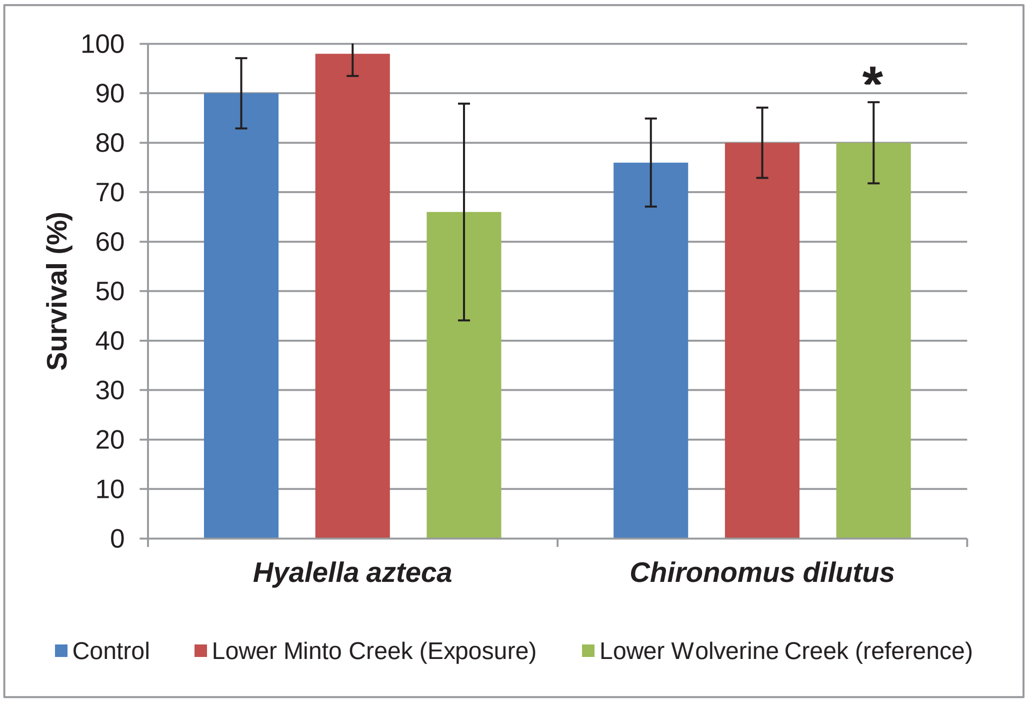
4.3 Sediment Toxicity

Sediment collected in lower Minto Creek did not result in a significant reduction in survival and growth of either *H. azteca* or *C. dilutus* relative to laboratory controls, providing some evidence that the Minto Creek sediment is non-toxic to aquatic invertebrates (Figure 4.3; Appendix B).

4.4 Summary

Overall, concentrations of metals in receiving environment sediments were below reference and/or sediment guidelines with the exception of upper Minto Creek where mean concentrations of copper, manganese, and molybdenum were greater than reference by at least two times and mean copper was also higher than ISQG (and the PEL at one station). Similar elevations relative to ISQG were apparent in previous years and only copper was higher in 2011 than in previous years. In lower Minto Creek, where sediment is less sparsely distributed and some depositional habitat is supported, sediment metal concentrations were below reference and/or sediment guidelines and sediment toxicity testing demonstrated that sediments collected from lower Minto Creek were non-toxic to *H. azteca* and *C. dilutus*.

a)



b)

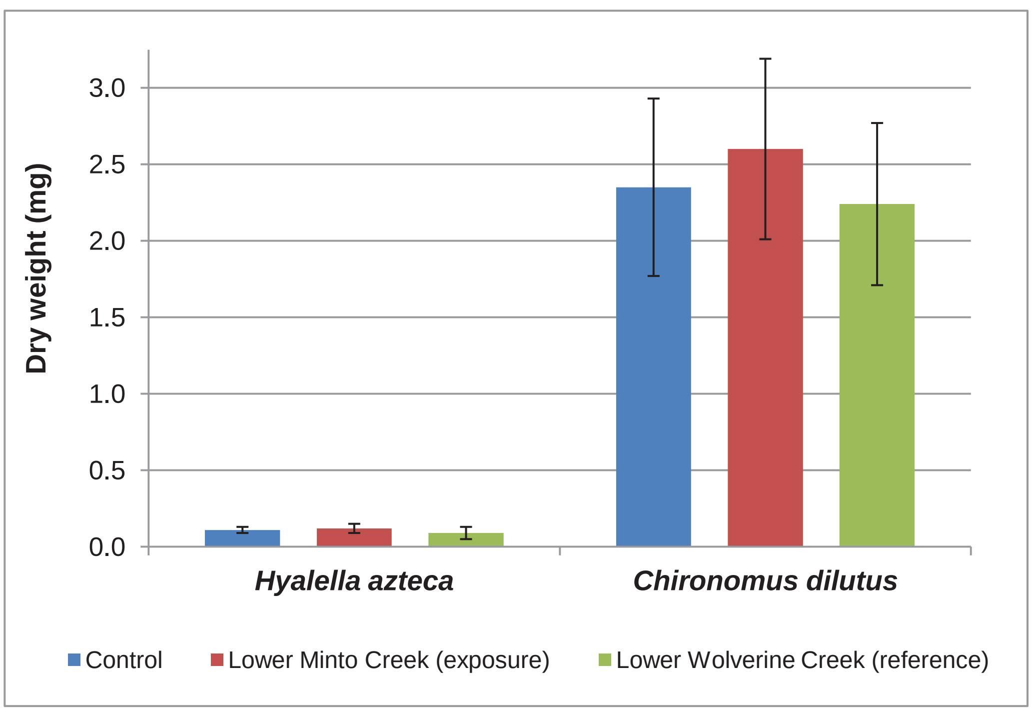


Figure 4.3: Survival (a) and dry weight (b) of *Hyalella azteca* and *Chironomus dilutus* exposed to laboratory control sediment and sediment collected from lower Minto Creek and lower Wolverine Creek. Data presented as mean ± standard deviation. Asterisk indicates significant difference from the laboratory control sediment.

5.0 PERIPHYTON COMMUNITY

5.1 Primary Metrics

All four periphyton community metrics (density, taxon richness, Simpson's Evenness and Bray-Curtis distance) differed between study areas (Appendix Table D.4). Density was significantly lower at lower Minto Creek than at lower Wolverine Creek, with means of and 326,318 and 2,273,337 cells/cm^2, respectively (Appendix Tables D.2 and D.4). A total of 65 periphyton taxa were identified across both areas (Appendix Tables D.1 and D.3). Lower Minto Creek had significantly fewer taxa than Lower Wolverine Creek for both the qualitative and quantitative calculations with a difference between means of 6.4 and 3.6, respectively (Appendix Tables D.1-D.4). Simpson's E was significantly higher at lower Minto Creek than lower Wolverine Creek, with means of 0.12 and 0.06, respectively. Finally, the Bray-Curtis distance was significantly more distance from the reference median at lower Minto Creek than at lower Wolverine Creek, with means of 0.78 and 0.19, respectively (Appendix Table D.4).

5.2 Community Composition

Dominant phyla in lower Minto and Wolverine creeks were the Cyanophycea (blue-green algae) and Bacillariophyceae (diatoms), which comprised approximately 75% and 15% of total cells, respectively. Rhodophyta (red algae) represented a large proportion of the community (~15%) at lower Minto Creek (Figure 5.1). The dominant taxon at both sites was the blue-green algae *Homoeothrix varians*, which had mean abundances at lower Minto Creek and lower Wolverine Creek of 190,452 and 1,965,112 cells/cm^2, respectively (Appendix Table D.2). This translates into this one species representing approximately 58% and 86% of the community of lower Minto Creek and lower Wolverine Creek, respectively.

5.3 Temporal Comparisons

A difference in community composition is evident between periphyton samples taken at the mouth of lower Minto Creek in 1994 and 2011. In 1994, Bacillariophyceae was the dominant phylum (89%) with Cyanophyceae as the second dominant phylum (10%). In 2011, Cyanophyceae was the dominant phylum (67%) with Bacillaroiphyceae as the second dominant phylum (17%; Figure 5.1).

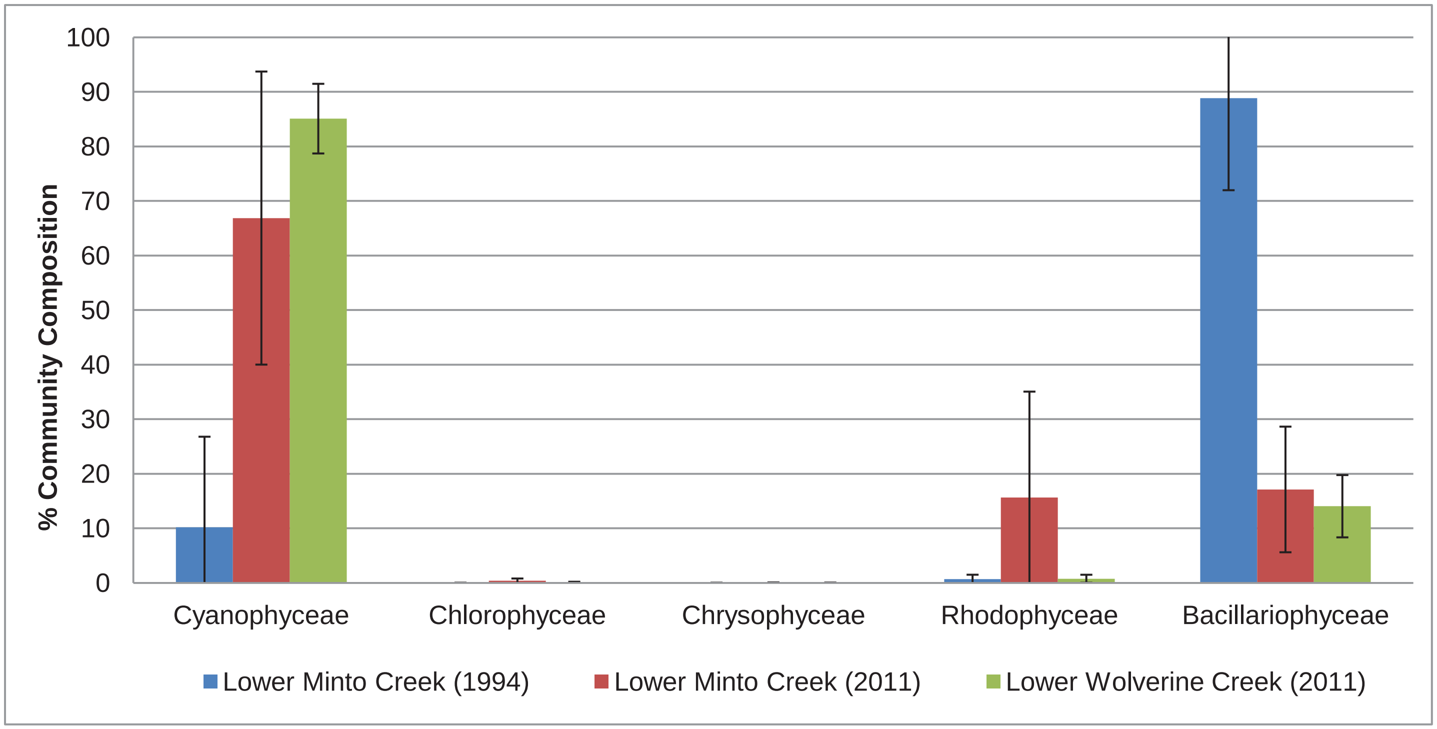


Figure 5.1: Periphyton community composition in lower Minto Creek (1994 and 2011) and lower Wolverine Creek (2011). Data presented as mean ± standard deviation.

5.4 Summary

Overall, the periphyton community of lower Minto Creek differed significantly from that of lower Wolverine Creek in terms of density (lower), taxon richness (lower), Simpson's Evenness (higher) and Bray-Curtis distance (greater), but general taxonomic dominance (particular dominance of the blue-green algae *Homoeothrix varians*) were similar. The observed differences were likely due to subtle differences in habitat conditions. Periphyton communities of both lower Minto Creek and lower Wolverine Creek in 2011 differed from the community documented at lower Minto Creek in 1994. This suggests a possible natural temporal shift in community structure.

6.0 BENTHIC INVERTEBRATE COMMUNITY

6.1 Primary Metrics

Benthic invertebrate density (individuals/m^2) was significantly higher in lower Minto Creek than at the lower Wolverine Creek reference area (4,258 versus 1,554; Figure 6.1b; Appendix Tables E.4-E.6) and mean number of benthic invertebrate taxa was significantly lower in lower Minto Creek (18.6) compared to lower Wolverine Creek (24.0; Figure 6.1a; Appendix Tables E.4-E.6). Simpson's Evenness (E) was also significantly lower at lower Minto Creek compared to the reference area (Figure 6.1c; Appendix Tables E.4-E.6), with the very low evenness score suggesting that the mine-exposed benthic invertebrate community was dominated by relatively few species. Lower Minto Creek Bray-Curtis index (distance from the reference median) was significantly higher than that of lower Wolverine Creek (Figure 6.1d; Appendix Tables E.4-E.6). Collectively, comparison of the primary benthic invertebrate community metrics indicated a clear difference between the benthic invertebrate communities of lower Minto Creek and lower Wolverine Creek.

6.2 Community Composition

Dominant taxonomic groups in lower Minto and Wolverine creeks included EPT taxa (Ephemeroptera, Plecoptera and Trichoptera or mayflies, stoneflies and caddisflies, respectively), chironomids (non-biting midges), oligochaetes (worms) and nematans (roundworms). The relative abundance of organisms from the pollution and enrichment intolerant EPT orders was significantly lower at lower Minto Creek compared to lower Wolverine Creek (Figure 6.2a; Appendix Tables E.4-E.6). Chironomid midges were found at similar relative abundance in both areas (Figure 6.2b; Appendix Tables E.4-E.6). The relative abundance of pollution tolerant oligochaete worms (Chapman et al. 1982a; 1982b) was significantly lower at Minto Creek, whereas the relative abundance of roundworms was significantly higher in Minto Creek (Figures 6.2c and 6.2d, Appendix Tables E.4-E.6).

Correspondence Analysis (CA) explained 68 percent of the total community variance in the first three CA axes (Appendix Table E.7). The first axis of CA explained 40.4 percent of the total variation in benthic invertebrate abundance and significantly separated lower Minto Creek from lower Wolverine Creek (Figure 6.3; Appendix Tables E.4-E.7). Reference stations in lower Wolverine Creek were characterized by low CA-1 scores that indicated the presence of the pollution-sensitive EPT taxa (Taeniopterygidae, Perlodidae, Heptageniidae, Ephemerellidae, and Chloroperlidae) as well as Hesperoconopa, Synorthocladius, and Orthocladius (Figure 6.3; Appendix Table E.7; Merritt et. al. 2008).

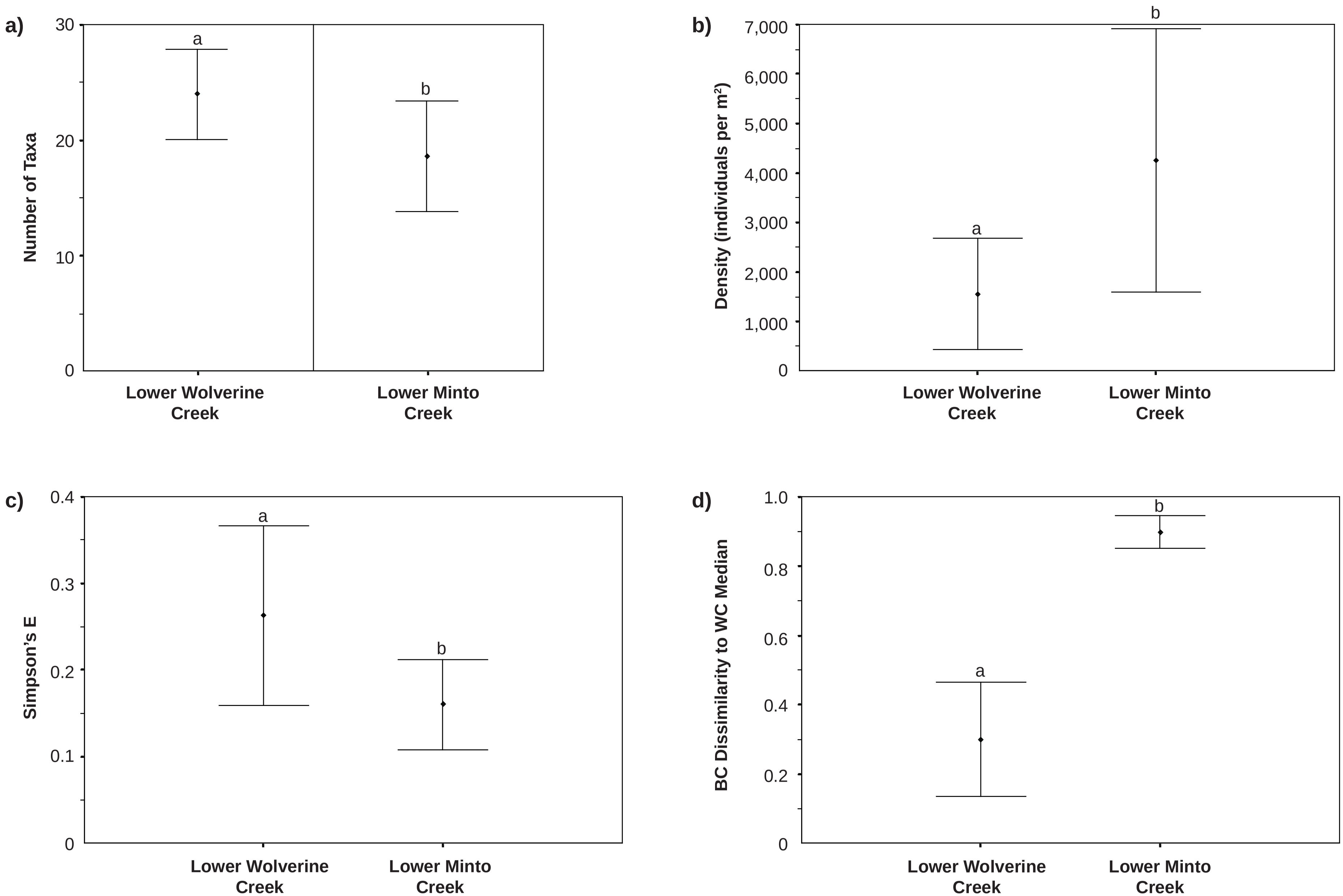


Figure 6.1: Comparison of a) number of taxa, b) benthic invertebrate density, c) Simpson's Evenness, and d) Bray-Curtis Dissimilarity at the lower Minto Creek exposure area compared to the lower Wolverine Creek reference area. Data represents area means and 95% confidence intervals (n=5 in all areas). Different letters above 95% confidence interval bars indicate areas that were significantly different ($p<0.1$).

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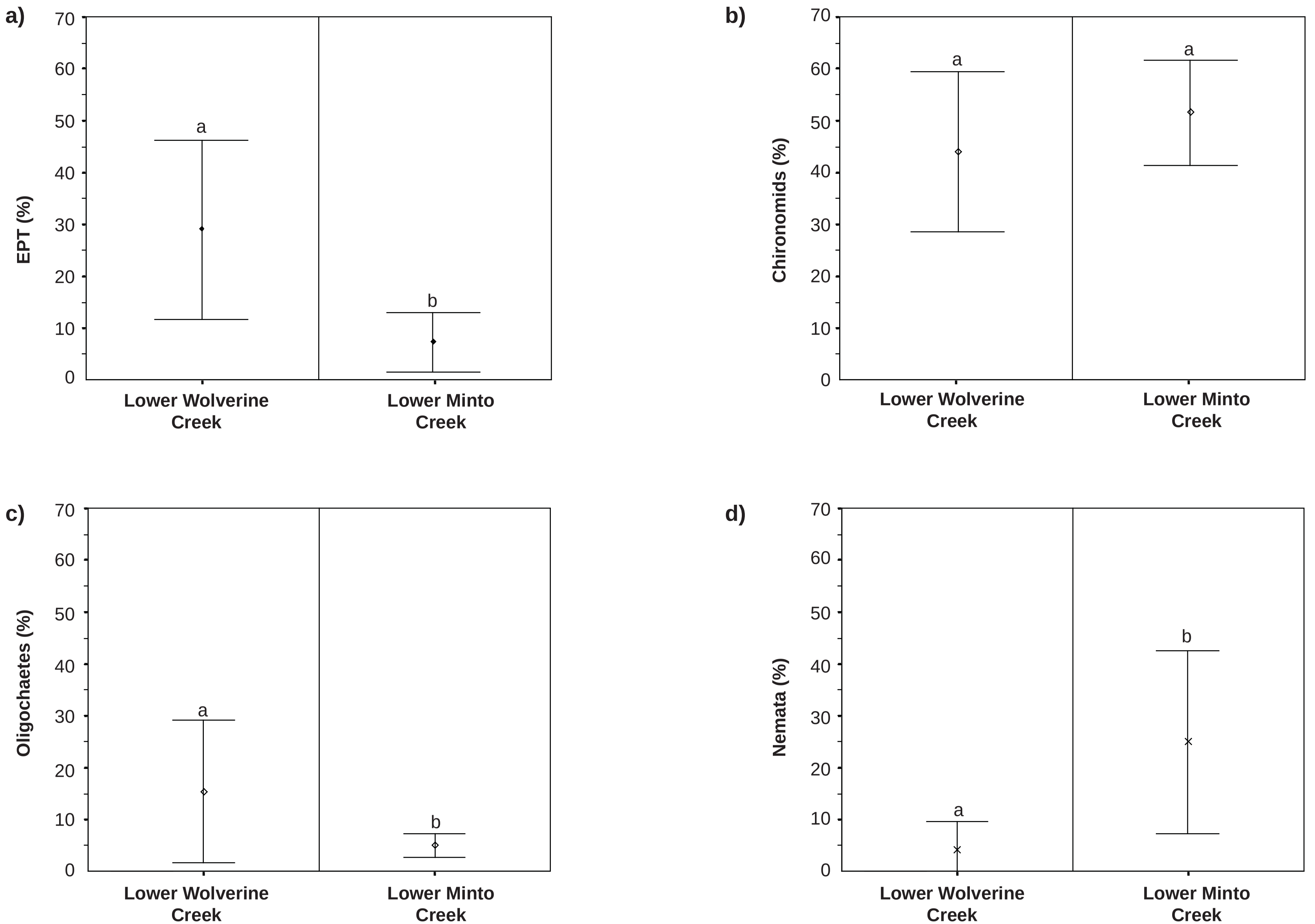

Figure 6.2: The relative abundance as percent of total organisms in an area for a) EPT, b) Chironomidae, c) Oligochaetes, and d) Nemata. Data represents area means and 95% confidence intervals (n=5 in all areas). Different letters above 95% confidence interval bars indicate areas that were significantly different (p<0.1).

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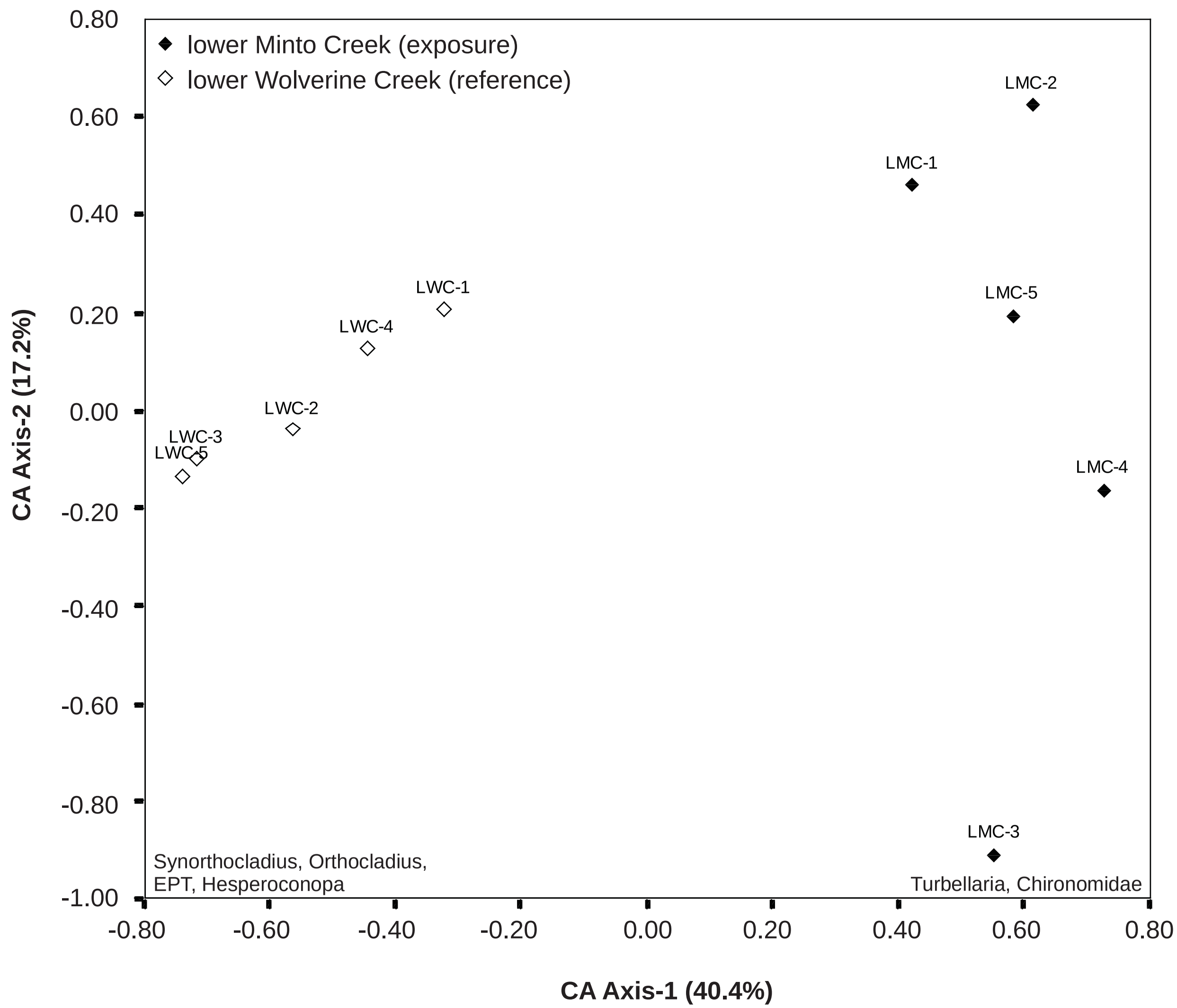

Figure 6.3: Scatterplot of benthic invertebrate community CA Axis-1 versus CA Axis-2.

Exposure stations had significantly higher positive CA-1 scores, indicating the absence of the above taxa and the presence of facultatively tolerant taxa such as Turbellaria and several Chironomidae taxa (Figure 6.3; Appendix Table E.7). No significant differences between Minto Creek and Wolverine Creek were evident in CA Axis-2 or CA Axis-3 (Appendix Table E.6).

6.3 Temporal Comparisons

Temporal comparisons of the benthic invertebrate community condition of lower Minto Creek were made in order to augment data interpretation, but their power is tempered by temporal changes in sampling location, sampling methodology, level of replication and analytical processing techniques. For example, 1994 baseline data were collected near the mouth of Minto Creek as three single grab samples, 2006 data were collected at Station W2 in the same manner, 2008 and 2010 data were collected at Station W2 as three-grab composites and 2011 data were collected as five replicate three-grab samples from a large area upstream of Station W2. Only the latter (2011) represent an area (i.e., lower Minto Creek) rather than a station.

Mean number of taxa in lower Minto Creek in 2011 (18.6 taxa) was lower than the 1994 baseline (HKP 1994) and the reference area in lower Wolverine Creek (both 24 taxa) but greater than in 2006 (15 taxa), which was also a year that the mine did not discharge (Figure 6.4). Number of taxa documented in 2011 fell within the range of taxa observed in previous studies (Figure 6.4). Although benthic invertebrate density in lower Minto Creek was lowest in 2011 (Figure 6.4), density was still greater than the lower Wolverine Creek reference (4,258 versus 1,554 individuals/m^2; Figure 6.1b; Appendix Tables E.4-E.6). In 2011, evenness in lower Minto Creek was comparable to 2006 (when the mine was not discharging) and was lower than that of lower Wolverine Creek (Figures 6.1c and 6.4; Appendix Tables E.4-E.6). Changes in density and evenness over time likely reflected high temporal variability of benthic invertebrate communities in the region, also evident at reference areas (Minnow 2009b; 2011). High inter-annual variability in environmental conditions such as flow and deep freezing can, in turn, influence benthic invertebrate community composition features among years.

6.4 Kick-and-Sweep/Reference Condition Approach

Evaluation of 2011 kick-and-sweep data using the 2008 Yukon Reference Model determined that both the effluent exposed area of lower Minto Creek and the reference area of lower Wolverine Creek were within the 90% confidence ellipse of reference and are therefore considered to be in reference condition (Appendix Figures E.1 and E.2). In

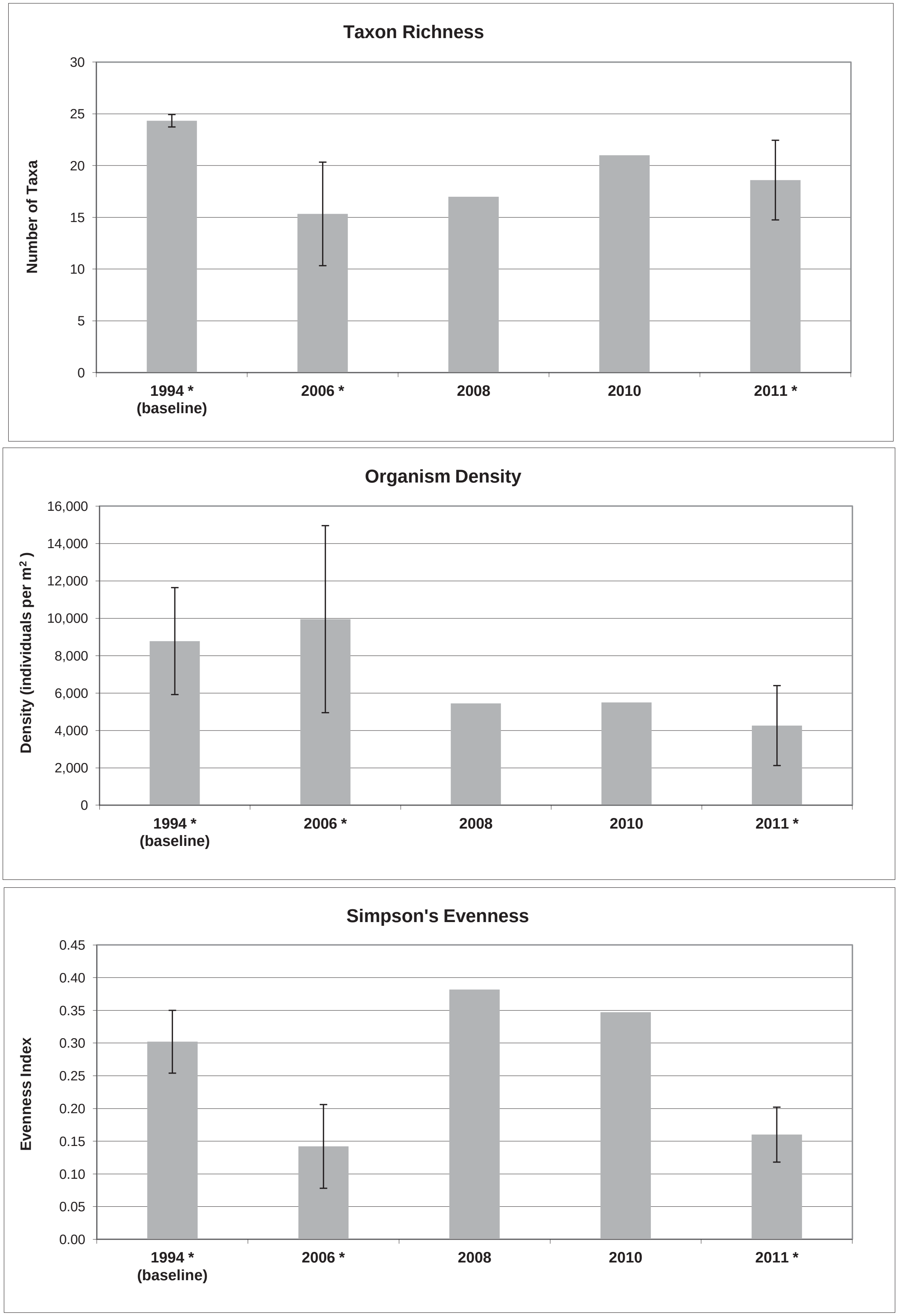

Figure 6.4: Primary benthic invertebrate community metrics at lower Minto Creek, 1994-2011. Data presented as mean ± standard deviation where replicated. Asterisk (*) indicates a year the mine was not discharging.

contrast, the 2010 Yukon Reference Model identified both sites as being potentially stressed (i.e., between the 90% and 99% confidence ellipses; Appendix Figures E.3 and E.4). The differences between the results of the 2008 and 2010 Yukon models could be due to a number of possible factors including differences in the number of reference areas in each model (i.e., 40 versus 22, respectively), poor error rates for both models, and the use of “unregenerated forest” as a predictor variable in the 2010 model (Appendix E).

The kick-and-sweep benthic community of lower Minto Creek had richness and abundance values of 21 taxa and 1,388 organisms/sample, respectively; while the benthic community at lower Wolverine Creek had richness and abundance values of 14 taxa and 1,352, respectively (Appendix Table E.9). In contrast, the 2008 Yukon Reference Model had mean total number of taxa and abundance values of 10.23 and 699, respectively and the 2010 Yukon Reference Model had mean richness and abundance values of 11.40 and 1,584, respectively (Appendix Table E.9). Therefore, taxon richness was higher at our study areas than the 2008 and 2010 models and density was higher at our study areas than the 2008 model only. Relative to the predictive reference community of the 2008 model, lower Minto Creek and lower Wolverine Creek had Bray-Curtis distances of 0.30 and 0.56, respectively. Relative to the predictive community of the 2010 model, lower Minto Creek and Lower Wolverine Creek had Bray-Curtis distances of 0.83 and 0.94, respectively (Appendix Table E.9). Simpson’s Evenness for lower Minto Creek and lower Wolverine Creek were 0.27 and 0.19, respectively (Appendix Table E.9).

Because lower Minto Creek and lower Wolverine Creek both fell within the unstressed confidence ellipse of the 2008 model, no mine related influences were suggested at Minto Creek. Although input of the data into the 2010 model indicated that both lower Minto Creek and lower Wolverine Creek were potentially stressed, the fact that both fell within the same confidence ellipse also suggests that mining activity has had a negligible effect on the benthic invertebrate community of lower Minto Creek.

6.5 Kick-and-Sweep/Hess Comparison

Comparison of benthic invertebrate community data collected by kick-and-sweep to those collected by Hess indicated slightly more taxa collected by kick-and-sweep in Minto Creek (21 versus 18.6), but the opposite in lower Wolverine Creek (14 versus 24; Appendix Tables E.5 and E.9). Accordingly, if kick-and-sweep data were used outside the RCA model, conclusions based on exposure-reference comparisons would be opposite based on kick-and-sweep relative to Hess (i.e., one would conclude that there were more taxa in Minto Creek based on kick-and-sweep sample and the opposite based on Hess sampling). Similarly, opposite conclusions would be derived for Simpson's Evenness, and taxonomic proportions of EPT taxa, chironomidae, oligochaetes and nemata (Appendix Tables E.5 and E.9). The probable reason for the contradiction is the relative uniformity of habitat in lower Wolverine Creek compared to lower Minto Creek. For instance, kick-and-sweep and Hess sampling in lower Wolverine Creek were both conducted at areas of cobble-gravel substrate (the predominant habitat feature) whereas in Minto Creek, kick-and-sweep sampling reflected a variety of habitat including overhanging vegetation and woody debris in addition to cobble-gravel, whereas Hess sampling only targeted cobble-gravel substrate. This suggests that caution should be applied in deriving conclusions based on kick-and-sweep data when habitat homogeneity/variety differs among areas and supports the application of the control-impact design using a good reference area with matching and tightly controlled habitat conditions.

6.6 Summary

Based on control-impact comparison of benthic invertebrate data collected by Hess sampling, the benthic invertebrate community of lower Minto Creek differed from that of lower Wolverine Creek on the basis of density (higher), taxon richness (lower), Simpson's Evenness (lower), Bray-Curtis dissimilarity (greater), percent EPT (lower), percent oligochaetes (lower), and percent Nemata (higher), as well as for the first axis of Correspondence Analysis. Lower Simpson's E and percent EPT taxa were consistent with what was observed in upper Minto Creek as part of the Environmental Effects Monitoring (EEM) study, but the lower number of taxa was opposite (Minnow/Access 2012). Comparison of benthic invertebrate community density, taxon richness and evenness in 2011 to those documented in previous years indicated substantial temporal variability. High temporal variability in benthic invertebrate community metrics has also been observed at reference areas (Minnow 2009b; 2011), presumably due to inter-annual variability in environmental conditions (e.g., flow, ice scour). The high temporal variability in benthic community data, potentially related to collection methods/replication or natural environmental factors, make it difficult to distinguish any mine-related influences, but the comparisons to reference and previously collected data do not indicate any substantial mine influence.

Application of two RCA Yukon Reference Models (2008 and 2010) did not agree in their designation of lower Minto Creek and lower Wolverine Creek. Both areas were designated as within reference condition based on the 2008 model and both areas were identified as potentially stressed based on the 2010 model. The fact that neither model distinguished the areas (e.g., lower Minto Creek as being stressed and lower Wolverine

Creek as in reference condition) suggested that mining activity has had little influence on the benthic community of lower Minto Creek. In consideration of both the control-impact comparisons of lower Minto Creek to lower Wolverine Creek, which documented some community differences, the RCA results for both creeks and results from other studies in Minto Creek, there is no clear evidence of mine-related impact to the erosional benthic invertebrate community of lower Minto Creek.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The Minto Mine sediment, periphyton and benthic assessment undertaken in September 2011 served to quantitatively compare water quality (field measures and chemistry), sediment quality and benthic invertebrate community condition of Minto Creek relative to reference creeks and also drew on previous data for interpretation. Water of upper Minto Creek had higher conductivity than lower Minto Creek, both of which had higher conductivity than reference creeks. This suggests a mine influence even in the absence of effluent discharge, perhaps by seepage. Phosphorus, aluminum, and iron were greater than Water Use Licence standards (WUL) in lower Minto Creek, but these standards were also not met at the reference lower Wolverine Creek (where chromium was also higher than the WUL standard). This indicates that the WUL standards are inappropriate. Concentrations of chlorophyll *a* in lower Minto Creek were low and similar to those in lower Wolverine Creek, resulting in a classification of oligotrophic (low primary productivity). As previously documented, sediments of Minto Creek had concentrations of several analytes greater than Interim Sediment Quality Guidelines for the protection of aquatic life (or "Threshold Effect Levels"). However, only in upper Minto Creek, where sediment is very sparsely distributed, was one metal - copper - present at concentrations greater than guidelines (including one sample higher than the Probable Effect Level) and was substantially greater than the reference concentrations. In lower Minto Creek, where sediment deposits are more common, there were no instances of concentrations greater than both guidelines and reference. Furthermore, sediment of lower Minto Creek was non-toxic to the test organisms *Hyalella azteca* (an amphipod) and *Chironomus dilutus* (a midge larva).

The periphyton community of lower Minto Creek differed significantly from that of lower Wolverine Creek in terms of density (lower), taxon richness (lower), Simpson's Evenness (higher) and Bray-Curtis distance (greater), but general taxonomic dominance (particularly the dominance of the blue-green algae *Homoeothrix varians*) were similar. The observed differences were likely due to subtle differences in habitat conditions. Periphyton communities of both lower Minto Creek and lower Wolverine Creek in 2011 differed from the community documented at lower Minto Creek in 1994. This suggests a possible natural temporal shift in community structure.

Based on control-impact comparison of benthic invertebrate data collected by Hess sampling, the benthic invertebrate community of lower Minto Creek differed from that of lower Wolverine Creek on the basis of density (higher), taxon richness (lower), Simpson's Evenness (lower), Bray-Curtis dissimilarity (greater), percent EPT (lower), percent oligochaetes (lower), and percent Nemata (higher), as well as for the first axis of Correspondence Analysis. Lower Simpson's E and percent EPT taxa were consistent with what was observed in upper Minto Creek in EEM, but the lower number of taxa was opposite (Minnow/Access 2012). Comparison of benthic invertebrate community density, taxon richness and evenness in 2011 to those documented in previous years indicated substantial temporal variability. High temporal variability in benthic invertebrate community metrics has also been observed at reference areas (Minnow 2009b; 2011), presumably due to inter-annual variability in environmental conditions (e.g., flow, ice scour). The high temporal variability in benthic community data, potentially related to collection methods/replication or natural environmental factors, make it difficult to distinguish any mine-related influences, but the comparisons to reference and previously collected data do not indicate any substantial mine influence.

Application of two RCA Yukon Reference Models (2008 and 2010) did not agree in their designation of lower Minto Creek and lower Wolverine Creek. Both areas were designated as within reference condition based on the 2008 model and both areas were identified as potentially stressed based on the 2010 model. The fact that neither model distinguished the areas (e.g., lower Minto Creek as being stressed and lower Wolverine Creek as in reference condition) suggested that mining activity has had little influence on the benthic invertebrate community of lower Minto Creek. In consideration of both the control-impact comparisons of lower Minto Creek to lower Wolverine Creek, which documented some community differences, the RCA results for both creeks and results from other studies in Minto Creek, there is no clear evidence of mine-related impact to the erosional benthic invertebrate community of lower Minto Creek.

7.2 Recommendations

Based on the results and conclusions of the 2011 Minto Mine sediment, periphyton and benthic assessment, the following recommendations for future monitoring are provided:

- Include chlorophyll *a* sampling of periphyton, expressed as milligrams of periphyton per unit area of creek bottom;
- Continue to assess the erosional benthic invertebrate community of lower Minto Creek using the design applied in 2011 with the following exception. Revise the sieve size applied to benthic invertebrate community monitoring from 250 um to

500 um to reflect the industry standard and to reduce the collection of small organisms/life stages that are difficult to identify precisely.

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Appendix A

Data Quality Assessment

APPENDIX A: DATA QUALITY ASSESSMENT

LIST OF TABLES

After Page…

A1.0 INTRODUCTION

Data Quality Assessment (DQA) was conducted on data collected as part of this study. The objective of DQA is to define the overall quality of the data presented in the report, and, by extension, the confidence with which the data can be used to derive conclusions.

A1.1 Background

A variety of factors can influence the chemical and biological measurements made in an environmental study and thus affect the accuracy and/or precision of the data. Inconsistencies in sampling or laboratory methods, use of instruments that are inadequately calibrated or which cannot measure to the desired level of accuracy or precision, and contamination of samples in the field or laboratory are just some of the potential factors that can lead to the reporting of data that do not accurately reflect actual environmental conditions. Depending on the magnitude of the problem, inaccuracy or imprecision have the potential to affect the reliability of any conclusions made from the data. Therefore, it is important to ensure that monitoring programs incorporate appropriate steps to control the non-natural sources of data variability (i.e., minimize the variability that does not reflect natural spatial and temporal variability in the environment) and thus assure the quality of the data.

Data quality as a concept is meaningful only when it relates to the intended use of the data. That is, one must know the context in which the data will be interpreted in order to establish a relevant basis for judging whether or not the data set is adequate. DQA involves comparison of actual field and laboratory measurement performance to data quality objectives (DQOs) established for a particular study, such as evaluation of method detection limits, blank sample data, data precision (based on field and laboratory duplicate samples), and data accuracy (based on matrix spike recoveries and/or analysis of standards or certified reference materials).

DQOs were established at the outset of the field program that reflect reasonable and achievable performance expectations (Table A.1). Programs involving a large amount of samples and analytes usually result in some results that exceed the DQOs. This is particularly so for multi-element scans (e.g., ICP scans for metals) since the analytical conditions are not necessarily optimal for every element included in the scan. Generally, scan results may be considered acceptable if no more than 20% of the parameters fail to meet the DQOs. Overall, the intent of comparing data to DQOs was not to reject any measurement that did not meet the DQO, but to ensure any

Table A.1: Data quality objectives for environmental samples.

Quality Control Measure	Quality Control Sample Type	Study Component		
		Water Quality	Sediment Quality	Benthic Invertebrate Community
Method Detection Limits (MDL)	Comparison actual MDL versus target MDL	MDL for each parameter should be at least as low as applicable guidelines, ideally ≤1/10th guideline value[a]	MDL for each parameter should be at least as low as applicable guidelines, ideally ≤1/10th guideline value[a]	n/a
Blank Analysis	Laboratory Blank	≤two-times the laboratory MDL	≤two-times the laboratory MDL	n/a
Field Precision	Field Duplicates	n/a	≤40% RPD	n/a
Laboratory Precision	Laboratory Duplicates	≤25% RPD	≤35% RPD	n/a
	Sub-Sampling Error	n/a	n/a	≤20% difference between sub-samples
Accuracy	Recovery of Matrix Spikes	75-125%	n/a	n/a
	Recovery of Certified Reference Materials (CRMs)	85-115%	70-130%	n/a
	Organism Recovery	n/a	n/a	≥ 90%

[a] or below predictions, if applicable and no guideline exists for the substance.
[b] RPD - Relative Percent Difference
n/a - not applicable

questionable data received more scrutiny to determine what effect, if any, this had on interpretation of results within the context of this project.

A1.2 Types of Quality Control Samples

Several types of quality control (QC) samples were assessed based on samples collected (or prepared) in the field and laboratory. These samples, and a description of each, include the following:

- **Blanks** are samples of de-ionized water and/or appropriate reagent(s) that are handled and analyzed the same way as regular samples. These samples will reflect any contamination of samples occurring in the field (in the case of field or travel blanks) or the laboratory (in the case of laboratory or method blanks). Analyte concentrations should be non-detectable although a data quality objective of twice the method detection limit allows for slight “noise” around the detection limit.
- **Laboratory Duplicates** are replicate sub-samples created in the laboratory from randomly selected field samples which are sub-sampled and then analyzed independently using identical analytical methods. The laboratory duplicate sample results reflect any variability introduced during laboratory sample handling and analysis and thus provide a measure of laboratory precision.
- **Spike Recovery Samples** are created in the laboratory by adding a known amount/concentration of a given analyte (or mixture of analytes) to a randomly selected test sample previously divided to create two sub-samples. The spiked and regular sub-samples are then analyzed in an identical manner. The spike recovery represents the difference between the measured spike amount (total amount in spiked sample minus amount in original sample) relative to the known spike amount (as a percentage). Two types of spike recovery samples are commonly analyzed. Spiked blanks (or blank spikes) are created using laboratory control materials whereas matrix spikes are created using field-collected samples. The analysis of spiked samples provides an indication of the accuracy of analytical results.
- **Certified Reference Materials** are samples containing known chemical concentrations that are processed and analyzed along with batches of environmental samples. The sample results are then compared to target

results to provide a measure of analytical accuracy. The results are reported as the percent of the known amount that was recovered in the analysis.

Two types of QC were applied to benthic invertebrate community samples as follows:

- **Organism Recovery Checks** for benthic invertebrate community samples involve the re-processing of previously sorted material from a randomly selected sample to determine the number of invertebrates that were not recovered during the original sample processing. The reprocessing is conducted by an analyst not involved during the original processing to reduce any bias. This check allows the determination of accuracy through assessment of recovery efficiency.

- **Sub-Sampling Error** is assessed for studies in which benthic invertebrate community samples require sub-sampling (due to excessive sample volume and/or invertebrate density). By comparing the numbers of benthic invertebrates recovered between at least two sub-samples, this measure provides an evaluation of how effective the sub-sampling method was in evenly dividing the original sample. Therefore, sub-sampling error provides a measure of analytical accuracy and precision. The processing of entire benthic invertebrate community samples in representative sample fractions also allows an evaluation of sub-sampling accuracy.

A2.0 WATER SAMPLES

A2.1 Method Detection Limits

Target laboratory method detection limits (MDL) for water sample analyses were established at levels below all applicable water quality guidelines and (Table A.2). Most reported MDLs were at or below the target concentrations with the exception of 14 analytes (i.e., alkalinity, total suspended solids, aluminum, beryllium, bismuth, cobalt, copper, iron, magnesium, nickel, thallium, titanium, vanadium, and zinc). Since the achieved MDL was still typically well below any applicable water quality guidelines and water use licence limits, it was determined that all sample data for this project could be reliably interpreted relative to the guidelines.

A2.2 Laboratory Blank Sample Analysis

All blank samples that were analyzed contained non-detectable analyte concentrations indicating no inadvertent contamination of samples within the laboratory during analysis (Tables A.3).

A2.3 Data Precision

Close agreement was generally achieved between laboratory duplicate samples indicating reported sample results were associated with excellent analytical precision (Table A.4).

A2.4 Data Accuracy

Analyte recoveries for matrix spikes and certified reference materials all met the data quality objectives (Tables A.5 and A.6) indicating excellent analytical accuracy of water sample analysis.

Table A.2: Laboratory method detection limits (MDLs) relative to targets and to water quality guidelines. Shading indicates MDLs that were above the target concentration.

	Analyte	Units	Method Detection Limit		Water Use Licence	Water quality guidelines[f]		
			Target	ALS Achieved	Limits	Canadian Water Quality Guideline (for protection of freshwater aquatic life)[a]	British Columbia Water Quality Guidelines 2006 (plus updates)[b,c]	Ontario Provincial Water Quality Objective[d]
	Alkalinity, Total (as $CaCO_3$)	mg/L	1	2.0	-	-	**43 - 109**	≥ 25% background
	Ammonia (as N)	mg/L	0.05	0.0050	0.35	**1.27**	pH and temperature dependent	pH and temperature dependent
	Bromide (Br)	mg/L	-	0.050	-	-	-	-
	Chloride (Cl)	mg/L	1	0.50	-	**150**	150 (approved)	0.002
	Conductivity	µS/cm	-	2.0	-	-	-	-
	Cyanide, Total	mg/L	-	0.0050	-	**0.005 (free)**	0.005 (free)	0.005 (WAD)
	Total Dissolved Solids	mg/L	10	10	-	-	-	-
	Fluoride (F)	mg/L	0.1	0.020	-	**0.120 (inorganic fluoride)[e]**	0.2 maximum at hardness <50 mg/L CaCO3; 0.3 maximum at hardness ≥50 mg/L CaCO3 (total fluoride) (approved)	-
	Hardness (as $CaCO_3$)	mg/L	0.5	0.50	-	-	-	-
	Total Inorganic Carbon	mg/L	-	0.50	-	-	-	-
	Nitrate plus Nitrite (N)	mg/L	-	0.0051	-	-	-	-
	Nitrate (N)	mg/L	0.1	0.0050	2.9	**2.9**	3.0 (new 2009 guideline)	-
	Nitrite (N)	mg/L	0.01	0.0010	0.06	**0.06**	0.02 (approved)	0.06
	Dissolved Organic Carbon	mg/L	0.5	0.50	-	-	**13 - 19**	-
	Total Organic Carbon	mg/L	0.5	0.50	-	-	**13 - 20**	-
	Orthophosphate-Dissolved (as P)	mg/L	0.5	0.0010	-	-	-	-
	Phosphorus (P)-Total dissolved	mg/L	-	0.0020	-	-	-	-
	Total Phosphorus (P)	mg/L	0.005	0.0020	0.02	-	0.005 (in lakes) (approved)	**0.03 for rivers[e]**
	pH	pH units	-	0.10	**6.0-9.0**	**6.5-9.0**	6.5 - 9.0 (approved)	6.5-8.5
	Sulfate (SO4)	mg/L	1	0.50	-	-	**100 (approved)**	-
	Total Suspended Solids	mg/L	1	3.0	-	**21.1**	mean of background plus 5 in 30 days when background is less than or equal to 25 (approved)	-
	Turbidity	NTU	0.1	0.10	-	**9.5**	mean of background plus 2 in 30 days when background is ≤8 (approved)	-
Total ICP MS Scan	Total Aluminum (Al)	mg/L	0.0005	0.0030	0.62	**0.100**	0.05 (dissolved at pH ≥ 6.5) (approved)	0.075 (pH 6.5 - 9.0)[e]
	Total Antimony (Sb)	mg/L	0.0001	0.00010	-	-	**0.02 (working)**	0.02[e]
	Total Arsenic (As)	mg/L	0.0001	0.00010	0.005	**0.005**	0.005 (approved)	0.005[e]
	Total Barium (Ba)	mg/L	0.0005	0.000050	-	-	**1 (working)**	-
	Total Beryllium (Be)	mg/L	0.00005	0.00010	-	-	**0.0053 (working)**	0.011 -1.1
	Total Bismuth (Bi)	mg/L	0.0001	0.00050	-	-	-	-
	Total Boron (B)	mg/L	0.05	0.010	-	**1.5 (2009 update)**	1.2 (approved)	0.2[e]
	Total Cadmium (Cd)	mg/L	0.00001	0.000010	0.00004	**'0.00004 or 0.00007**	0.000023 (hardness dependent) (working)	0.0001 - 0.0005[e]
	Total Calcium (Ca)	mg/L	0.05	0.050	-	-	-	-
	Total Chromium (Cr)	mg/L	0.0005	0.00010	0.002	**0.001 (hexavalent)**	0.001 (for hexavalent form) (working)	0.001 (hexavalent), 0.0089 (trivalent)
	Total Cobalt (Co)	mg/L	0.00005	0.00010	-	-	**0.004 (approved)**	0.0009
	Total Copper (Cu)	mg/L	0.0001	0.00050	0.013	**0.003 or 0.004**	0.00004 - 0.04 (hardness dependent) (approved)	0.001 - 0.005[e]
	Total Iron (Fe)	mg/L	0.005	0.030	1.1	**0.3**	1 (new 2008 guideline)	0.3
	Total Lead (Pb)	mg/L	0.00005	0.000050	0.004	**0.004 or 0.007**	0.004 - 0.016 (hardness dependent) (approved)	0.001 - 0.005 (hardness dependent)[e]
	Total Lithium (Li)	mg/L	-	0.00050	-	-	0.014 (secondary chronic value) or 0.096 (final chronic value) (working)	-
	Total Magnesium (Mg)	mg/L	0.05	0.10	-	-	-	-
	Total Manganese (Mn)	mg/L	0.0002	0.000050	-	-	**1.2 or 1.7**	-
	Total Molybdenum (Mo)	mg/L	0.0001	0.000050	0.073	**0.073**	1 (approved)	0.04[e]
	Total Nickel (Ni)	mg/L	0.0001	0.00050	0.11	**0.11 or 0.15**	0.025 - 0.15 (hardness dependent) (working)	0.025
	Total Phosphorus (P)	mg/L	-	0.30	-	-	0.005 (in lakes) (approved)	**0.03 for rivers[e]**
	Total Potassium (K)	mg/L	0.05	0.050	-	-	**373 (working)**	-
	Total Selenium (Se)	mg/L	0.0002	0.00010	0.001	**0.001**	0.002 (approved)	0.100
	Total Silicon (Si)	mg/L	0.1	0.050	-	-	-	-
	Total Silver (Ag)	mg/L	0.00001	0.000010	-	**0.0001**	0.00005 - 0.0015 (hardness dependent) (approved)	0.0001
	Total Sodium (Na)	mg/L	0.05	0.050	-	-	-	-
	Total Strontium (Sr)	mg/L	0.0001	0.00010	-	-	-	-
	Total Thallium (Tl)	mg/L	0.000005	0.000010	-	**0.0008**	0.0003 (working)	0.0003[e]
	Total Tin (Sn)	mg/L	0.0001	0.00010	-	-	-	-
	Total Titanium (Ti)	mg/L	0.0005	0.010	-	-	**2 (working)**	-
	Total Uranium (U)	mg/L	0.00001	0.000010	-	**0.015**	0.3 (working)	0.005[e]
	Total Vanadium (V)	mg/L	0.0002	0.0010	-	-	**0.006 (working)**	0.006[e]
	Total Zinc (Zn)	mg/L	0.0005	0.0030	0.03	**0.03**	0.075 - 0.24 (hardness dependent) (approved)	0.02[e]

Note: see Appendix Table B.4 for explanatory notes on selected water quality guideline.

[a] CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. 1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg.

[b] BCMOE (British Columbia Ministry of the Environment). 2006a. British Columbia Approved Water Quality Guidelines. Environmental Protection Division, Victoria, British Columbia.

[c] BCMOE (British Columbia Ministry of the Environment). 2006b. A Compendium of Working Water Quality Guidelines for British Columbia. Environmental Protection Division, Victoria, British Columbia.

[d] OMOE (Ontario Ministry of Environment and Energy). 1994. Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment and Energy (Ontario), July 1994.

[e] interim objective or guideline

Table A.3: Laboratory blank results associated with analysis of water samples. Shaded data did not meet the data quality objective of ≤ 2x the method detection limit (MDL).

	Analytes	Units	MDL	ALS Job Number L1057576									
Physical tests, anions, nutrients, cyanide and organics	Alkalinity, Total (as CaCO3)	mg/L	2.0	ND	ND								
	Ammonia (as N)	mg/L	0.0050	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Bromide (Br)	mg/L	0.050	ND	ND	ND	ND	ND					
	Chloride (Cl)	mg/L	0.50	ND	ND	ND	ND	ND					
	Conductivity	uS/cm	2.0	ND	ND	ND	ND	ND	ND	ND			
	Cyanide, Total	mg/L	0.0050	ND									
	Dissolved Organic Carbon	mg/L	0.50	ND	ND	ND							
	Fluoride (F)	mg/L	0.020	ND	ND	ND	ND	ND					
	Nitrate (as N)	mg/L	0.0050	ND	ND	ND	ND	ND					
	Nitrite (as N)	mg/L	0.0010	ND	ND	ND	ND	ND					
	Orthophosphate-Dissolved (as P)	mg/L	0.0010	ND									
	Sulfate (SO4)	mg/L	0.50	ND	ND	ND	ND	ND					
	Total Dissolved Solids	mg/L	10	ND	ND	ND	ND						
	Total Inorganic Carbon	mg/L	0.50	ND									
	Total Organic Carbon	mg/L	0.50	ND	ND	ND	ND	ND	ND				
	Total Suspended Solids	mg/L	3.0	ND	ND	ND	ND						
	Turbidity	NTU	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Total ICP-MS Scan	Aluminum (Al)-Total	mg/L	0.0030	ND									
	Antimony (Sb)-Total	mg/L	0.00010	ND									
	Arsenic (As)-Total	mg/L	0.00010	ND									
	Barium (Ba)-Total	mg/L	0.000050	ND									
	Beryllium (Be)-Total	mg/L	0.00010	ND									
	Bismuth (Bi)-Total	mg/L	0.00050	ND									
	Boron (B)-Total	mg/L	0.010	ND									
	Cadmium (Cd)-Total	mg/L	0.000010	ND									
	Calcium (Ca)-Total	mg/L	0.050	ND									
	Chromium (Cr)-Total	mg/L	0.00010	ND									
	Cobalt (Co)-Total	mg/L	0.00010	ND									
	Copper (Cu)-Total	mg/L	0.00050	ND									
	Iron (Fe)-Total	mg/L	0.030	ND									
	Lead (Pb)-Total	mg/L	0.000050	ND									
	Lithium (Li)-Total	mg/L	0.00050	ND									
	Magnesium (Mg)-Total	mg/L	0.10	ND									
	Manganese (Mn)-Total	mg/L	0.000050	ND									
	Molybdenum (Mo)-Total	mg/L	0.000050	ND									
	Nickel (Ni)-Total	mg/L	0.00050	ND									
	Phosphorus (P)-Total	mg/L	0.30	ND	ND	ND	ND	ND	ND	ND	ND	ND	
	Potassium (K)-Total	mg/L	0.050	ND									
	Selenium (Se)-Total	mg/L	0.00010	ND									
	Silicon (Si)-Total	mg/L	0.050	ND									
	Silver (Ag)-Total	mg/L	0.000010	ND									
	Sodium (Na)-Total	mg/L	0.050	ND									
	Strontium (Sr)-Total	mg/L	0.00010	ND									
	Thallium (Tl)-Total	mg/L	0.000010	ND									
	Tin (Sn)-Total	mg/L	0.00010	ND									
	Titanium (Ti)-Total	mg/L	0.010	ND									
	Uranium (U)-Total	mg/L	0.000010	ND									
	Vanadium (V)-Total	mg/L	0.0010	ND									
	Zinc (Zn)-Total	mg/L	0.0030	ND									
Dissolved ICP-MS Scan	Aluminum (Al)-Dissolved	mg/L	0.0030	ND									
	Antimony (Sb)-Dissolved	mg/L	0.00010	ND									
	Arsenic (As)-Dissolved	mg/L	0.00010	ND									
	Barium (Ba)-Dissolved	mg/L	0.000050	ND									
	Beryllium (Be)-Dissolved	mg/L	0.00010	ND									
	Bismuth (Bi)-Dissolved	mg/L	0.00050	ND									
	Boron (B)-Dissolved	mg/L	0.010	ND									
	Cadmium (Cd)-Dissolved	mg/L	0.000010	ND									
	Calcium (Ca)-Dissolved	mg/L	0.050	ND									
	Chromium (Cr)-Dissolved	mg/L	0.00010	ND									
	Cobalt (Co)-Dissolved	mg/L	0.00010	ND									
	Copper (Cu)-Dissolved	mg/L	0.00050	ND									
	Iron (Fe)-Dissolved	mg/L	0.030	ND									
	Lead (Pb)-Dissolved	mg/L	0.000050	ND									
	Lithium (Li)-Dissolved	mg/L	0.00050	ND									
	Magnesium (Mg)-Dissolved	mg/L	0.10	ND									
	Manganese (Mn)-Dissolved	mg/L	0.000050	ND									
	Mercury (Hg)-Dissolved	mg/L	0.000010	ND									
	Molybdenum (Mo)-Dissolved	mg/L	0.000050	ND									
	Nickel (Ni)-Dissolved	mg/L	0.00050	ND									
	Phosphorus (P)-Dissolved	mg/L	0.30	ND									
	Phosphorus (P)-Total Dissolved	mg/L	-	ND	ND	ND	ND	ND	ND	ND	ND		
	Potassium (K)-Dissolved	mg/L	0.050	ND									
	Selenium (Se)-Dissolved	mg/L	0.00010	ND									
	Silicon (Si)-Dissolved	mg/L	0.050	ND									
	Silver (Ag)-Dissolved	mg/L	0.000010	ND									
	Sodium (Na)-Dissolved	mg/L	0.050	ND									
	Strontium (Sr)-Dissolved	mg/L	0.00010	ND									
	Thallium (Tl)-Dissolved	mg/L	0.000010	ND									
	Tin (Sn)-Dissolved	mg/L	0.00010	ND									
	Titanium (Ti)-Dissolved	mg/L	0.010	ND									
	Uranium (U)-Dissolved	mg/L	0.000010	ND									
	Vanadium (V)-Dissolved	mg/L	0.0010	ND									
	Zinc (Zn)-Dissolved	mg/L	0.0030	ND									

Table A.4: Laboratory duplicate results for water sample analyses. Shaded values did not meet data quality objective of ≤ 25% relative percent difference.

Analyte	Units	ALS Job Number L1057576		
		Replicate 1	Replicate 2	Relative Percent Difference[a]
Alkalinity, Total (as CaCO3)	mg/L			
Ammonia (as N)	mg/L			
Bromide (Br)	mg/L			
Chloride (Cl)	mg/L			
Conductivity	uS/cm			
Cyanide, Total	mg/L	<0.0050	<0.0020	86
Total Dissolved Solids	mg/L			
Fluoride (F)	mg/L			
Hardness (as CaCO3)	mg/L			
Total Inorganic Carbon	mg/L	8.69	8.55	2
Nitrate and Nitrite (as N)	mg/L			
Nitrate (as N)	mg/L			
Nitrite (as N)	mg/L			
Dissolved Organic Carbon	mg/L	15.2	15.5	2
Total Organic Carbon	mg/L	16.1	15.8	2
Orthophosphate-Dissolved (as P)	mg/L			
Phosphorus (P)-Total Dissolved	mg/L			
Phosphorus (P)-Total	mg/L			
pH	pH units			
Sulfate (SO4)	mg/L			
Total Suspended Solids	mg/L			
Turbidity	NTU			
Aluminum (Al)-Total	mg/L	0.717	0.741	3
Antimony (Sb)-Total	mg/L	<0.00010	0.00011	10
Arsenic (As)-Total	mg/L	0.00128	0.00128	0
Barium (Ba)-Total	mg/L	0.0747	0.0752	1
Beryllium (Be)-Total	mg/L	<0.00010	<0.00010	0
Bismuth (Bi)-Total	mg/L	<0.00050	<0.00050	0
Boron (B)-Total	mg/L	<0.010	<0.010	0
Cadmium (Cd)-Total	mg/L	0.000014	0.000016	13
Calcium (Ca)-Total	mg/L	37	37.1	0.3
Chromium (Cr)-Total	mg/L	0.00167	0.00173	4
Cobalt (Co)-Total	mg/L	0.00073	0.00074	1
Copper (Cu)-Total	mg/L	0.00278	0.00283	2
Iron (Fe)-Total	mg/L	1.95	1.99	2
Lead (Pb)-Total	mg/L	0.000303	0.000309	2
Lithium (Li)-Total	mg/L	0.00128	0.00118	8
Magnesium (Mg)-Total	mg/L	10.7	10.8	1
Manganese (Mn)-Total	mg/L	0.163	0.165	1
Molybdenum (Mo)-Total	mg/L	0.00113	0.00114	1
Nickel (Ni)-Total	mg/L	0.00276	0.00279	1
Phosphorus (P)-Total	mg/L	<0.30	<0.30	0
Potassium (K)-Total	mg/L	0.936	0.945	1
Selenium (Se)-Total	mg/L	0.00013	0.00012	8
Silicon (Si)-Total	mg/L	8.66	8.81	2
Silver (Ag)-Total	mg/L	<0.000010	<0.000010	0
Sodium (Na)-Total	mg/L	6.25	6.28	0.5
Strontium (Sr)-Total	mg/L	0.269	0.27	0.4
Thallium (Tl)-Total	mg/L	<0.000010	<0.000010	0
Tin (Sn)-Total	mg/L	<0.00010	<0.00010	0
Titanium (Ti)-Total	mg/L	0.032	0.032	0
Uranium (U)-Total	mg/L	0.000785	0.00081	3
Vanadium (V)-Total	mg/L	0.0032	0.0032	0
Zinc (Zn)-Total	mg/L	0.0035	0.0036	3

[a] The method detection limit (MDL) value was used in instances where values less than the MDL were reported.

Table A.5: Laboratory matrix spike recoveries for water sample analyses. Shaded values did not meet data quality objective of 75 - 125% recovery.

Analytes		ALS Job Number L1057576			
Anions, nutrients and organics	Ammonia (as N)	97	102	98	106
	Bromide (Br)	82	90		
	Chloride (Cl)	101	103	101	101
	Fluoride (F)	111	115	112	111
	Nitrate (as N)	102	104	101	101
	Nitrite (as N)	94	97	89	98
	Sulfate (SO4)	103	106	100	104
	Total Organic Carbon	NC			

Table A.6: Certified reference material results for water sample analyses. Shaded values did not meet the data quality objective of 85-115% recovery.

	Analytes	ALS Job Number L1057576									
Physical tests, anions, nutrients, cyanide and organics	Alkalinity, Total (as CaCO3)	102									
	Ammonia (as N)	103	106	108	108	106	106	108	105	101	106
	Bromide (Br)[a]	102	97								
	Chloride (Cl)[a]	102	101								
	Conductivity	103									
	Cyanide, Total[a]	96									
	Fluoride (F)[a]	110	110								
	Nitrate (as N)[a]	103	102								
	Nitrite (as N)[a]	96	100								
	Orthophosphate-Dissolved (as P)	98									
	pH	100									
	Sulfate (SO4)[a]	104	103								
	Total Dissolved Solids[a]	103	100	103	109						
	Total Inorganic Carbon	98									
	Total Organic Carbon	97	103	102	93	101	99	101			
	Total Suspended Solids[a]	93	88	88	97						
	Turbidity	103	105	104	105	104	103	106	103	103	
Total ICP-MS Scan	Aluminum (Al)-Total	105									
	Antimony (Sb)-Total	101									
	Arsenic (As)-Total	105									
	Barium (Ba)-Total	104									
	Beryllium (Be)-Total	105									
	Bismuth (Bi)-Total	104									
	Boron (B)-Total	96									
	Cadmium (Cd)-Total	109									
	Calcium (Ca)-Total	105									
	Chromium (Cr)-Total	104									
	Cobalt (Co)-Total	104									
	Copper (Cu)-Total	103									
	Iron (Fe)-Total	104									
	Lead (Pb)-Total	107									
	Lithium (Li)-Total	102									
	Magnesium (Mg)-Total	104									
	Manganese (Mn)-Total	105									
	Molybdenum (Mo)-Total	105									
	Nickel (Ni)-Total	107									
	Phosphorus (P)-Total	101	96	96	98	100	94	95	97	95	
	Potassium (K)-Total	108									
	Selenium (Se)-Total	102									
	Silicon (Si)-Total	106									
	Silver (Ag)-Total	96									
	Sodium (Na)-Total	105									
	Strontium (Sr)-Total	104									
	Thallium (Tl)-Total	104									
	Tin (Sn)-Total	105									
	Titanium (Ti)-Total	107									
	Uranium (U)-Total	106									
	Vanadium (V)-Total	106									
	Zinc (Zn)-Total	104									
Dissolved ICP-MS Scan	Aluminum (Al)-Dissolved	101									
	Antimony (Sb)-Dissolved	98									
	Arsenic (As)-Dissolved	102									
	Barium (Ba)-Dissolved	99									
	Beryllium (Be)-Dissolved	102									
	Bismuth (Bi)-Dissolved	98									
	Boron (B)-Dissolved	95									
	Cadmium (Cd)-Dissolved	105									
	Calcium (Ca)-Dissolved	103									
	Chromium (Cr)-Dissolved	100									
	Cobalt (Co)-Dissolved	100									
	Copper (Cu)-Dissolved	100									
	Iron (Fe)-Dissolved	97									
	Lead (Pb)-Dissolved	102									
	Lithium (Li)-Dissolved	100									
	Magnesium (Mg)-Dissolved	102									
	Manganese (Mn)-Dissolved	101									
	Mercury (Hg)-Dissolved[a]	99									
	Molybdenum (Mo)-Dissolved	102									
	Nickel (Ni)-Dissolved	104									
	Phosphorus (P)-Dissolved	101									
	Phosphorus (P)-Total Dissolved	98	95	98	99	95	96	96	97		
	Potassium (K)-Dissolved	103									
	Selenium (Se)-Dissolved	100									
	Silicon (Si)-Dissolved	103									
	Silver (Ag)-Dissolved	92									
	Sodium (Na)-Dissolved	101									
	Strontium (Sr)-Dissolved	101									
	Thallium (Tl)-Dissolved	100									
	Tin (Sn)-Dissolved	100									
	Titanium (Ti)-Dissolved	100									
	Uranium (U)-Dissolved	101									
	Vanadium (V)-Dissolved	102									
	Zinc (Zn)-Dissolved	103									

[a] Results are based on analysis of a Laboratory Control Sample (LCS). A LCS is similar to a Certified Reference Material (CRM) except that the former is developed by ALS whereas the latter is commercially available.

A3.0 SEDIMENT SAMPLES

A3.1 Method Detection Limits

Target laboratory method detection limits (MDL) for sediment sample analyses were established at levels below all potentially applicable sediment quality guidelines (Table A.7). All reported MDLs were at or below the target concentrations, with the exception of total organic carbon (TOC) and total Kjeldahl nitrogen (TKN; Table A.7). This did not compromise interpretation of results because all values for TOC and TKN were greater than the method detection limit.

A3.2 Laboratory Blank Sample Analysis

All blank samples contained non-detectable analyte concentrations indicating no inadvertent contamination of samples within the laboratory during analysis (Table A.8).

A3.3 Data Precision

The field and laboratory duplicate sediment samples showed very good agreement in analyte concentrations (Tables A.9 and A.10) indicating very good precision.

A3.4 Data Accuracy

Recoveries of all analytes in certified reference materials met the data quality objective (Table A.11). These data indicated excellent analytical accuracy associated with the analysis of sediment samples.

Table A.7: Laboratory method detection limits (MDL) for sediment samples relative to targets and to guidelines. Shaded values indicate target MDL was not achieved.

	Analytes	Units	Target MDL	Achieved MDL	Sediment Quality Guidelines					
					Canada[a]		British Columbia[b]		Ontario[e]	
					ISQG[c]	PEL[d]	ISQG[c]	PEL[d]	LEL[f]	SEL[g]
Particle size, carbon analytes, TKN and pH	Particle Size	%	0.1	0.1						
	Total Carbon by Combustion	%		0.1						
	Total Organic Carbon	%	0.05	0.10					10	100
	CaCO3 Equivalent	%		0.70						
	Inorganic Carbon	%		0.10						
	Total Kjeldahl Nitrogen (TKN)	%	0.001	0.020					0.055	0.048
	pH (1:2 soil:water)	pH units		0.10						
Total ICP-MS Scan	Total Aluminum (Al)	mg/kg	100	50						
	Total Antimony (Sb)	mg/kg	0.2	0.10						
	Total Arsenic (As)	mg/kg	1	0.050	5.9	17	5.9	17	6	33
	Total Barium (Ba)	mg/kg	0.5	0.50						
	Total Beryllium (Be)	mg/kg	0.2	0.20						
	Total Bismuth (Bi)	mg/kg	5	0.20						
	Total Cadmium (Cd)	mg/kg	0.1	0.050	0.6	3.5	0.6	3.5	0.6	10
	Total Calcium (Ca)	mg/kg	100	50						
	Total Chromium (Cr)	mg/kg	1	0.50	37.3	90	37.3	90	26	110
	Total Cobalt (Co)	mg/kg	0.3	0.10						
	Total Copper (Cu)	mg/kg	0.5	0.50	35.7	197	35.7	197	16	110
	Total Iron (Fe)	mg/kg	100	50			21,200	43,766	20,000	40,000
	Total Lead (Pb)	mg/kg	1	0.50	35.0	91.3	35	91	31	250
	Total Lithium (Li)	mg/kg	-	1.0						
	Total Magnesium (Mg)	mg/kg	100	20						
	Total Manganese (Mn)	mg/kg	1	1.0					460	1,100
	Total Mercury (Hg)	mg/kg	0.05	0.0050	0.170	0.486	0.170	0.486	0.2	2
	Total Molybdenum (Mo)	mg/kg	0.5	0.50						
	Total Nickel (Ni)	mg/kg	0.8	0.50			16	75	16	75
	Total Phosphorus (P)	mg/kg	50	50					600	2000
	Total Potassium (K)	mg/kg	200	100						
	Total Selenium (Se)	mg/kg	0.5	0.20			2			
	Total Silver (Ag)	mg/kg	0.2	0.10			0.5			
	Total Sodium (Na)	mg/kg	100	100						
	Total Strontium (Sr)	mg/kg	1	0.50						
	Total Thallium (Tl)	mg/kg	0.05	0.050						
	Total Tin (Sn)	mg/kg	1	2.0						
	Total Titanium (Ti)	mg/kg	5	1.0						
	Total Uranium (U)	mg/kg	0.05	0.050						
	Total Vanadium (V)	mg/kg	5	0.20						
	Total Zinc (Zn)	mg/kg	5	1.0	123	315	123	315	120	820

[a] CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. 1999 plus updates, Winnipeg, MB.)
[b] BCMOE (British Columbia Ministry of Environment). 2006. A compendium of Working Water Quality Guidelines for British Columbia. Updated August 2006.)
[c] Interim sediment quality guideline
[d] Probable effect level
[e] OMOE (Ontario Ministry of Environment). 1993. Guidelines For The Protection and Management Of Aquatic Sediment Quality In Ontario. August 1993, Reprinted October, 1996. MOE (1993).
[f] Lowest effect level.
[g] Severe effect level.

Table A.8: Laboratory blank results associated with analyses of sediment samples. Shaded values did not meet the data quality objective of ≤ 2x the method detection limit.

Analytes		Units	ALS Job Number L1058864			
			Method Detection Limit	Method Blank		
Carbon analytes and TKN	Total Carbon by Combustion	%	0.1	ND	ND	
	CaCO3 Equivalent	%	0.70	ND	ND	
	Inorganic Carbon	%	0.10	ND	ND	
	Total Kjeldahl Nitrogen	%	0.020	ND	ND	ND
Total ICP-MS Scan	Total Aluminum (Al)	mg/kg	50	ND	ND	
	Total Antimony (Sb)	mg/kg	0.2	ND	ND	
	Total Arsenic (As)	mg/kg	1	ND	ND	
	Total Barium (Ba)	mg/kg	0.5	ND	ND	
	Total Beryllium (Be)	mg/kg	0.2	ND	ND	
	Total Bismuth (Bi)	mg/kg	1	ND	ND	
	Total Cadmium (Cd)	mg/kg	0.1	ND	ND	
	Total Calcium (Ca)	mg/kg	50	ND	ND	
	Total Chromium (Cr)	mg/kg	1	ND	ND	
	Total Cobalt (Co)	mg/kg	0.1	ND	ND	
	Total Copper (Cu)	mg/kg	0.5	ND	ND	
	Total Iron (Fe)	mg/kg	50	ND	ND	
	Total Lead (Pb)	mg/kg	1	ND	ND	
	Total Lithium (Li)	mg/kg	50	ND	ND	
	Total Magnesium (Mg)	mg/kg	1	ND	ND	
	Total Manganese (Mn)	mg/kg	0.05	ND	ND	
	Total Mercury (Hg)	mg/kg	0.5	ND	ND	
	Total Molybdenum (Mo)	mg/kg	0.5	ND	ND	
	Total Nickel (Ni)	mg/kg	200	ND	ND	
	Total Phosphorus (P)	mg/kg	50			
	Total Potassium (K)	mg/kg	0.2	ND	ND	
	Total Selenium (Se)	mg/kg	100	ND	ND	
	Total Silver (Ag)	mg/kg	1	ND	ND	
	Total Sodium (Na)	mg/kg	0.05	ND	ND	
	Total Strontium (Sr)	mg/kg	5	ND	ND	
	Total Thallium (Tl)	mg/kg	5	ND	ND	
	Total Tin (Sn)	mg/kg	0.05	ND	ND	
	Total Titanium (Ti)	mg/kg	5	ND	ND	
	Total Uranium (U)	mg/kg	5	ND	ND	
	Total Vanadium (V)	mg/kg	0.20	ND	ND	
	Total Zinc (Zn)	mg/kg	1.0	ND	ND	

ND - Non-Detectable. Indicates analyte concentrations that were less than the MDL during analysis.

Table A.9: Field duplicate results for analysis of sediment samples. Shaded values did not meet the data quality objective of ≤ 40% relative percent difference.

	Analytes	Units	ALS Job Number L1058864					
			Station ID LMC-3 (September 12, 2011)			Station ID UMC-3 (September 13, 2011)		
			Replicate 1	Replicate 2	Relative Percent Difference[a]	Replicate 1	Replicate 2	Relative Percent Difference[a]
Carbon analytes, TKN and pH	Total Carbon by Combustion	%	4.8	6.0	22	2.5	2.5	0
	Total Organic Carbon	%	4.59	5.88	25	2.35	2.51	7
	CaCO3 Equivalent	%	1.45	1.06	31	0.94	0.82	14
	Inorganic Carbon	%	0.17	0.13	27	0.11	<0.10	10
	Total Kjeldahl Nitrogen	%	0.251	0.281	11	0.175	0.145	19
	pH (1:2 soil:water)	pH units	7.65	7.78	2	8.00	8.18	2
Total ICP-MS Scan	Total Aluminum (Al)	mg/kg	11100	11300	2	13600	12500	8
	Total Antimony (Sb)	mg/kg	0.61	0.53	14	0.51	0.45	13
	Total Arsenic (As)	mg/kg	7.47	6.61	12	6.83	6.24	9
	Total Barium (Ba)	mg/kg	250	232	7	236	202	16
	Total Beryllium (Be)	mg/kg	0.52	0.45	14	0.58	0.51	13
	Total Bismuth (Bi)	mg/kg	<0.20	<0.20	0	<0.20	<0.20	0
	Total Cadmium (Cd)	mg/kg	0.265	0.202	27	0.242	0.200	19
	Total Calcium (Ca)	mg/kg	13600	11600	16	9440	9290	2
	Total Chromium (Cr)	mg/kg	28.2	27.4	3	33.3	31.6	5
	Total Cobalt (Co)	mg/kg	10.9	10.5	4	13.3	12.7	5
	Total Copper (Cu)	mg/kg	37.1	32.2	14	206	206	0
	Total Iron (Fe)	mg/kg	23500	23200	1	26800	25300	6
	Total Lead (Pb)	mg/kg	6.18	5.86	5	6.60	6.22	6
	Total Lithium (Li)	mg/kg	8.5	8.4	1	9.5	8.4	12
	Total Magnesium (Mg)	mg/kg	6130	6290	3	10100	9860	2
	Total Manganese (Mn)	mg/kg	908	843	7	2230	1750	24
	Total Mercury (Hg)	mg/kg	0.0544	0.0444	20	0.0293	0.0224	27
	Total Molybdenum (Mo)	mg/kg	0.67	0.58	14	2.17	1.74	22
	Total Nickel (Ni)	mg/kg	27.7	26.8	3	51.9	51.6	1
	Total Phosphorus (P)	%	815	842	3	986	998	1
	Total Potassium (K)	mg/kg	790	850	7	1420	1300	9
	Total Selenium (Se)	mg/kg	0.51	0.40	24	0.62	0.48	25
	Total Silver (Ag)	mg/kg	0.11	<0.10	10	0.16	0.15	6
	Total Sodium (Na)	mg/kg	210	250	17	530	560	6
	Total Strontium (Sr)	mg/kg	108	91.7	16	97.9	92.8	5
	Total Thallium (Tl)	mg/kg	0.081	0.083	2	0.095	0.085	11
	Total Tin (Sn)	mg/kg	<2.0	<2.0	0	<2.0	<2.0	0
	Total Titanium (Ti)	mg/kg	507	575	13	714	690	3
	Total Uranium (U)	mg/kg	1.59	1.25	24	0.907	0.799	13
	Total Vanadium (V)	mg/kg	51.2	49.7	3	58.6	57.2	2
	Total Zinc (Zn)	mg/kg	51.8	53.5	3	97.7	88.9	9

[a] The method detection limit (MDL) value was used in instances where values less than the MDL were reported.

Table A.10: Laboratory duplicate results for analysis of sediment samples. Shaded values did not meet the data quality objective of ≤ 25% relative percent difference (RPD).

	Analytes	Units	ALS Job Number L1058864								
			Replicate 1	Replicate 2	RPD[a]	Replicate 1	Replicate 2	RPD[a]	Replicate 1	Replicate 2	RPD[a]
Particle size, carbon analytes, TKN and pH	% Gravel (>2mm)	%	<0.10	<0.10	0						
	% Sand (2.0mm - 0.063mm)	%	25.8	25.6	1						
	% Silt (0.063mm - 4um)	%	61.7	62.4	1						
	% Clay (<4um)	%	12.6	12	5						
	Total Carbon by Combustion	%	8.8	8.9	1						
	CaCO3 Equivalent	%	1.75	2.08	17	1.58	1.76	11			
	Inorganic Carbon	%	0.21	0.25	17	0.19	0.21	10			
	Total Kjeldahl Nitrogen (TKN)	%	0.209	0.195	7	0.251	0.259	3	0.281	0.291	3
	pH (1:2 soil:water)	pH units	7.52	7.48	1						
Total ICP-MS Scan	Total Aluminum (Al)	mg/kg									
	Total Antimony (Sb)	mg/kg									
	Total Arsenic (As)	mg/kg									
	Total Barium (Ba)	mg/kg									
	Total Beryllium (Be)	mg/kg									
	Total Bismuth (Bi)	mg/kg									
	Total Cadmium (Cd)	mg/kg									
	Total Calcium (Ca)	mg/kg									
	Total Chromium (Cr)	mg/kg									
	Total Cobalt (Co)	mg/kg									
	Total Copper (Cu)	mg/kg									
	Total Iron (Fe)	mg/kg									
	Total Lead (Pb)	mg/kg									
	Total Lithium (Li)	mg/kg									
	Total Magnesium (Mg)	mg/kg									
	Total Manganese (Mn)	mg/kg									
	Total Mercury (Hg)	mg/kg	0.0318	0.0321	1						
	Total Molybdenum (Mo)	mg/kg									
	Total Nickel (Ni)	mg/kg									
	Total Phosphorus (P)	mg/kg									
	Total Potassium (K)	mg/kg									
	Total Selenium (Se)	mg/kg									
	Total Silver (Ag)	mg/kg									
	Total Sodium (Na)	mg/kg									
	Total Strontium (Sr)	mg/kg									
	Total Thallium (Tl)	mg/kg									
	Total Tin (Sn)	mg/kg									
	Total Titanium (Ti)	mg/kg									
	Total Uranium (U)	mg/kg									
	Total Vanadium (V)	mg/kg									
	Total Zinc (Zn)	mg/kg									

[a] The method detection limit (MDL) value was used in instances where values less than the MDL were reported.

Table A.11: Recoveries of certified reference material (CRM) for sediment sample analyses. Shaded values did not meet data quality objective of 70 - 130%.

Analytes		Percent Recoveries (ALS Job Number L1058864)		
Particle size, carbon analytes and TKN[a]	% Sand (2.0mm - 0.063mm)	104		
	% Silt (0.063mm - 4um)	95		
	% Clay (<4um)	96		
	Total Carbon by Combustion	107	100	
	CaCO3 Equivalent	112	105	
	Inorganic Carbon	113	105	
	Total Kjeldahl Nitrogen	95	105	104
	Total Phosphorus (P)	103	102	
Total ICP-MS Scan	Total Aluminum (Al)	97	95	
	Total Antimony (Sb)	98	81	
	Total Arsenic (As)	107	108	
	Total Barium (Ba)	100	94	
	Total Beryllium (Be)	97		
	Total Bismuth (Bi)	97		
	Total Cadmium (Cd)	108		
	Total Calcium (Ca)	105	101	
	Total Chromium (Cr)	105	103	
	Total Cobalt (Co)	100	98	
	Total Copper (Cu)	98	94	
	Total Iron (Fe)	97	100	
	Total Lead (Pb)	94	96	
	Total Lithium (Li)	86	83	
	Total Magnesium (Mg)	99	96	
	Total Manganese (Mn)	99	101	
	Total Mercury (Hg)	98	101	
	Total Molybdenum (Mo)	108		
	Total Nickel (Ni)	102	101	
	Total Phosphorus (P)	103	102	
	Total Potassium (K)	96	88	
	Total Selenium (Se)	100	104	
	Total Silver (Ag)	93		
	Total Sodium (Na)	99	94	
	Total Strontium (Sr)	102	100	
	Total Thallium (Tl)	100	102	
	Total Tin (Sn)	106		
	Total Titanium (Ti)	118	116	
	Total Uranium (U)	101		
	Total Vanadium (V)	106	106	
	Total Zinc (Zn)	95	97	

[a] Results reported by the lab as IRM (Internal Reference Material) which is a reference material developed by the lab and is similar to commercially available CRMs.

A4.0 BENTHIC MACROINVERTEBRATE SAMPLES

The objective for percent organism recovery was met for each of the eight re-sorted samples, with an average percent recovery of approximately 97% (Table A.12a). Precision and accuracy of the sub-sampled benthic invertebrate community samples also met the DQO of 20% (Appendix Table A.12b). Overall, the benthic invertebrate community sample data were of excellent quality, meeting established precision, accuracy and percent recovery QC criteria.

Table A.12a: Percent recovery of benthic invertebrates, Minto Mine Cycle 2 EEM. Shading indicates that the data quality objective of ≥90% was not met.

Site	Number of organisms recovered (initial sort)	Number of organisms in re-sort	Percent recovery
LWC Replicate 5	334	342	98
LMC Replicate2	334	340	98
LMC Replicate 4	432	452	95

Table A.12b: Calculation of subsampling error for benthic invertebrate samples, Minto Mine Cycle 2 EEM. Shading indicates that the data quality objective of <20% was not met.

Sample	Number of organisms in fraction 1 (25%)	Number of organisms in fraction 2 (25%)	Number of organisms in fraction 3 (25%)	Number of organisms in fraction 4 (25%)	Actual density	Precision (range of RPD)[a]		Accuracy (range expressed as %)[b]	
LMC Replicate 4	434	385	450	411	1680	6.3	9	8.3	7
LWC K&S	408	441	356	385	1590	7.5	19	10.4	11

[a] relative percent difference among subsamples

[b] range of deviation of abundance estimates derived from sub-samples compared to analysis of entire sample (expressed as % of total organisms present)

A5.0 DATA QUALITY STATEMENT

The quality of data for this project was adequate to serve the project objectives.

Appendix B

Supporting Information and Data

Table B.1: Habitat characteristics for benthic invertebrate stations, Minto Mine, September 2011.

Characteristics		Lower Wolverine Creek (Reference)					Lower Minto Creek (Exposure)				
		LWC-1	LWC-2	LWC-3	LWC-4	LWC-5	LMC-1	LMC-2	LMC-3	LMC-4	LMC-5
Latitude (dd mm ss.s)		62 42 15.4	62 42 17.9	62 42 23.7	62 42 25.0	62 42 26.6	62 38 49.9	62 38 49.8	62 38 48.9	62 38 49.6	62 38 49.8
Longitude (ddd mm ss.s)		137 17 54.4	137 17 51.6	137 17 46.9	137 17 46.1	137 17 46.3	137 06 17.9	137 06 16.3	137 06 10.5	137 06 09.0	137 06 08.0
Approximate Length of Reach Assessed (m)		20	20	20	30	30	10	10	15	10	20
Gradient (%)		2	2	1	2	1.5	2	4	3		5
Velocity (m/s)	Mean (min-max)	0.61 (0.52-0.80)	0.38 (0.23-0.53)	0.42 (0.27-0.62)	0.26 (0.19-0.31)	0.76 (0.59-1.04)	0.34 (0.29-0.38)	0.61 (0.23-0.89)	0.32 (0.12-0.43)	0.40 (0.13-0.84)	0.18 (0.07-0.35)
Depth (m)	Mean	0.40	0.33	0.10	0.15	0.12	0.16	0.11	0.17	0.19	0.27
	Maximum	>0.60	~0.70	~0.60	~0.25	~20	0.35	~0.5	~0.3	~0.35	~0.40
Width (m)	Wetted	12	19	6	6.65	13	2.52	2.89	2.47	2.63	2.17
	Bankfull	20	21	20	15	13	3.50	4.40	4.43	3.88	2.78
General Morphology	% pool	0	0	40	0	0	0	0	0	0	0
	% riffle	80	70	60	30	50	50	40	50	20	20
	% run	20	20	-	70	50	50	60	50	80	80
Bank Condition		Moderate	Moderate	-	-	Moderate	Moderate	Stable	Moderate	Stable	Moderate
Substrate Coverage	% bedrock	0	0	0	0	0	0	0	0	0	0
	% boulder	0	0	0	0	0	0	0	0	0	0
	% cobble	70	70	70	70	70	70	90	70	80	80
	% gravel	20	15	20	15	15	15	5	15	15	10
	% sand and finer	10	15	10	15	15	15	5	15	5	10
Instream Cover (% total Surface)	undercut banks	0	<1	<1	<1	1	<1	5	<1	0	<1
	boulder	0	0	0	0	0	0	0	0	0	0
	woody debris	5	1	1	1	1	1	10	1	10	1
	deep pool	0	0	1	0	0	0	0	0	0	0
	macrophytes	0	0	1	0	<1	0	0	0	0	0
	other	0	1 (leaf litter)	1 (leaf litter)	1 (leaf litter)	<1 (leaf litter)	1 (leaf litter)	-	1 (leaf litter)	-	1 (leaf litter)
Overhead Canopy (%Surface)	Dense	0	0	0	0	0	0	0	0	0	0
	Partially Open	0	0	1	1	1	10	60	50	80	50
	Open	100	100	99	99	99	90	40	50	20	50
Aquatic Vegetation (% areal coverage)	Emergent	0	0	0	0	0	0	0	0	0	0
	Submergent	0	0	0	0	<1 (moss)	0	0	0	0	0
	Floating	0	0	0	0	0	0	0	0	0	0
	Attached Algae	70 (brown periphyton)	70 (brown periphyton)	70 (brown periphyton)	70 (brown periphyton)	70 (skim of brown periphyton)	70 (brown periphyton)	50 (periphyton)	70 (skim of brown periphyton)	70 (periphyton)	80 (brown periphyton)
Riparian vegetation		willow, alder, cottonwood, spruce	spruce, aspen, cottonwood, grass	spruce, aspen, birch, grass	spruce, birch, aspen, grass, moss	spruce, grass, willow, cottonwood, aspen	alder, aspen, birch, cottonwood	alder, aspen, birch, cottonwood	willow, alder, aspen, grass, moss	willow, alder, aspen, grass, moss	willow, alder, aspen, grass, moss
Surrounding Land Use		forest	forest	forest	forest	forest	forest, mine road	forest	forest, mine, road	forest	tall shrubs, road ~ 500 m away
Evidence of Anthropogenic Disturbance		none	none	none	none	none	mine, road	mine, road	mine, road	mine, road	mine, road
General Comments/Notes		-	-	large log dam upstream	small channel on side	island (cobble, gravel, sand) takes up most of the channel width	-	small log jam and waterfall u/s	turbidity makes it hard to tell if there are any macrophytes	small log jam upstream	small waterfall d/s of Hess

Table B.2: Intermediate axis length and embededdness of 100 cobble washed during Hess sampling at benthic invertebrate stations, Minto Mine WUL, 2011.

Cobble Number	LWC-1		LWC-2		LWC-3		LWC-4	
	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)
1	10.0		5.0		6.5		2.9	
2	8.0		10.4		7.5		4.3	
3	10.5		11.1		9.3		5.8	
4	6.1		4.4		4.7		4.4	
5	7.5		7.2		6.1		3.5	
6	5.0		7.5		5.5		2.9	
7	6.5		9.4		4.3		3.0	
8	7.0		7.1		6.5		4.0	
9	7.0		7.5		5.0		2.7	
10	6.0	30	4.7	10	2.7	20	1.9	60
11	8.0		4.5		4.7		2.5	
12	3.9		7.2		3.1		2.9	
13	10.9		5.8		10.1		2.6	
14	5.0		4.5		4.3		3.5	
15	5.5		6.8		6.9		3.4	
16	7.4		3.8		6.2		4.5	
17	5.8		6.5		3.4		7.4	
18	5.6		9.4		3.3		5.1	
19	6.2		7.4		5.7		5.5	
20	5.4	20	5.5	20	4.4	40	6.0	60
21	3.7		6.3		5.9		6.7	
22	4.4		5.3		4.2		3.8	
23	5.4		3.5		4.9		4.1	
24	4.6		4.3		3.2		4.2	
25	3.3		9.7		4.8		4.3	
26	4.2		4.3		3.4		5.3	
27	4.4		5.5		3.5		5.4	
28	4.6		3.6		4.8		4.5	
29	6.7		3.9		4.7		9.8	
30	4.3	20	3.1	30	5.2	20	9.0	10
31	3.8		4.1		4.7		3.9	
32	3.7		7.6		2.4		4.1	
33	2.8		4.1		3.0		4.3	
34	3.9		4.8		5.9		4.2	
35	7.2		5.5		5.7		3.8	
36	6.7		9.7		7.3		3.7	
37	5.4		6.4		8.0		3.6	
38	5.9		10.7		9.8		3.4	
39	4.3		3.2		4.1		4.2	
40	4.0	40	2.9	10	7.8	10	2.3	40
41	5.7		6.0		3.5		3.1	
42	3.7		3.9		4.5		3.7	
43	4.2		5.1		4.6		3.3	
44	4.2		4.0		5.4		3.4	
45	2.6		3.9		4.6		3.1	
46	2.9		3.6		4.8		3.2	
47	2.9		4.5		2.6		2.6	
48	2.8		4.2		3.6		2.7	
49	2.5		2.7		4.1		2.9	
50	4.5	20	6.0	20	3.5	10	2.5	10
51	4.9		7.0		2.9		12.4	
52	5.1		3.1		2.6		7.3	
53	6.1		3.5		3.5		9.6	
54	3.2		4.4		5.7		9.2	
55	3.3		3.6		5.5		10.8	
56	2.1		2.6		4.3		3.8	
57	2.2		3.1		4.7		5.5	
58	3.5		4.1		2.6		5.1	
59	2.7		4.0		3.4		6.5	
60	2.8	10	2.6	60	2.6	40	2.5	20
61	3.2		2.7		1.5		5.7	
62	2.5		3.6		3.0		4.2	
63	2.1		4.6		3.4		3.7	
64	2.4		3.6		2.3		3.8	
65	2.5		5.1		4.2		3.7	
66	3.8		6.1		2.9		7.1	
67	3.4		6.5		2.8		6.5	
68	4.0		4.0		3.3		4.9	
69	4.5		3.6		3.1		4.2	
70	3.2	30	3.0	30	3.2	10	4.4	30
71	3.2		4.1		2.8		4.1	
72	2.9		2.5		3.5		3.3	
73	3.9		3.4		3.1		3.4	
74	2.7		4.5		2.7		3.5	
75	2.5		4.1		2.7		2.9	
76	2.1		3.6		4.4		4.0	
77	1.8		8.1		4.1		2.1	
78	1.7		6.5		4.5		2.9	
79	2.5		3.0		5.4		6.8	
80	3.2	20	3.5	50	6.5	30	8.6	50
81	2.3		3.9		2.5		3.1	
82	3.5		2.8		2.7		4.6	
83	4.4		5.0		3.2		3.1	
84	4.9		2.4		5.2		3.2	
85	4.9		4.0		3.8		2.9	
86	5.6		4.2		3.0		3.2	
87	6.8		3.3		3.8		3.3	
88	5.5		5.3		3.0		3.8	
89	5.3		4.7		2.5		2.7	
90	4.8	20	4.8	30	4.5	50	3.4	20
91	4.0		4.6		2.0		2.6	
92	3.6		3.4		4.1		2.6	
93	3.2		3.5		2.5		3.9	
94	7.5		2.6		5.0		3.1	
95	5.3		3.8		4.6		8.7	
96	5.9		3.0		3.9		6.6	
97	7.5		2.7		3.0		4.9	
98	4.0		4.4		4.0		6.3	
99	4.3		4.4		3.8		4.2	
100	4.7	20	3.8	20	3.0	10	6.4	50
Minimum	**1.7**		**2.4**		**1.5**		**1.9**	
Maximum	**10.9**		**11.1**		**10.1**		**12.4**	
Mean	**4.6**		**4.9**		**4.3**		**4.5**	
Geometric mean	**4.2**		**4.6**		**4.0**		**4.1**	
Median	**4.3**	**20**	**4.3**	**25**	**4.1**	**20**	**3.9**	**35**

Note: intermediate axis length is the second longest axis on a cobble. Embeddedness refers to how deeply the cobble is surrounded or buried by other substrate.

Table B.2: Intermediate axis length and embededdness of 100 cobble washed during Hess sampling at benthic invertebrate stations, Minto Mine WUL, 2011.

Cobble Number	LWC-5		LMC-1		LMC-2		LMC-3	
	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)
1	10.4		9.5		7.2		3.0	
2	5.4		5.7		6.4		4.3	
3	5.7		6.6		4.6		5.9	
4	8.4		6.6		6.9		13.0	
5	7.3		3.3		6.1		4.3	
6	5.7		3.0		9.9		3.4	
7	4.8		3.8		5.6		4.4	
8	5.4		4.2		5.4		3.0	
9	4.3		5.7		3.6		4.1	
10	5.6	40	5.7	40	4.2	20	5.1	50
11	8.4		7.5		4.0		4.1	
12	2.7		7.0		7.2		3.0	
13	3.5		9.9		4.1		2.1	
14	6.3		6.6		4.5		6.0	
15	8.7		6.0		3.4		3.7	
16	3.3		3.9		3.6		3.5	
17	3.6		5.0		4.1		3.1	
18	4.7		5.5		2.9		3.7	
19	4.1		5.5		4.1		3.6	
20	4.6	20	5.9	20	4.1	40	3.5	30
21	4.9		4.0		3.8		5.7	
22	3.8		5.0		3.5		3.7	
23	4.2		4.6		3.3		3.7	
24	5.1		3.2		3.7		2.5	
25	5.4		3.8		4.0		3.3	
26	3.9		5.0		3.2		2.9	
27	3.6		3.2		4.4		2.2	
28	4.7		4.3		3.2		7.9	
29	3.7		5.0		3.3		6.0	
30	3.6	10	3.2	20	3.2	30	3.1	10
31	4.1		3.5		3.4		3.5	
32	2.3		4.8		3.2		3.1	
33	4.7		2.3		3.3		3.3	
34	3.4		7.6		2.2		4.8	
35	3.2		4.6		2.7		2.4	
36	3.5		6.0		3.0		3.3	
37	3.3		3.8		2.9		2.2	
38	4.0		5.9		11.6		4.3	
39	3.9		6.2		9.1		8.8	
40	2.7	10	4.8	10	5.8	20	8.4	40
41	5.7		5.1		6.1		6.5	
42	3.8		3.9		5.7		9.5	
43	4.2		7.9		5.2		7.6	
44	3.9		5.8		5.1		7.8	
45	4.1		6.2		3.6		4.1	
46	2.6		4.0		6.9		7.6	
47	2.4		4.6		5.4		6.2	
48	2.5		4.8		4.9		4.1	
49	4.3		3.4		6.1		6.7	
50	3.4	50	4.4	30	4.1	10	5.5	10
51	2.5		3.8		4.3		4.3	
52	3.7		3.5		3.3		3.2	
53	2.4		3.7		4.7		7.7	
54	3.3		3.6		4.4		6.5	
55	3.7		2.7		4.0		6.4	
56	4.4		3.1		3.8		2.6	
57	3.6		3.0		3.9		2.7	
58	3.5		4.3		5.0		3.3	
59	2.8		3.3		5.2		2.4	
60	3.2	40	3.7	30	3.6	40	3.4	10
61	3.3		3.5		3.8		3.0	
62	3.4		2.5		3.8		3.4	
63	2.9		3.5		3.5		6.7	
64	2.2		3.3		4.7		3.8	
65	2.6		2.9		3.3		3.8	
66	3.1		2.2		3.6		4.1	
67	2.4		2.8		3.9		7.1	
68	2.7		3.8		2.5		4.2	
69	3.2		2.6		3.0		2.8	
70	2.9	40	3.2	50	2.8	30	7.8	50
71	3.6		2.4		3.3		7.4	
72	2.5		3.2		2.6		5.6	
73	2.9		2.8		3.0		8.6	
74	2.4		2.7		11.3		5.4	
75	3.0		6.7		13.8		3.4	
76	3.3		3.3		5.4		4.8	
77	3.0		3.3		4.2		6.8	
78	6.6		5.4		4.4		5.7	
79	6.8		3.6		3.5		6.2	
80	4.4	40	4.0	20	3.0	20	4.8	10
81	6.4		4.3		3.1		3.6	
82	5.8		4.6		2.7		4.4	
83	4.1		4.0		3.0		3.6	
84	4.4		3.6		3.4		4.2	
85	4.4		3.8		9.0		3.4	
86	4.6		3.3		9.4		4.1	
87	4.5		2.1		6.7		3.9	
88	6.3		3.2		5.0		4.0	
89	4.4		3.1		4.5		4.7	
90	4.7	30	2.4	20	4.1	40	3.8	20
91	4.8		3.4		6.0		3.7	
92	4.9		8.0		5.1		3.1	
93	3.2		5.8		3.6		2.8	
94	2.7		5.6		5.6		3.9	
95	3.1		5.7		3.7		3.0	
96	4.2		5.7		3.1		3.1	
97	4.6		4.4		2.9		2.4	
98	4.8		4.6		2.7		2.1	
99	2.9		5.4		2.9		2.5	
100	3.3	20	8.8	30	3.2	20	3.8	10
Minimum	**2.2**		**2.1**		**2.2**		**2.1**	
Maximum	**10.4**		**9.9**		**13.8**		**13.0**	
Mean	**4.2**		**4.5**		**4.6**		**4.6**	
Geometric mean	**3.9**		**4.3**		**4.3**		**4.2**	
Median	**3.9**	**35**	**4.0**	**25**	**4.0**	**25**	**3.9**	**15**

Note: intermediate axis length is the second longest axis on a cobble. Embeddedness refers to how deeply the cobble is surrounded or buried by other substrate.

Table B.2: Intermediate axis length and embededdness of 100 cobble washed during Hess sampling at benthic invertebrate stations, Minto Mine WUL, 2011.

Cobble Number	LMC-4		LMC-5	
	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)
1	4.3		3.8	
2	7.0		4.4	
3	7.5		3.1	
4	7.2		4.1	
5	11.0		8.9	
6	8.4		6.8	
7	4.3		4.9	
8	3.8		4.8	
9	6.4		4.8	
10	6.1	20	3.1	10
11	6.1		3.8	
12	6.4		2.8	
13	4.2		4.0	
14	4.1		3.0	
15	5.8		2.5	
16	5.9		4.3	
17	6.8		6.2	
18	4.6		7.6	
19	7.7		5.4	
20	3.4	50	4.9	50
21	4.3		5.6	
22	4.7		3.4	
23	5.0		2.4	
24	4.2		4.3	
25	5.3		3.4	
26	10.0		4.0	
27	3.9		3.0	
28	15.4		4.1	
29	9.5		5.4	
30	8.7	60	4.1	50
31	6.8		12.1	
32	6.2		7.8	
33	3.3		4.4	
34	7.6		4.4	
35	4.9		3.0	
36	4.6		3.8	
37	3.9		5.3	
38	3.9		6.9	
39	5.3		7.0	
40	5.3	30	6.5	20
41	6.0		3.3	
42	2.6		3.7	
43	3.5		3.5	
44	6.8		3.6	
45	3.6		3.1	
46	7.2		4.3	
47	7.4		3.0	
48	6.7		3.2	
49	4.3		12.5	
50	6.4	30	6.2	40
51	3.5		7.8	
52	4.1		4.0	
53	2.6		2.9	
54	4.7		4.3	
55	8.5		4.3	
56	3.9		3.7	
57	3.9		4.9	
58	2.9		3.1	
59	4.5		4.6	
60	3.1	60	3.1	50
61	4.0		3.6	
62	6.2		3.2	
63	4.7		2.8	
64	3.4		5.4	
65	3.7		4.2	
66	4.0		2.9	
67	3.2		5.3	
68	3.1		3.1	
69	3.9		2.8	
70	3.9	30	2.9	20
71	4.2		3.1	
72	2.4		3.4	
73	3.3		2.1	
74	3.0		2.8	
75	3.1		4.3	
76	3.7		4.1	
77	1.9		3.4	
78	3.0		2.9	
79	3.3		3.3	
80	3.4	50	4.7	20
81	3.3		3.0	
82	3.2		3.1	
83	3.5		3.6	
84	4.7		2.9	
85	3.2		3.0	
86	2.9		2.2	
87	2.6		3.1	
88	3.1		3.6	
89	6.4		3.6	
90	3.5	50	3.2	30
91	6.0		3.4	
92	3.7		2.7	
93	4.3		3.3	
94	4.0		2.3	
95	3.0		4.0	
96	2.9		2.7	
97	3.3		3.8	
98	3.4		2.9	
99	3.2		2.3	
100	3.0	20	3.3	60
Minimum	**1.9**		**2.1**	
Maximum	**15.4**		**12.5**	
Mean	**4.8**		**4.2**	
Geometric mean	**4.5**		**3.9**	
Median	**4.2**	**40**	**3.6**	**35**

Note: intermediate axis length is the second longest axis on a cobble. Embeddedness refers to how deeply the cobble is surrounded or buried by other substrate.

Table B.3: Dissolved water quality results at reference and exposure areas, Minto Mine WUL, 2011.

Analyte		Units	Upper McGinty Creek (reference)	Upper Minto Creek (exposure)	Lower Wolverine Creek (reference)	Lower Minto Creek (exposure)
Dissolved ICP-MS Scan	Aluminum (Al)-Dissolved	mg/L	0.0535	0.0044	0.0309	0.0182
	Antimony (Sb)-Dissolved	mg/L	<0.00010	<0.00010	<0.00010	<0.00010
	Arsenic (As)-Dissolved	mg/L	0.00064	0.00026	0.00052	0.00095
	Barium (Ba)-Dissolved	mg/L	0.0391	0.0811	0.0393	0.0623
	Beryllium (Be)-Dissolved	mg/L	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Dissolved	mg/L	<0.00050	<0.00050	<0.00050	<0.00050
	Boron (B)-Dissolved	mg/L	<0.010	0.017	<0.010	<0.010
	Cadmium (Cd)-Dissolved	mg/L	<0.000010	<0.000010	0.000011	<0.000010
	Calcium (Ca)-Dissolved	mg/L	16.6	57.4	20.7	37.1
	Chromium (Cr)-Dissolved	mg/L	0.00057	0.00010	0.00053	0.00044
	Cobalt (Co)-Dissolved	mg/L	0.00036	<0.00010	0.00021	0.00034
	Copper (Cu)-Dissolved	mg/L	0.00189	0.00167	0.00314	0.00162
	Iron (Fe)-Dissolved	mg/L	0.652	<0.030	0.303	0.674
	Lead (Pb)-Dissolved	mg/L	<0.000050	<0.000050	0.000050	<0.000050
	Lithium (Li)-Dissolved	mg/L	<0.00050	0.00198	0.00127	0.00086
	Magnesium (Mg)-Dissolved	mg/L	4.90	23.2	10.8	10.5
	Manganese (Mn)-Dissolved	mg/L	0.0798	0.0149	0.0422	0.133
	Mercury (Hg)-Dissolved	mg/L	<0.000010	<0.000010	<0.000010	<0.000010
	Molybdenum (Mo)-Dissolved	mg/L	0.000733	0.00315	0.000551	0.00105
	Nickel (Ni)-Dissolved	mg/L	0.00151	0.00072	0.00223	0.00183
	Phosphorus (P)-Dissolved	mg/L	<0.30	<0.30	<0.30	<0.30
	Potassium (K)-Dissolved	mg/L	0.386	2.11	0.577	0.832
	Selenium (Se)-Dissolved	mg/L	0.00020	0.00035	0.00024	0.00013
	Silicon (Si)-Dissolved	mg/L	6.90	5.43	6.02	6.98
	Silver (Ag)-Dissolved	mg/L	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Dissolved	mg/L	3.53	16.4	6.71	6.21
	Strontium (Sr)-Dissolved	mg/L	0.109	0.649	0.186	0.257
	Thallium (Tl)-Dissolved	mg/L	<0.000010	<0.000010	<0.000010	<0.000010
	Tin (Sn)-Dissolved	mg/L	<0.00010	<0.00010	0.00020	<0.00010
	Titanium (Ti)-Dissolved	mg/L	<0.010	<0.010	<0.010	<0.010
	Uranium (U)-Dissolved	mg/L	0.000226	0.00270	0.000810	0.000744
	Vanadium (V)-Dissolved	mg/L	0.0011	<0.0010	0.0016	0.0012
	Zinc (Zn)-Dissolved	mg/L	<0.0030	<0.0030	<0.0030	<0.0030

Table B.4: Explanatory notes for selected water quality guidelines, Minto Mine WUL, 2011.

Analyte		Water Quality Guidelines	Unit	CCME[a]	BCMOE[b,c]	PWQO[d]
Ions, nutrients, physical anlaytes	Alkalinity (Total as CaCO3)	43 - 109	mg/L	-	Guideline is ± 25% of background concentration (working guideline). The lower and upper values of background (56.8 and 87.2 mg/L) were used to calculate ± 25%.	-
	Ammonia (Total)	1.27	mg/L	Ammonia guideline based on field pH of 8.00 and temperature of 5°C	-	-
	Dissolved Oxygen	variable	mg/L and %	-	-	Temperature dependent guideline is 54% and 7 mg/L at temperatures of approximately 5° C and 54% and 6 mg/L at temperatures around 10° C.
	Dissolved Organic Carbon	13 - 19	mg/L	-	Guideline is median of background ± 20%. The median of the background values (16.2 mg/L) ± 20% is 13 - 19 mg/L.	-
	Fluoride	0.12	mg/L	Interim guideline (0.12 mg/) is for inorganic fluorides.	-	-
	Sulphate	100	mg/L	-	Guideline is the maximum (100 mg/L) rather than the chronic (50 mg/L) value (approved).	-
	Total Organic Carbon	8.8 - 13.2	mg/L	-	Guideline is median of background ± 20%. The median of background (16.7 mg/L) ± 20% is 13 - 20 mg/L.	-
	Total Phosphorus	0.030	mg/L	-	-	Guideline (0.03 mg/L) is for rivers and streams (interim).
	Total Suspended Solids	26	mg/L	Guideline is background plus 5 mg/L. The median of background (16.1 mg/L) plus 5 mg/L is 21.1 mg/L.	-	-
	Turbidity	10	NTU	Guideline is background plus 2 NTU. The median of background (7.5 NTU) plus 2 NTU is 9.5 NTU.	-	-
Total ICP MS Scan	Aluminum	0.100	mg/L	Guideline is pH-dependent. Field pH is consistently >6.5 in Minto Creek therefore guideline is 0.1 mg/L.	-	-
	Cadmium	0.00004 or 0.00007	mg/L	Guideline is hardness-dependent. Hardness of 247 mg/L in upper Minto Creek and of 136 mg/L in lower Minto Creek were used to calculate their respective guidelines.	-	-
	Chromium	0.001	mg/L	Guideline (0.001 mg/L) based on benchmark for hexavalent chromium (Cr VI).	-	-
	Copper	0.003 or 0.004	mg/L	Guideline is hardness-dependent. Hardness of 247 mg/L in upper Minto Creek and of 136 mg/L in lower Minto Creek were used to determine their respective guidelines.	-	-
	Lead	0.004 or 0.007	mg/L	Guideline is hardness-dependent. Hardness of 247 mg/L in upper Minto Creek and of 136 mg/L in lower Minto Creek were used to determine their respective guidelines.	-	-
	Manganese	1.2 or 1.7	mg/L	-	Guideline is hardness-dependent. Hardness of 247 mg/L in upper Minto Creek and of 136 mg/L in lower Minto Creek were used to determine their respective guidelines.	-
	Mercury	0.000026	mg/L	Guideline (0.000026 mg/L) based on inorganic mercury	-	-
	Nickel	0.11 or 0.15	mg/L	Guideline is hardness-dependent. Hardness of 247 mg/L in upper Minto Creek and of 136 mg/L in lower Minto Creek were used to determine their respective guidelines.	-	-

[a] CCME (Canadian Council of Ministers of the Environment). 1999 (plus updates). Canadian Environmental Quality Guidelines. CCME, Winnipeg.
[b] BCMOE (British Columbia Ministry of the Environment). 2006a. British Columbia Approved Water Quality Guidelines. Environmental Protection Division, Victoria, British Columbia.
[c] BCMOE (British Columbia Ministry of the Environment). 2006b. A Compendium of Working Water Quality Guidelines for British Columbia. Environmental Protection Division, Victoria, British Columbia.
[d] Provincial Water Quality Objectives (PWQO; MOEE 1994).

Table B.5: Concentration of chlorophyll *a* measured at five benthic stations in lower Wolverine and lower Minto Creeks, Minto Mine WUL, 2011.

Lower Wolverine Creek (reference)		Lower Minto Creek (exposure)	
Station	µg/L	Station	µg/L
LWC-1	0.141	LMC-1	0.300
LWC-2	0.140	LMC-2	0.367
LWC-3	0.286	LMC-3	0.257
LWC-4	0.137	LMC-4	0.163
LWC-5	0.227	LMC-5	0.286
Mean	0.186	Mean	0.275
Standard Deviation	0.067	Standard Deviation	0.074

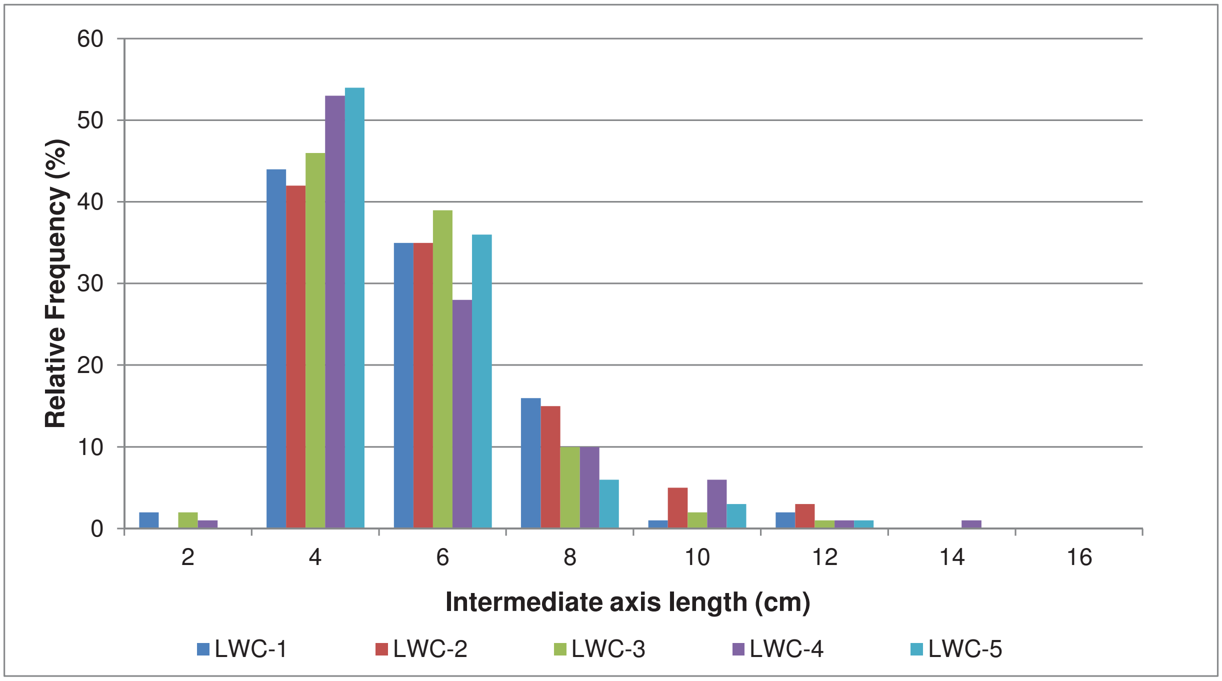

Figure B.1a: Intermediate axis length of 100 rocks measured at five benthic stations in lower Wolverine Creek.

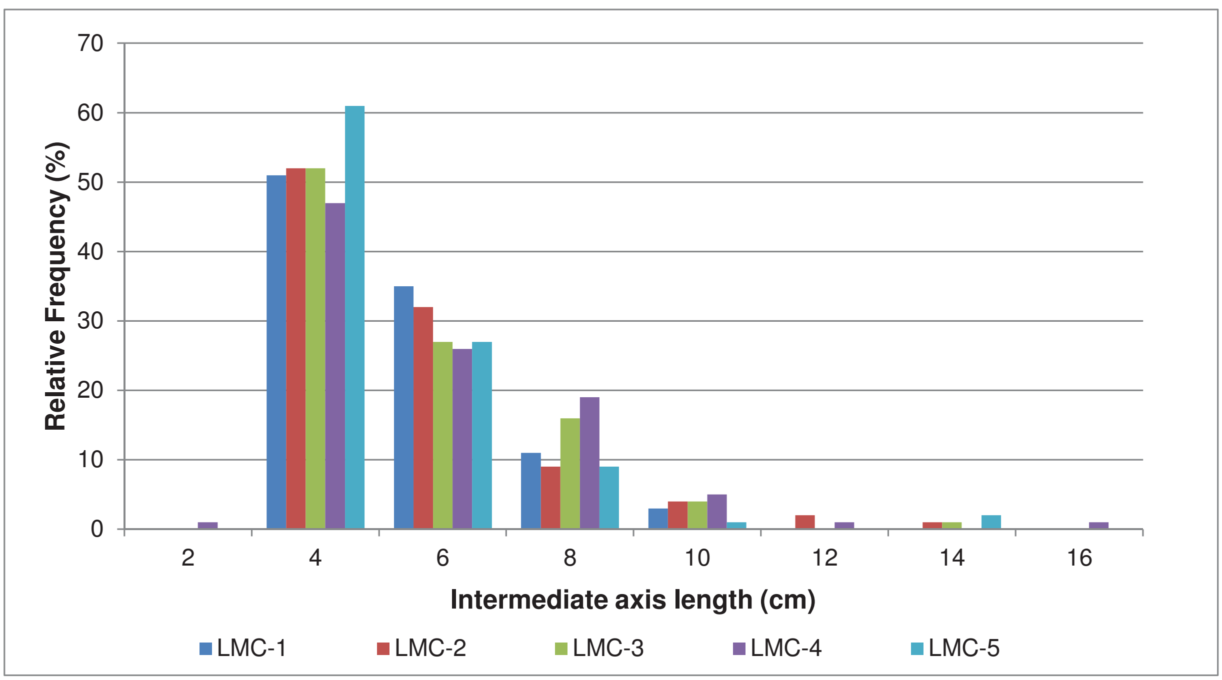

Figure B.1b: Intermediate axis length of 100 rocks measured at five benthic stations in lower Minto Creek.

Nautilus Environmental

Minnow Environmental Freshwater Sediment Toxicity Testing on LMC and LWC Samples (Collected September 10 and 12, 2011)

Final Toxicity Test Report

Report date: December 15, 2011

Submitted to:

Minnow Environmental
Georgetown, ON

Burnaby Laboratory
8664 Commerce Court
Burnaby, BC
V5A 4N7

Nautilus Environmental

WO#: 11417-418

Ms. Jocelyn Kelly
Minnow Environmental Inc.
2 Lamb St.
Georgetown, ON
L7G 3M9

December 15, 2011

Ms. Kelly:

Re: Freshwater sediment toxicity testing (Samples collected September 10 and 12, 2011)

Nautilus Environmental is pleased to provide you with the results of the toxicity tests conducted on freshwater sediment samples received on September 21, 2011. Testing was conducted using *Hyalella azteca* and *Chironomus dilutus* following Environment Canada methods. Test results provided in this revised report met all the acceptability criteria specified by Environment Canada protocols for both species. A summary of the test methods and results are provided in the following report.

Please feel free to contact the undersigned at 604-420-8773 should you have any questions or require any additional information.

Nautilus Environmental

Edmund Canaria, R.P. Bio
Senior Environmental Biologist

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1.0 INTRODUCTION

Nautilus Environmental laboratory conducted freshwater sediment toxicity tests for Minnow Environmental on the samples identified as LMC and LWC. The samples were collected on September 10 and 12, 2011 in 2 or 4L HDPE plastic containers and transported in coolers with ice gel packs. The samples were received at the Nautilus Laboratory on September 21, 2011. The samples were stored in the dark at 4 ± 2°C prior to testing.

The sediment samples were evaluated for toxicity using the 14-d *Hyalella azteca* and 10-d *Chironomus dilutus* sediment toxicity tests. The following report describes the results of these toxicity tests. The test results presented herein relate only to the samples tested. Copies of raw laboratory data sheets and statistical analyses for each test are provided in Appendices A and B. The sediment description sheet and chain-of-custody form are provided in Appendices C and D, respectively.

2.0 METHODS

2.1 Sediment Toxicity Tests

The 14-d *H. azteca* and 10-d *C. dilutus* tests were conducted according to procedures described by Environment Canada (1997a and 1997b). Methods and test conditions for the toxicity tests are summarized in Tables 1 and 2. Toxicity testing of the two samples were initiated on September 30, 2011. Statistical analyses were performed using the CETIS (Tidepool Scientific Software, 2011) software program. Total ammonia concentrations in the overlying and interstitial waters were analyzed by ALS Laboratory Group.

2.2 Quality Assurance/Quality Control (QA/QC)

Nautilus follows a comprehensive QA/QC program to ensure that all data generated are of high quality and are scientifically defensible. To meet these objectives, Nautilus has implemented a number of quality control procedures that include the following:

- Negative controls to ensure that appropriate testing performance criteria are met;
- Positive controls to assess the health and sensitivity of the test organisms;
- Use of appropriate species, life stage and test methods to meet the study objectives;
- Appropriate number of replicates to allow the proper statistical analyses;

- Calibration and proper maintenance of instruments to ensure accurate measurements;
- Proper documentation and recordkeeping to allow traceability of performance;
- Adequate supervision and training of staff to ensure that methods are followed;
- Proper handling and storage of samples to ensure sample integrity;
- Procedures in place to address issues that may arise during testing and ensure the implementation of appropriate corrective actions; and
- Rigorous review of data by a Registered Professional Biologist to ensure they are of good quality and are scientifically defensible prior to release to the client.

Table 1. Summary of test conditions for the 14-d *Hyalella azteca* sediment toxicity test.

Test organism	*Hyalella azteca*
Test organism source	Aquatic BioSystems, Fort Collins, CO
Test organism age	2 – 9 d old
Test type	Static
Test duration	14 days
Test vessel	375-mL glass jars
Test Treatment	100 mL sediment; 175 mL overlying water
Test replicates	5 replicates per treatment
No. of organisms	10 per replicate
Control/dilution water	Moderately hard synthetic water prepared from dechlorinated city water
Test solution renewal	None
Test temperature	23 ± 1°C
Feeding	1.5 mL of YCT per replicate daily
Light intensity	500 to 1000 lux at water surface
Photoperiod	16 hours light/8 hours dark
Aeration	Gentle aeration throughout test
Test protocol	Environment Canada (1997a), EPS 1/RM/33
Test endpoints	Survival and dry weight
Test acceptability criterion for controls	Mean control survival of ≥80% and ≥0.1 mg/amphipod dry weight
Reference Toxicant	NaCl

Table 2. Summary of test conditions for the 10-d *Chironomus dilutus* sediment toxicity test.

Test organism	*Chironomus dilutus*
Test organism source	Aquatic BioSystems, Fort Collins, CO
Test organism age	3rd Instar
Test type	Static
Test duration	10 days
Test vessel	375-mL glass jars
Test Treatment	100 mL sediment; 175 mL overlying water
Test replicates	5 – 6 replicates per treatment
No. of organisms	10 per replicate
Control/dilution water	Moderately-hard synthetic water prepared from dechlorinated city water
Test solution renewal	None
Test temperature	23 ± 1°C
Feeding	6.0 mg Tetramin in 1.5 mL suspension per replicate daily
Light intensity	500 to 1000 lux at water surface
Photoperiod	16 hours light/8 hours dark
Aeration	Gentle aeration throughout test
Test protocol	Environment Canada (1997b), EPS 1/RM/32
Test endpoint	Survival and dry weight
Test acceptability criteria for controls	Mean control survival of ≥70%; and ≥0.6 mg/worm dry weight
Reference toxicant	KCl

3.0 RESULTS

3.1 14-d *Hyalella azteca* Sediment Toxicity Test

Results of the 14-d *H. azteca* toxicity test are summarized in Table 3. Sample LMC did not exhibit any significant reduction in either survival or growth relative to the control. Sample LWC exhibited reduced survival, but growth was not adversely affected compared to the control sediment. Survival in the control sediment was 90% compared to 98 and 66% in LMC and LWC, respectively. Dry weight in the control was 0.11 mg, and it was 0.12 and 0.09 mg in LMC and LWC, respectively. Ammonia concentrations in the samples were not high enough to have caused any adverse effects (see Table 5).

3.2 10-d *Chironomus dilutus* Sediment Toxicity Test

Results of the 10-d *C. dilutus* toxicity test are summarized in Table 4. Survival and growth were not significantly affected in any of the two samples compared to the control sediment. Survival was 80% in both LMC and LWC, compared to 76% in the control sediment. Dry weight was 2.60 mg (LMC) and 2.24 mg (LWC), compared to 2.35 mg in the control sediment. Measured levels of ammonia were relatively low to cause any adverse effects (see Table 6).

3.3 Quality Assurance/Quality Control

The test results reported for the 10-d C. *dilutus* and 14-d *H. azteca* met the acceptability criteria for test validity specified in the protocols. The reference toxicant test results for each species are summarized in Table 7. Results of the reference toxicant tests conducted during the testing program were all within the in-house historical range for the two test species, indicating that the organisms used in the toxicity tests were of acceptable quality.

Table 3. **Toxicity test results for the 14-d *Hyalella azteca* sediment toxicity test.**

Sample ID	Survival (%) (Mean ± SD)	Dry Weight (mg) (Mean ± SD)
Control Sediment	90.0 ± 7.1	0.11 ± 0.02
LMC	98.0 ± 4.5	0.12 ± 0.03
LWC	66.0 ± 21.9 *	0.09 ± 0.04

(*) Asterisks indicate samples that are significantly different from the control sediment.
SD = Standard Deviation.

Table 4. **Toxicity test results for the 10-d *Chironomus dilutus* sediment toxicity test.**

Sample ID	Survival (%) (Mean ± SD)	Dry Weight (mg) (Mean ± SD)
Control Sediment	76.0 ± 8.9	2.35 ± 0.58
LMC	80.0 ± 7.1	2.60 ± 0.59
LWC	80.0 ± 8.2	2.24 ± 0.53

SD = Standard Deviation.

Table 5. **Summary of overlying and interstitial total ammonia concentrations for the 14-d *H. azteca* sediment toxicity test.**

Sample ID	Overlying Water Total Ammonia (mg/L N)		Interstitial Water Total Ammonia (mg/L N)	
	Day 0	Day 14	Day 0	Day 14
Control Sediment	0.115	5.14	0.038	2.68
LMC	0.0063	0.0629	0.066	0.301
LWC	0.069	0.116	0.191	0.54

Table 6. **Summary of overlying and interstitial total ammonia concentrations for the 10-d *C. dilutus* sediment toxicity test.**

Sample ID	Overlying Water Total Ammonia (mg/L N)		Interstitial Water Total Ammonia (mg/L N)	
	Day 0	Day 10	Day 0	Day 10
Control Sediment	0.115	8.12	0.038	3.30
LMC	0.0063	0.115	0.066	0.275
LWC	0.069	0.114	0.191	0.431

Table 7. Reference toxicant test results.

Test Species	Endpoint	Historical Mean and Range	CV (%)	Test Date
H. azteca	Survival (LC50) = 3.2 g/L NaCl	4.4, 3.0 - 6.7 g/L NaCl	23	September 30, 2011
C. dilutus	Survival (LC50) = 5.4 g/L KCl	6.6, 4.4 – 9.8 g/L KCl	22	September 30, 2011

4.0 REFERENCES

Environment Canada. 1997a. Biological test method: test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca*. Environmental Protection Series EPS 1/RM/33. December 1997. Environment Canada, Method Development and Application Section, Environmental Technology Centre, Ottawa, ON. 123 pp.

Environment Canada. 1997b. Biological test method: test for survival and growth in sediment using the larvae of freshwater midges *(Chironomus tentans* and *Chrironomus riparius)*. Environmental Protection Series EPS 1/RM/32. December 1997. Environment Canada, Method Development and Application Section, Environmental Technology Centre, Ottawa, ON. 131 pp.

Tidepool Scientific Software. 2011. CETIS comprehensive environmental toxicity information system. Tidepool Scientific Software, McKinleyville, CA. 222 pp.

APPENDIX A – *Hyalella azteca* Toxicity Test Data

Hyalella azteca Sediment Test Summary Sheet

Client: Minnow
Work Order No.: 11418
Start Date: September 30, 2011
Set up by: ~~EGS~~ KJL, GHP

Sample Information:

Sample ID: LMC, LWC
Sample Date: Sept 10-12, 2011
Date Received: Sept 21, 2011
Sample Volume: 4L

Test Organism Information:

Species: *Hyalella azteca*
Supplier: Aquatic BioSystems
Date received: September 29, 2011
Age or size (Day 0): 5 - 7 d old

NaCl Reference Toxicant Results:

Reference Toxicant ID: HA44
Stock Solution ID: NA
Date Initiated: September 30, 2011
96-h LC50 (95% CL): 3.2 (2.4-4.4) ~~5.6 (5.4 - 5.8)~~ g NaCl

96-h LC50 Reference Toxicant Mean and Range: 4.4, 3.0 - 6.7 g/L NaCl CV (%): 23

Test Results:

Sample ID	Survival ± SD (%)				Average Dry Wt. ± SD (mg)		
Control Sediment	90.0	±	7.1		0.11	±	0.02
LMC	98.0	±	4.5		0.12	±	0.03
LWC	66.0	±	21.9	*	0.09	±	0.04

(*) Asterisk indicates samples that are significantly different from the control sediment.

Reviewed by: A. Eng

Date reviewed: Dec 13/11

Chronic *H. azteca* Sediment Toxicity Test Data Sheet
Freshwater Sediment Water Quality

Client: Minnow Environmental
Test #: 11418

Start Date: Sept 30/2011
Termination Date: Oct 14/2011
Test Organism: *H. azteca*

Dissolved oxygen (mg/L)

Sample ID	Day														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sediment Control	7.8	7.8	7.9	8.0	7.9	7.9	7.6	8.2	8.1	8.1	8.0	7.8	6.8	7.8	7.5
LMC	6.2	7.6	7.9	7.7	7.7	7.8	7.6	8.0	8.2	8.1	8.1	7.9	7.0	7.7	7.4
LWC	6.1	7.8	8.0	7.9	7.9	7.8	7.5	8.1	8.1	8.1	8.0	7.9	7.0	7.5	7.4
Technician Initials	GHP	KJL	KJL	ARG	ARG	ARG	ARG	ARG	~	~	~	KJL	KJL	ARG	KJL

pH

Sample ID	Day														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sediment Control	7.9	7.8	7.7	7.5	7.8	7.7	7.7	7.8	7.9	8.0	8.0	7.8	8.0	7.7	7.9
LMC	7.7	8.0	7.9	7.6	7.9	7.9	7.8	7.9	8.0	8.1	8.1	8.0	8.0	7.8	8.0
LWC	7.4	7.8	7.7	7.6	7.7	7.8	7.7	7.8	8.0	8.1	8.1	7.8	7.9	7.7	7.9
Technician Initials	GHP	KJL	KJL	ARG	ARG	ARG	ARG	ARG	~	~	~	KJL	KJL	ARG	KJL

Comments:

Reviewed by: A. Tang

Date Reviewed: December 12, 2011

Chronic *H. azteca* Sediment Toxicity Test Data Sheet

Freshwater Sediment Water Quality

Client: Minnow Environmental
WO #: 11418

Start Date: Sept 30/2011
Termination Date: Oct 14/2011
Test Organism: *H. azteca*

Temperature (°C)

Sample ID	Day 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sediment Control	23.0	23.0	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.6	22.5	23.5	24.0	23.0	23.0
LMC	23.0	23.0	22.0	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	23.5	24.0	23.0	23.0
LWC	23.0	23.0	22.0	22.5	22.5	22.5	22.5	23.0	22.5	22.5	22.5	23.5	24.0	23.0	23.0
Technician Initials	GHP	KJL	KJL	ARG	ARG	ARG	ARG	ARG	–	–	–	KJL	KJL	ARG	KJL

Conductivity (µS)

Sample ID	Day 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sediment Control	335	~~400~~ 350	354	369	376	385	395	398	414	427	453	454	464	~~467~~ 427	436
LMC	352	~~584~~ 409	406	430	442	447	453	454	459	456	465	474	493	461	476
LWC	341	366	~~359~~ 349	358	364	366	367	368	367	372	376	379	380	372	383
Technician Initials	GHP	KJL	KJL	ARG	ARG	ARG	ARG	ARG	–	–	–	KJL	KJL	ARG	KJL

Comments:

Reviewed by: A. Tang   Date Reviewed: December 12, 2011

H. azteca Sediment Toxicity Test Data Sheet
Freshwater Sediment 14-d Survival and Weight

Client: Minnow Environmental
Work Order No.: 11418

Start Date: Sept 30/11
Termination Date: Oct 14/11
Test Organism: *H. azteca*

Sample ID	Pan No. light blue	Rep	No. alive	No. dead	No. missing	Initials	Pan weight (mg)	Pan + organism (mg)	No. weighed	Initials
Sediment Control	1	A	8	0	2	KJL	1322.76	1323.65	8	KJL
	2	B	9	1	0	↓	1326.22	1326.84	9	↓
	3	C	10	0	0	↓	1328.63	1329.95	10	↓
	4	D	9	1	0	↓	1329.81	1330.77	9	↓
	5	E	9	1	0	↓	1330.68	1331.59	8 ②	↓
LMC	6	A	GHP ~~6~~ 9	1	0	GHP	1325.88	1326.69	9	ARG
	7	B	~~7~~ 10	0	0	↓	1326.46	1327.25	10	↓
	8	C	~~8~~ 10	0	0	↓	1324.53	1325.81	9 ②	↓
	9	D	~~9~~ 10	0	0	↓	1325.41	1326.88	10	↓
	10	E	~~10~~ 10	0	0	↓	1327.99	1329.31	10	↓
LWC	11	A	8	0	2	GHP	1329.11	1330.08	8	↓
	12	B	8	2	0	↓	1326.05	1326.73	8	↓
	13	C	3①	0	7	↓	1322.87	1322.98	3	↓
	14	D	8	1	1	↓	1331.28	1331.80	8	↓
	15	E	6	3	1	↓	1327.58	1328.36	6	↓

Comments: 10% reweigh - pan 7 - 1327.33, 11 - 1330.11
① Checked by KJL ② lost in transfer

Reviewed by: A. Tang

Date Reviewed: December 12, 2011

Hyalella 14-d Survival and Growth Sediment Test — Nautilus Environmental

Analysis ID:	03-6565-7413	Endpoint:	Mean Dry Weight-mg	CETIS Version:	CETISv1.8.0
Analyzed:	18 Oct-11 15:00	Analysis:	Parametric-Two Sample	Official Results:	Yes

Batch ID:	01-4829-1856	Test Type:	Growth-Survival (10d)	Analyst:	
Start Date:	30 Sep-11	Protocol:	EC/EPS 1/RM/33	Diluent:	Mod-Hard Synthetic Water
Ending Date:	14 Oct-11	Species:	Hyalella azteca	Brine:	
Duration:	14d 0h	Source:	Aquatic Biosystems, CO	Age:	

Sample Code	Sample ID	Sample Date	Receive Date	Sample Age	Client Name	Project
Sed Control	00-2354-3606	30 Sep-11		N/A	SLR	
LMC	19-5106-3879	12 Sep-11	21 Sep-11	18d 0h	Minnow	
LWC	12-3677-7261	10 Sep-11	21 Sep-11	20d 0h		

Sample Code	Material Type	Sample Source	Station Location	Latitude	Longitude
Sed Control	Sediment Sample	Minnow Environmental			
LMC	Sediment Sample	Minnow Environmental			
LWC	Sediment Sample	Minnow Environmental			

Data Transform	Zeta	Alt Hyp	MC Trials	NOEL	LOEL	TOEL	TU	PMSD
Untransformed	0	C > T	Not Run					35.3%

Equal Variance t Two-Sample Test

Sample Code	vs	Sample Code	Test Stat	Critical	DF	MSD	P-Value	Decision(α:5%)
Sed Control		LMC	-0.6624	1.86	8	0.03239	0.7368	Non-Significant Effect
		LWC	0.9357	1.86	8	0.03761	0.1884	Non-Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.002365601	0.001182801	2	1.172	0.3428	Non-Significant Effect
Error	0.012111	0.00100925	12			
Total	0.0144766	0.002192051	14			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Bartlett Equality of Variance	0.9313	9.21	0.6277	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.9429	0.8328	0.4208	Normal Distribution

Mean Dry Weight-mg Summary

Sample Code	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
Sed Control	5	0.1065	0.09771	0.1153	0.06889	0.132	0.01034	0.02313	21.71%	0.0%
LMC	5	0.118	0.1061	0.13	0.079	0.147	0.01402	0.03134	26.55%	-10.83%
LWC	5	0.08758	0.0728	0.1024	0.03666	0.13	0.01738	0.03887	44.38%	17.77%

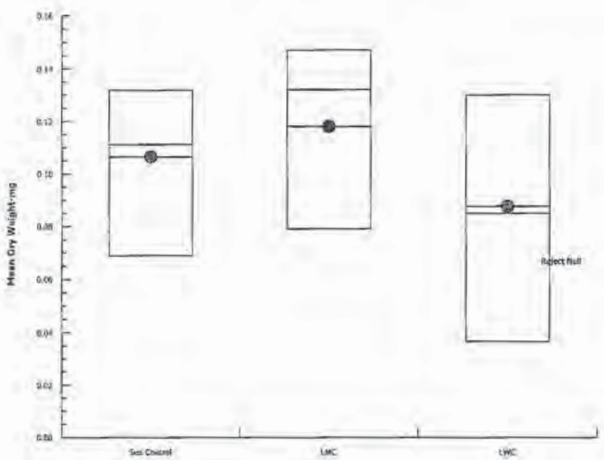
Hyalella 14-d Survival and Growth Sediment Test | **Nautilus Environmental**

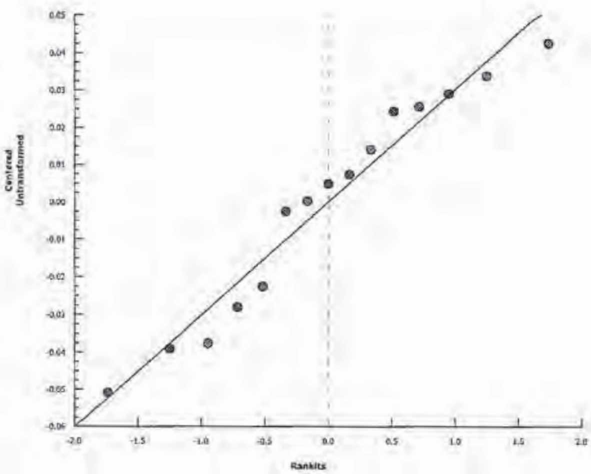
Analysis ID: 03-6565-7413 **Endpoint:** Mean Dry Weight-mg **CETIS Version:** CETISv1.8.0
Analyzed: 18 Oct-11 15:00 **Analysis:** Parametric-Two Sample **Official Results:** Yes

Mean Dry Weight-mg Detail

Sample Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Sed Control	0.1113	0.06889	0.132	0.1067	0.1137
LMC	0.08999	0.079	0.1422	0.147	0.132
LWC	0.1212	0.08499	0.03666	0.065	0.13

Graphics





Hyalella 14-d Survival and Growth Sediment Test — **Nautilus Environmental**

Analysis ID:	12-6583-9414	**Endpoint:**	~~10d~~ 14d Survival Rate	**CETIS Version:**	CETISv1.8.0
Analyzed:	18 Oct-11 15:00	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes

Batch ID:	01-4829-1856	**Test Type:**	Growth-Survival (10d)	**Analyst:**	
Start Date:	30 Sep-11	**Protocol:**	EC/EPS 1/RM/33	**Diluent:**	Mod-Hard Synthetic Water
Ending Date:	14 Oct-11	**Species:**	Hyalella azteca	**Brine:**	
Duration:	14d 0h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Sample Code	Sample ID	Sample Date	Receive Date	Sample Age	Client Name	Project
Sed Control	00-2354-3606	30 Sep-11		N/A	SLR	
LMC	19-5106-3879	12 Sep-11	21 Sep-11	18d 0h	Minnow	
LWC	12-3677-7261	10 Sep-11	21 Sep-11	20d 0h		

Sample Code	Material Type	Sample Source	Station Location	Latitude	Longitude
Sed Control	Sediment Sample	Minnow Environmental			
LMC	Sediment Sample	Minnow Environmental			
LWC	Sediment Sample	Minnow Environmental			

Data Transform	Zeta	Alt Hyp	MC Trials	NOEL	LOEL	TOEL	TU	PMSD
Angular (Corrected)	0	C > T	Not Run					17.3%

Equal Variance t Two-Sample Test

Sample Code	vs	Sample Code	Test Stat	Critical	DF	MSD	P-Value	Decision(α:5%)
Sed Control		LMC	-2.166	1.86	8	0.1083	0.9689	Non-Significant Effect
		LWC	2.586	1.86	8	0.2127	0.0161	Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.4691766	0.2345883	2	9.95	0.0028	Significant Effect
Error	0.2829165	0.02357638	12			
Total	0.7520931	0.2581646	14			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Bartlett Equality of Variance	4.935	9.21	0.0848	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.8671	0.8328	0.0306	Normal Distribution

10d Survival Rate Summary

Sample Code	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
Sed Control	5	0.9	0.8731	0.9269	0.8	1	0.03162	0.07071	7.86%	0.0%
LMC	5	0.98	0.963	0.997	0.9	1	0.02	0.04472	4.56%	-8.89%
LWC	5	0.66	0.5767	0.7433	0.3	0.8	0.09798	0.2191	33.2%	26.67%

Angular (Corrected) Transformed Summary

Sample Code	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
Sed Control	5	1.253	1.212	1.294	1.107	1.412	0.04827	0.1079	8.61%	0.0%
LMC	5	1.379	1.352	1.407	1.249	1.412	0.03259	0.07288	5.28%	-10.07%
LWC	5	0.9574	0.8692	1.046	0.5796	1.107	0.1037	0.2319	24.22%	23.6%

YWB - July 16, 2014 - QZ14-031

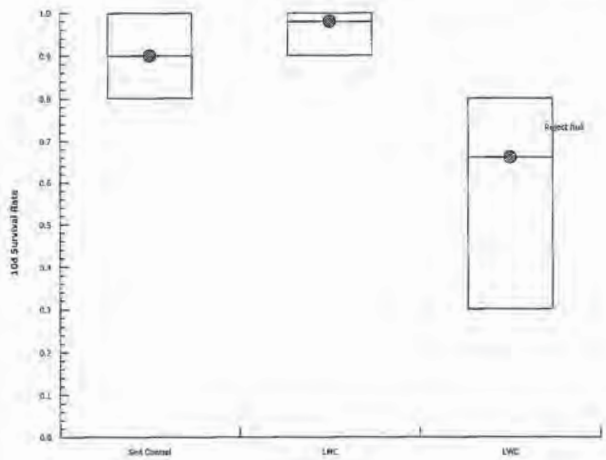
Hyalella 14-d Survival and Growth Sediment Test | Nautilus Environmental

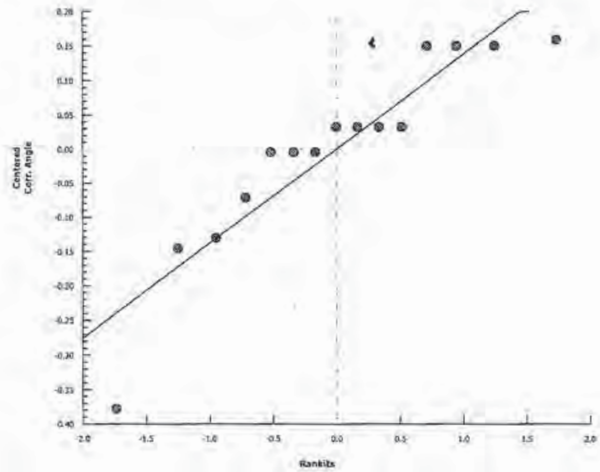
Analysis ID:	12-6583-9414	**Endpoint:**	10d Survival Rate	**CETIS Version:**	CETISv1.8.0
Analyzed:	18 Oct-11 15:00	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes

14 ~~10d~~ Survival Rate Detail

Sample Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Sed Control	0.8	0.9	1	0.9	0.9
LMC	0.9	1	1	1	1
LWC	0.8	0.8	0.3	0.8	0.6

Graphics





Nautilus Environmental
Sediment Toxicity Test - Water Quality Data For Ammonia

Client : Minnow Environmental

Work Order No: 11418

Species : *H. azteca*

Sample Type: Interstitial Ammonia

Date Measured: 14/10/2011 (Day 14)

Sample ID	Conductivity (µS)	pH	Total Ammonia (mg/L)	Unionized Ammonia (mg/L)	Tech Init
Sediment Control	405	7.2	|	|	JAB
LMC	520	7.1	|	|	↓
LWC	414	7.0	|	|	↓

Comments:

Reviewed by: A. Tang

Date Reviewed: December 12, 2011

YWB - July 16, 2014 - QZ14-031

Client: Minnow Environmental

W.O.#: 1148

Hardness and Alkalinity Datasheet

		Alkalinity					Hardness			
Sample ID (Day 14)	Sample Date	Sample Volume (mL)	(mL) 0.02N HCL/H_2SO_4 used to pH 4.5	(mL) of 0.02N HCL/H_2SO_4 used to pH 4.2	Total Alkalinity (mg/L$CaCO_3$)		Sample Volume (mL)	Volume of 0.01M EDTA Used (mL)	Total Hardness (mg/L $CaCO_3$)	Technician
Sediment Control	Oct 14/11	50	4.6	4.7	96		50	4.6	92	ARG
LMC	Oct 14/11	50	5.5	5.6	114		50	8.1	162	ARG
LWC	Oct 14/11	50	4.7	4.8	98		50	7.0	140	ARG

Notes:

Reviewed by: A. Tang

Date Reviewed: December 12, 2011

Day 14

NAUTILUS ENVIRONMENTAL
ATTN: Edmund Canaria
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 17-OCT-11
Report Date: 25-OCT-11 12:40 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: L1072816
Project P.O. #: NOT SUBMITTED
Job Reference: 11418 OAM14
C of C Numbers:
Legal Site Desc:

Can Dang
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1072816-1	L1072816-2	L1072816-3	L1072816-4	L1072816-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	14-OCT-11	14-OCT-11	14-OCT-11	14-OCT-11	14-OCT-11
	Sampled Time					
	Client ID	SEDIMENT CONTROL-OAM14	LMC-OAM14	LWC-OAM14	SEDIMENT CONTROL-IAM14	LMC-IAM14
Grouping	**Analyte**					
WATER						
Anions and Nutrients	Ammonia (as N) (mg/L)	5.14	0.0629	0.116	2.68	0.301

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L1072816-6 WATER 14-OCT-11 LWC-IAM14				
Grouping	**Analyte**					
WATER						
Anions and Nutrients	Ammonia (as N) (mg/L)	0.54				

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Nautilus

TESTING LOCATION (Please Circle)

L1072816

(1) British Columbia
8664 Commerce Court
Burnaby, British Columbia, Canada V5A 4N3
Phone 604.420.8773
Fax 604.357.1361

Chain of Custody

Date Oct 17/11 Page 1 of 2

Sample Collection By:

Report to: (1)		Invoice To: (1)	
Company		Company	
Address		Address	
City/State/Zip		City/State/Zip	
Contact		Contact	
Phone		Phone	
Email	edmund@nautilusenvironmental.com	Email	edmund@nautilusenvironmental.com

ANALYSES REQUIRED

L1072816-COFC

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Ammonia	Receipt Temp
1	Sediment Control - OAM14	14-Oct-11			125ml Bottle	1	Overlying Ammonia Water - Day 14	x	
2	LMC - OAM14	14-Oct-11			125ml Bottle	1	Overlying Ammonia Water - Day 14	x	
3	LWC - OAM14	14-Oct-11			125ml Bottle	1	Overlying Ammonia Water - Day 14	x	
4									
5									
6									
7									
8									
9									
10									

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:	11418 OAM14	Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: Hyalella sediment test. Day 14. All samples are preserved.

RELINQUISHED BY (CLIENT)		RELINQUISHED BY (COURIER)	
(Signature) [signature]	(Time) 1800h	(Signature)	(Time)
(Printed Name) Karen Lee	(Date) Oct 14/11	(Printed Name)	(Date)
(Company) Nautilus Environmental		(Company)	

RECEIVED BY (COURIER)		RECEIVED BY (LABORATORY)	
(Signature)	(Time)	(Signature)	(Time) 17:15
(Printed Name)	(Date)	(Printed Name) [signature]	(Date) Oct 17
(Company)		(Company)	19°C

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

YWB - July 16, 2014 - QZ14-031

Naut

"ING LOCATION (Please Circle)

(1) **British Columbia**
8664 Commerce Court
Burnaby, British Columbia, Canada V5A 4N3
Phone 604.420.8773
Fax 604.357.1361

L1072816.

Chain of Custody

Date Oct 17/11 Page 2 of 2

Sample Collection By:

Report to:	(1)	Invoice To:	(1)
Company		Company	
Address		Address	
City/State/Zip		City/State/Zip	
Contact		Contact	
Phone		Phone	
Email	edmund@nautilusenvironmental.com	Email	edmund@nautilusenvironmental.com

ANALYSES REQUIRED

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Ammonia
1	Sediment Control - IAM14	14-Oct-11			125ml Bottle	1	Interstitial Ammonia Water - Day 14	x
2	LMC - IAM14	14-Oct-11			125ml Bottle	1	Interstitial Ammonia Water - Day 14	x
3	LWC - IAM14	14-Oct-11			125ml Bottle	1	Interstitial Ammonia Water - Day 14	x
4								
5								
6								
7								
8								
9								
10								

Rec... (°C)

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:	11418 IAM14	Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: Hyalella sediment test. Day 14. All samples are preserved.

RELINQUISHED BY (CLIENT)
(Signature) Karen (Time) 1800h
(Printed Name) Karen Lee (Date) KL Oct 17/11
(Company) Nautilus Environmental

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) (Time) 17:15
(Printed Name) Meni (Date) Oct 17
(Company) 19°C

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

YWB - July 16, 2014 - QZ14-031

APPENDIX B – *Chironomus dilutus* Toxicity Test Data

Chironomus dilutus Sediment Test Summary Sheet

Client: Minnow
Work Order No.: 11417
Start Date: September 30, 2011
Set up by: KJL, GHP, ARG

Sample Information:

Sample ID: LMC, LWC
Sample Date: Sept 10-12, 2011
Date Received: Sept 21, 2011
Sample Volume: 4L

Test Organism Information:

Species: *C. dilutus*
Supplier: ABS, CO
Date received: September 29, 2011
Age or size (Day 0): 3rd Instar

NaCl Reference Toxicant Results:

Reference Toxicant ID: CT23
Stock Solution ID: NA
Date Initiated: September 30, 2011

96-h LC50 (95% CL): 5.4 (4.2 - 6.8) g/L KCl

96-h LC50 Reference Toxicant Mean and Range: 6.6, 4.4 - 9.8 g/L KCl CV (%) 22

Test Results:

Sample ID	Survival ± SD (%)			Average Dry Wt. ± SD (mg)		
Control Sediment	76.0	±	8.9	2.35	±	0.58
LMC	80.0	±	7.1	2.60	±	0.59
LWC	80.0	±	8.2	2.24	±	0.53

Reviewed by: A. Tang Date reviewed: Dec 13/11

C. dilutus

Chronic ~~H. azteca~~ Sediment Toxicity Test Data Sheet

Freshwater Sediment Water Quality

Client: Minnow Environmental
WO #: 11417

Start Date: Sept 30/2011
Termination Date: Oct 10/2011
Test Organism: *C. dilutus*

Temperature (°C)

Sample ID	Day 0	1	2	3	4	5	6	7	8	9	10	~~11~~	~~12~~	~~13~~ KJL	~~14~~
Sediment Control	23.0	23.0	22.5	22.5	22.5	23.0	23.0	23.0	23.0	23.0	23.0				
LMC	23.0	23.0	22.0	22.5	22.5	23.0	23.0	23.0	23.0	23.0	23.0				
LWC	23.0	23.0	22.5	22.5	22.5	23.0	23.0	23.0	23.0	23.0	23.0				
Technician Initials	GHP	KJL	KJL	ARG	ARG	ARG	ARG	ARG	~	~	~				

Conductivity (µS)

Sample ID	Day 0	1	2	3	4	5	6	7	8	9	10	~~11~~	~~12~~	~~13~~ KJL	~~14~~
Sediment Control	331	~~350~~ 400	405	424	431	437	446	447	461	476	489				
LMC	351 ~~328~~	~~409~~ 508	520	535	547	555	563	562	570	577	586				
LWC	329 ~~351~~	~~359~~ 366	374	384	390	393	390	384	376	375	381				
Technician Initials	GHP	KJL	KJL	ARG	ARG	ARG	ARG	ARG	~	~	~				

Comments:

Reviewed by: L. Eng

Date Reviewed: December 12, 2011

Nautilus Environmental

C. dilutus

Chronic ~~H. azteca~~ Sediment Toxicity Test Data Sheet

Freshwater Sediment Water Quality

Client: Minnow Environmental
Test #: 11417

Start Date: Sept 30/2011
Termination Date: Oct 10/2011
Test Organism: *C. dilutus*

Dissolved oxygen (mg/L)

Sample ID	Day 0	1	2	3	4	5	6	7	8	9	10	~~11~~	~~12~~	~~13~~	~~14~~
Sediment Control	7.8	7.5	7.5	7.8	7.9	7.8	7.7	8.1	8.1	8.1	8.1				
LMC	7.8	7.6	7.9	7.9	7.7	7.8	7.7	8.0	8.2	8.2	8.2				
LWC	7.7	7.6	7.8	8.0	7.8	7.9	7.8	8.1	8.1	8.2	8.1				
Technician Initials	GHP	KJL	KJL	ARG	ARG	ARG	ARG	ARG	~	~	~				

pH

Sample ID	Day 0	1	2	3	4	5	6	7	8	9	10	~~11~~	~~12~~	~~13~~	~~14~~
Sediment Control	7.9	7.8	7.7	7.5	7.8	7.7	7.7	7.8	8.0	8.1	8.1				
LMC	8.1	8.0	7.8	7.7	8.0	7.9	7.8	7.9	7.9	7.9	8.0				
LWC	7.9	7.8	7.8	7.6	7.9	7.7	7.7	7.7	8.0	8.1	8.1				
Technician Initials	GHP	KJL	KJL	ARG	ARG	ARG	ARG	ARG	~	~	~				

Comments:

Reviewed by: A. Tang

Date Reviewed: December 12, 2011

C. ~~tentans~~ dilutus
~~H. azteca~~ **Sediment Toxicity Test Data Sheet**
Freshwater Sediment Survival and Weight

Client: Minnow Environmental
WO #: 11417

Start Date: Sept 30/11
Termination Date: Oct 10/11
Test Organism: *C. dilutus*

Sample ID	Rep	Pan No. Brown	No. alive	No. dead	No. missing	Initials	Pan weight (mg)	Pan + organism (mg)	No. weighed	Initials
Sediment Control	A	1	8	0	2	A	1325.18	1349.36	8	ARG
	B	2	8	0	2		1322.68	1344.08	8	ARG
	C	3	8	0	2		1315.86	1332.79	8	ARG
	D	4	6	0	4		1316.15	1331.82	6	ARG
	E	5	8	0	2		1319.97	1331.51	8	ARG
LMC	A	6	8	0	2		1326.55	1349.40	8	ARG
	B	7	7	0	3		1327.60	1349.70	7	ARG
	C	8	8	0	2		1318.98	1336.87	8	ARG
	D	9	18	0	2		1317.88	1349.45	18	ARG
	E	10	8	0	2		1324.48	1348.48	8	ARG
LWC	A	11	8	0	2		1325.51	1346.99	8	ARG
	B	12	9	0	1		1325.97	1346.22	9	ARG
	C	13	8	0	2		1325.65	1345.79	8	ARG
	D	14	(1)	—	—		1322.81	—	0	ARG
	E	15	7	0	3		1325.40	1335.83	7	ARG

Comments: (1) no organisms found
Reweighed pans 7 (1349.95mg) and 11 (1347.18mg)

Reviewed by: A. Tang

Date Reviewed: December 12, 2011

CETIS Analytical Report

Chironomus 10-d Survival and Growth Sediment Test — **Nautilus Environmental**

Analysis ID:	11-5815-3545	**Endpoint:**	Mean Dry Weight-mg	**CETIS Version:**	CETISv1.8.0
Analyzed:	18 Oct-11 15:44	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes

Batch ID:	08-4895-4386	**Test Type:**	Growth-Survival (10d)	**Analyst:**	
Start Date:	30 Sep-11	**Protocol:**	EC/EPS 1/RM/32	**Diluent:**	Mod-Hard Synthetic Water
Ending Date:	10 Oct-11	**Species:**	Chironomus tentans	**Brine:**	
Duration:	10d 0h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Sample Code	Sample ID	Sample Date	Receive Date	Sample Age	Client Name	Project
Sed Control	19-3616-3544	30 Sep-11		N/A	Minnow	
LMC	19-5106-3879	12 Sep-11	21 Sep-11	18d 0h		
LWC	12-3677-7261	10 Sep-11	21 Sep-11	20d 0h		

Sample Code	Material Type	Sample Source	Station Location	Latitude	Longitude
Sed Control	Sediment Sample	Minnow Environmental			
LMC	Sediment Sample	Minnow Environmental			
LWC	Sediment Sample	Minnow Environmental			

Data Transform	Zeta	Alt Hyp	MC Trials	NOEL	LOEL	TOEL	TU	PMSD
Untransformed	0	C > T	Not Run					30.3%

Equal Variance t Two-Sample Test

Sample Code	vs	Sample Code	Test Stat	Critical	DF	MSD	P-Value	Decision(α:5%)
Sed Control		LMC	-0.6816	1.86	8	0.6878	0.7426	Non-Significant Effect
		LWC	0.3011	1.895	7	0.7108	0.3861	Non-Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.3221481	0.161074	2	0.4958	0.6221	Non-Significant Effect
Error	3.573854	0.3248958	11			
Total	3.896002	0.4859698	13			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Bartlett Equality of Variance	0.03926	9.21	0.9806	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.8584	0.8239	0.0289	Normal Distribution

Mean Dry Weight-mg Summary

Conc-Sed	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
Sed Control	5	2.349	2.127	2.57	1.443	2.897	0.26	0.5814	24.75%	0.0%
LMC	5	2.601	2.377	2.824	1.754	3.157	0.2631	0.5883	22.62%	-10.74%
LWC	4	2.236	2.035	2.437	1.49	2.685	0.2642	0.5284	23.63%	4.81%

YWB - July 16, 2014 - QZ14-031 ART

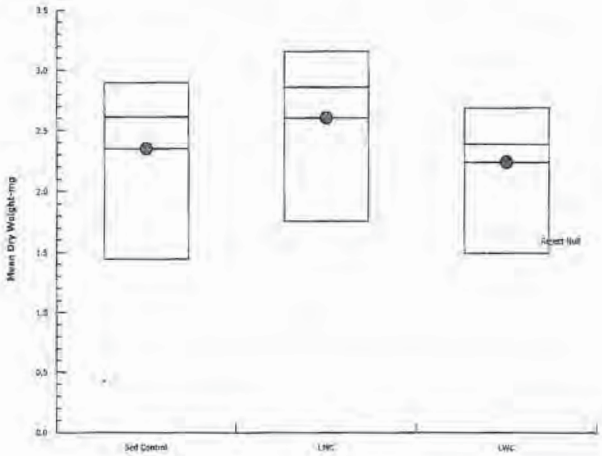
Chironomus 10-d Survival and Growth Sediment Test — **Nautilus Environmental**

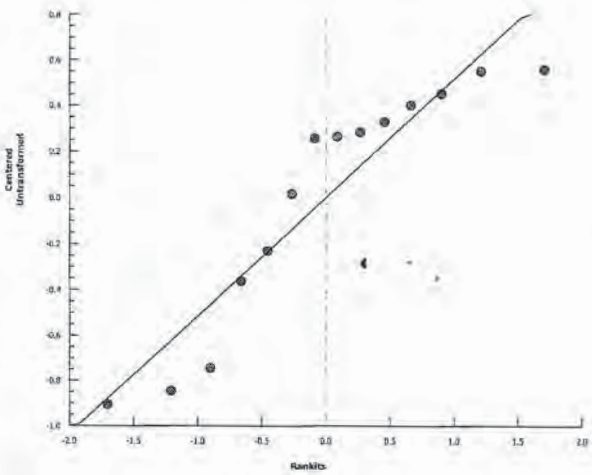
Analysis ID:	11-5815-3545	**Endpoint:**	Mean Dry Weight-mg	**CETIS Version:**	CETISv1.8.0
Analyzed:	18 Oct-11 15:44	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes

Mean Dry Weight-mg Detail

Conc-Sed	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Sed Control	2.897	2.675	2.116	2.612	1.443
LMC	2.856	3.157	2.236	1.754	3
LWC	2.685	2.25	2.518	1.49	

Graphics





Chironomus 10-d Survival and Growth Sediment Test — **Nautilus Environmental**

Analysis ID:	14-2928-1896	**Endpoint:**	10d Survival Rate	**CETIS Version:**	CETISv1.8.0
Analyzed:	13 Dec-11 10:17	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes

Batch ID:	08-4895-4386	**Test Type:**	Growth-Survival (10d)	**Analyst:**	
Start Date:	30 Sep-11	**Protocol:**	EC/EPS 1/RM/32	**Diluent:**	Mod-Hard Synthetic Water
Ending Date:	10 Oct-11	**Species:**	Chironomus tentans	**Brine:**	
Duration:	10d 0h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Sample Code	Sample ID	Sample Date	Receive Date	Sample Age	Client Name	Project
Sed Control	19-3616-3544	30 Sep-11		N/A	Minnow	
LMC	19-5106-3879	12 Sep-11	21 Sep-11	18d 0h		
LWC	12-3677-7261	10 Sep-11	21 Sep-11	20d 0h		

Sample Code	Material Type	Sample Source	Station Location	Latitude	Longitude
Sed Control	Sediment Sample	Minnow Environmental			
LMC	Sediment Sample	Minnow Environmental			
LWC	Sediment Sample	Minnow Environmental			

Data Transform	Zeta	Alt Hyp	MC Trials	NOEL	LOEL	TOEL	TU	PMSD
Angular (Corrected)	0	C > T	Not Run					15.0%

Equal Variance t Two-Sample Test

Sample Code	vs	Sample Code	Test Stat	Critical	DF	MSD	P-Value	Decision(α:5%)
Sed Control		LMC	-0.8201	1.86	8	0.112	0.7820	Non-Significant Effect
		LWC	-0.7424	1.895	7	0.1294	0.7590	Non-Significant Effect

Auxiliary Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:5%)
Extreme Value		1.959	2.507	0.5005	No Outliers Detected
Control Trend		4		0.7983	Non-significant Trend in Controls

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.008030114	0.004015057	2	0.4168	0.6692	Non-Significant Effect
Error	0.105974	0.009634003	11			
Total	0.1140042	0.01364906	13			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Bartlett Equality of Variance	0.06393	9.21	0.9685	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.9062	0.8239	0.1390	Normal Distribution

10d Survival Rate Summary

Sample Code	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
Sed Control	5	0.76	0.726	0.794	0.6	0.8	0.04	0.08944	11.77%	0.0%
LMC	5	0.8	0.7731	0.8269	0.7	0.9	0.03162	0.07071	8.84%	-5.26%
LWC	4	0.8	0.7689	0.8311	0.7	0.9	0.04082	0.08165	10.21%	-5.26%

Angular (Corrected) Transformed Summary

Sample Code	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
Sed Control	5	1.063	1.025	1.101	0.8861	1.107	0.04421	0.09887	9.3%	0.0%
LMC	5	1.112	1.078	1.147	0.9912	1.249	0.0409	0.09145	8.22%	-4.65%
LWC	4	1.114	1.073	1.154	0.9912	1.249	0.05277	0.1055	9.48%	-4.77%

YWB - July 16, 2014 - QZ14-031

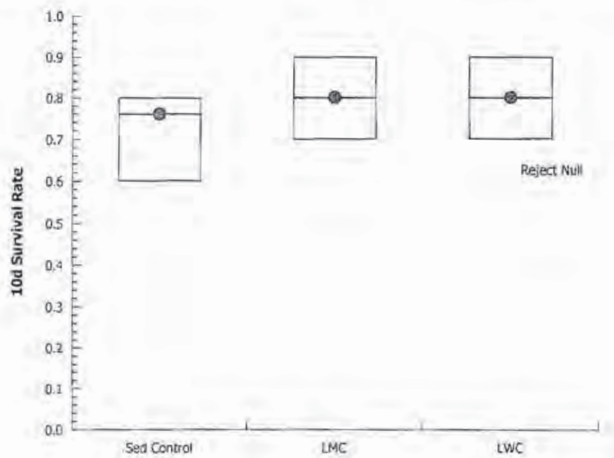
Chironomus 10-d Survival and Growth Sediment Test — **Nautilus Environmental**

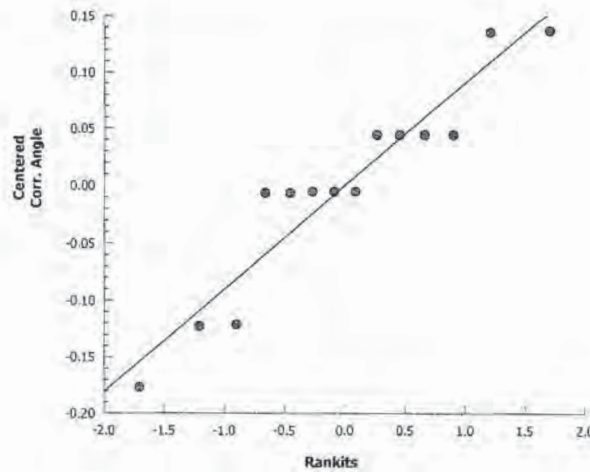
Analysis ID:	14-2928-1896	**Endpoint:**	10d Survival Rate	**CETIS Version:**	CETISv1.8.0
Analyzed:	13 Dec-11 10:17	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes

10d Survival Rate Detail

Sample Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Sed Control	0.8	0.8	0.8	0.6	0.8
LMC	0.8	0.7	0.8	0.9	0.8
LWC	0.8	0.9	0.8	0.7	

Graphics





Client: Minnow Environmental

W.O.#: 11417/11418

Hardness and Alkalinity Datasheet

	Alkalinity						Hardness			
Sample ID (Day 0)	Sample Date	Sample Volume (mL)	(mL) 0.02N HCL/H_2SO_4 used to pH 4.5	(mL) of 0.02N HCL/H_2SO_4 used to pH 4.2	Total Alkalinity (mg/L$CaCO_3$)		Sample Volume (mL)	Volume of 0.01M EDTA Used (mL)	Total Hardness (mg/L $CaCO_3$)	Technician
Sediment Control	Sept 30/11	50	2.9	3.1	66		50	4.8	96	ARG
LMC	Sept 30/11	50	4.3	4.5	94		50	5.8	116	↓
LWC	Sept 30/11	50	3.9	4.0	82		50	5.6	112	↓

Notes:

Reviewed by: A. Teng

Date Reviewed: December 12, 2011

Client: Minnow Environmental

W.O.#: 11417

Hardness and Alkalinity Datasheet

	Alkalinity					Hardness			
Chiron Sample ID (Day 10)	Sample Date	Sample Volume (mL)	(mL) 0.02N HCL/H_2SO_4 used to pH 4.5	(mL) of 0.02N HCL/H_2SO_4 used to pH 4.2	Total Alkalinity (mg/L$CaCO_3$)	Sample Volume (mL)	Volume of 0.01M EDTA Used (mL)	Total Hardness (mg/L $CaCO_3$)	Technician
Sediment Control	Oct 10/11	50	3.2	3.4	60	50	5.1	102	ARG
LMC	Oct 10/11	50	5.7	5.9	110	50	10.4	208	ARG
LWC	Oct 10/11	50	3.4	3.5	66	50	6.6	132	ARG

Notes:

Reviewed by: A. Tang   Date Reviewed: December 12, 2011

Nautilus Environmental
Sediment Toxicity Test - Water Quality Data For Ammonia

Client : Minnow Environmental
Work Order No: 11417

Species : C.dilutus / H. azteca
Sample Type: Interstitial Ammonia
Date Measured: Sept 30/11 (Day 0)

Day 0

Sample ID	Conductivity (µS)	pH	Total Ammonia (mg/L)	Unionized Ammonia (mg/L)	Tech Init
Control	316	7.5	|	|	JAB
LMC	384	7.5	|	|	↓
LWC	363	6.9	|	|	↓

Comments:

Reviewed by: A. Tang

Date Reviewed: Dec 12/11

Nautilus Environmental
Sediment Toxicity Test - Water Quality Data For Ammonia

Client: Minnow Environmental
Work Order No: 11417
Species: Chironomus dilutus
Sample Type: Interstitial Ammonia
Date Measured: Oct 10/11 (day 10)

Sample ID	Conductivity (µS)	pH	Total Ammonia (mg/L)	Unionized Ammonia (mg/L)	Tech Init
Control	457	7.1			JAB
LMC	611	7.3			↓
LWC	394	6.9			↓

Comments:

Reviewed by: A. Tang

Date Reviewed: Dec 12/11

ALS

contrLOL - Day 0

NAUTILUS ENVIRONMENTAL
ATTN: Edmund Canaria
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 30-SEP-11
Report Date: 07-OCT-11 16:22 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: **L1066212**
Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers:
Legal Site Desc:

Can Dang
Senior Account Manager

[This report shall not be reproduced except in full without the written authority of the Laboratory.]

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1066212-1	L1066212-2	L1066212-3		
	Description	WATER	WATER	WATER		
	Sampled Date	30-SEP-11	30-SEP-11	30-SEP-11		
	Sampled Time					
	Client ID	SEDIMENT CONTROL-OAM0	SEDIMENT CONTROL-IAM0	SEDIMETN CONTROL-IS0		
Grouping	**Analyte**					
WATER						
Anions and Nutrients	Ammonia (as N) (mg/L)	0.115	0.038			
	Sulphide as S (mg/L)			<0.020		

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

ALS Test Code	Matrix	Test Description	Method Reference**
S2-T-COL-VA	Water	Total Sulphide by Colorimetric	APHA 4500-S2 Sulphide

This analysis is carried out using procedures adapted from APHA Method 4500-S2 "Sulphide". Sulphide is determined using the methlyene blue colourimetric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Nautilus Environmental

TESTING LOCATION (Ple

Chain of Custody

Canada V5A 4N3 - L1066212

Date Sept 30/11 Page 1 of 1

L1066212-COFC

Sample Collection By:

Report to:		Invoice To:	
Company	(1)	Company	(1)
Address		Address	
City/State/Zip		City/State/Zip	
Contact		Contact	
Phone		Phone	
Email	edmund@nautilusenvironmental.com	Email	edmund@nautilusenvironmental.com

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Ammonia	Total Sulphides									Receipt Temperature (°C)
1	Sediment Control-OAMO	30-Sep-11			125ml Bottle	1	Overlying Ammonia Water - Day 0	x										
2	Sediment Control-IAMO	30-Sep-11			125ml Bottle	1	Interstitial Ammonia Water - Day 0	x										
3	Sediment Control-ISO	30-Sep-11			125ml Bottle	1	Interstitial Sulphides Water - Day 0		x									
4																		
5																		
6																		
7																		
8																		
9																		
10																		

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:		Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: Hyalella sediment test. Day 0. All samples are preserved.

RELINQUISHED BY (CLIENT)

(Signature) A. Teng (Time) 1900h

(Printed Name) ART (Date) Sept 30/11

(Company) Nautilus

RELINQUISHED BY (COURIER)

(Signature) (Time)

(Printed Name) (Date)

(Company)

RECEIVED BY (COURIER)

(Signature) (Time)

(Printed Name) (Date)

(Company)

RECEIVED BY (LABORATORY)

(Signature) [illegible] (Time) 19:35

(Printed Name) 19°C (Date) Sept 30

(Company)

YWB - July 16, 2014 - QZ14-031

Day 0 - Overlying N

NAUTILUS ENVIRONMENTAL
ATTN: Edmund Canaria
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 30-SEP-11
Report Date: 11-OCT-11 17:44 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: L1066211
Project P.O. #: 11417 OAM0
Job Reference:
C of C Numbers:
Legal Site Desc:

Can Dang
Senior Account Manager

ADDRESS: 8081 Lougheed Hwy, Suite 100, Burnaby, BC V5A 1W9 Canada | Phone: +1 604 253 4188 | Fax: +1 604 253 6700
ALS CANADA LTD Part of the ALS Group A Campbell Brothers Limited Company

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1066211-1	L1066211-2			
	Description	WATER	WATER			
	Sampled Date	30-SEP-11	30-SEP-11			
	Sampled Time					
	Client ID	LMC-OAM0	LWC0OAM0			
Grouping	**Analyte**					
WATER						
Anions and Nutrients	Ammonia (as N) (mg/L)	0.0063	0.069			

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Nautilus Environmental

TESTING LOCATION (Please Circle)

Chain of Custody

...ola, Canada V5A 4N3 L1066211

Date____ Page___ of___

L1066211-COFC

Sample Collection By:

Report to:		Invoice To:	
Company		Company	
Address		Address	
City/State/Zip		City/State/Zip	
Contact		Contact	
Phone		Phone	
Email	edmund@nautilusenvironmental.com	Email	edmund@nautilusenvironmental.com

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	ANALYSES REQUIRED: Total Ammonia	Receipt Temperature (°C)
1	LMC - OAMO	30-Sep-11			125ml Bottle	1	Overlying Ammonia Water - Day 0	x	
2	LWC - OAMO	30-Sep-11			125ml Bottle	1	Overlying Ammonia Water - Day 0	x	
3									
4									
5									
6									
7									
8									
9									
10									

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:	11417 OAMO	Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: Hyalella sediment test. Day 0. All samples are preserved.

RELINQUISHED BY (CLIENT)
(Signature) A. Teng (Time) 1900h
(Printed Name) ART (Date) Sept 30/11
(Company) Nautilus

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) Mani (Time) 19:35
(Printed Name) 19°C (Date) Sept 30
(Company)

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

Int - N - Day 0

NAUTILUS ENVIRONMENTAL
ATTN: Edmund Canaria
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 30-SEP-11
Report Date: 07-OCT-11 16:23 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: L1066210
Project P.O. #: 11417 IAM0
Job Reference:
C of C Numbers:
Legal Site Desc:

Can Dang
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1066210-1	L1066210-2			
	Description	WATER	WATER			
	Sampled Date	30-SEP-11	30-SEP-11			
	Sampled Time					
	Client ID	LMC-IAM0	LWC-IAM0			
Grouping	**Analyte**					
WATER						
Anions and Nutrients	Ammonia (as N) (mg/L)	0.066	0.191			

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

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VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

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mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

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Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Nautilus Environmental

TESTING LOCATION (Plea"

Chain of Custody

nada V5A 4N3

L1066210

Date______ Page___ of___

Sample Collection By:

Report to:		Invoice To:	
Company		Company	
Address		Address	
City/State/Zip		City/State/Zip	
Contact		Contact	
Phone		Phone	
Email	edmund@nautilusenvironmental.com	Email	edmund@nautilusenvironmental.com

ANALYSES REQUIRED

L1066210-COFC

#	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Ammonia	Receipt Temperature (°C)
1	LMC - IAMO	30-Sep-11			125ml Bottle	1	Interstitial Ammonia Water - Day 0	x	
2	LWC - IAMO	30-Sep-11			125ml Bottle	1	Interstitial Ammonia Water - Day 0	x	
3									
4									
5									
6									
7									
8									
9									
10									

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:	11417 IAMO	Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: Hyalella sediment test. Day 0. All samples are preserved.

RELINQUISHED BY (CLIENT)
(Signature) A. Tang (Time) 1900h
(Printed Name) AET (Date) Sept 30/11
(Company) Nautilus

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) [illegible] (Time) 19:35
(Printed Name) 19°C (Date) Sept 30
(Company)

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

YWB - July 16, 2014 - QZ14-031

C - dilutions
Day 10

NAUTILUS ENVIRONMENTAL
ATTN: Edmund Canaria
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 11-OCT-11
Report Date: 17-OCT-11 16:26 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: **L1070147**
Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers: 1, 2
Legal Site Desc:

Can Dang
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1070147-1	L1070147-2	L1070147-3	L1070147-4	L1070147-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-OCT-11	10-OCT-11	10-OCT-11	10-OCT-11	10-OCT-11
	Sampled Time					
	Client ID	SEDIMENT CONTROL-IAM10	LMC-IAM10	LWC-IAM10	SEDIMENT CONTROL-OAM10	LMC-OAM10
Grouping	**Analyte**					
WATER						
Anions and Nutrients	Ammonia (as N) (mg/L)	3.30	0.275	0.431	8.12	0.115

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1070147-6				
	Description	WATER				
	Sampled Date	10-OCT-11				
	Sampled Time					
	Client ID	LWC-OAM10				
Grouping	**Analyte**					
WATER						
Anions and Nutrients	Ammonia (as N) (mg/L)	0.114				

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

1	2

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

TESTING LOCATION (Please Circle)

intal

(1) British Columbia
8664 Commerce Court
Burnaby, British Columbia, Canada V5A 4N3
Phone 604.420.6773
Fax 604.357.1361

Chain of Custody

L1070147

Date Oct 11/11 Page 1 of 2

Sample Collection By:

Report to:	(1)	Invoice To:	(1)
Company		Company	
Address		Address	
City/State/Zip		City/State/Zip	
Contact		Contact	
Phone		Phone	
Email	edmund@nautilusenvironmental.com	Email	edmund@nautilusenvironmental.com

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Ammonia										Receipt Temperature (°C)
1	Sediment Control - IAM10	10-Oct-11			125ml Bottle	1	Interstitial Ammonia Water - Day 10	x										
2	LMC - IAM10	10-Oct-11			125ml Bottle	1	Interstitial Ammonia Water - Day 10	x										
3	LWC - IAM10	10-Oct-11			125ml Bottle	1	Interstitial Ammonia Water - Day 10	x										
4																		
5																		
6																		
7																		
8																		
9																		
10																		

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:	11417 IAM10	Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: Chironomid sediment test. Day 10. All samples are preserved.

RELINQUISHED BY (CLIENT)
(Signature) [signature] (Time) 1700h
(Printed Name) Karen Lee (Date) Oct 11/11
(Company) Nautilus Environmental

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) Weni (Time) 17:50
(Printed Name) (Date) Oct 11
(Company) 12°C

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

TESTING LOCATION (Please Circle)

L1070147-COFC

(1) British Columbia
8664 Commerce Court
Burnaby, British Columbia, Canada V5A 4N3
Phone 604.420.8773
Fax 604.357.1361

Chain of Custody

L1070147

Date Oct11/11 Page 2 of 2

Sample Collection By:

Report to: (1)		Invoice To: (1)	
Company		Company	
Address		Address	
City/State/Zip		City/State/Zip	
Contact		Contact	
Phone		Phone	
Email	edmund@nautilusenvironmental.com	Email	edmund@nautilusenvironmental.com

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	ANALYSES REQUIRED: Total Ammonia										Receipt Temperature (°C)
1	Sediment Control - OAM10	10-Oct-11			125ml Bottle	1	Overlying Ammonia Water - Day 10	x										
2	LMC - OAM10	10-Oct-11			125ml Bottle	1	Overlying Ammonia Water - Day 10	x										
3	LWC - OAM10	10-Oct-11			125ml Bottle	1	Overlying Ammonia Water - Day 10	x										
4																		
5																		
6																		
7																		
8																		
9																		
10																		

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:	11417 OAM10	Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: Chironomid sediment test. Day 10. All samples are preserved.

RELINQUISHED BY (CLIENT)
(Signature) [signature] (Time) 1700h
(Printed Name) Karen Lee (Date) oct-11/11
(Company) Nautilus Environmental

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) Meni (Time) 17:10
(Printed Name) (Date) Oct 11
(Company) 17°C

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

APPENDIX C – Sediment Description Sheet

Sediment Description Data Sheet

Client: Minnow Environmental
Work Order No.: 11417/11418

Date: 29-Sep-11
Test Organism: *C. dilutus, H. azteca*

Sample ID	Grain Size	Colour	Odour	Debris	Other	Initials
Control Sediment	sand	grey				KJL
LMC	mud/clay	dark brown	–			KJL
LWC	soft clay	dark brown			plant material	KJL

Reviewed by: A. Tang

Date Reviewed: December 12, 2011

APPENDIX D - Chain–of-Custody Form

Nautilus Environmental

BRITISH COLUMBIA
8664 Commerce Court
Burnaby British Columbia Canada V5A 4N7
Phone 604.420.8773
Fax 604.357.1361

Chain of Custody

0415

Date Sept. 15, '11 Page 1 of 1

Sample Collection by: Pierre Stecko + Jocelyn Kelly

Report to: + invoice	Invoice to:
Company Minnow Environmental	Company
Address 2 Lamb St.	Address
City Georgetown Prov. ON PC L7G 3M9	City Prov. PC
Contact Jocelyn Kelly	Contact
Phone No. 905-873-3371	Phone No.

SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NUMBER OF CONTAINERS	COMMENTS	chironomus tox (WO# 1417)	Hyalella tox (WO# 1418)											RECEIPT TEMPERATURE (°C)
LMC	Sept. 12	—	sediment	bucket	1		✓	✓											12.0
LWC	Sept. 10	—	"	"	1		✓	✓											

PROJECT INFORMATION	SAMPLE RECEIPT
CLIENT project # 2414	TOTAL NO. OF CONTAINERS
P.O. NO.	REC'D GOOD CONDITION
SHIPPED VIA:	

SPECIAL INSTRUCTIONS/COMMENTS:

RELINQUISHED BY (CLIENT)		RELINQUISHED BY (COURIER)	
(Signature) Jocelyn Kelly	(Time) Sept. 15 @ 14:25	(Signature)	(Time)
(Printed Name) Jocelyn Kelly	(Date)	(Printed Name)	(Date)
(Company) Minnow		(Company)	

RECEIVED BY (COURIER)		RECEIVED BY (LABORATORY)	
(Signature)	(Time)	(Signature) [signature]	(Time) 1040
(Printed Name)	(Date)	(Printed Name) John T	(Date) Sept 21/11
(Company)		(Company) Nautilus Env	

YWB - July 16, 2014 - QZ14-031

Additional costs may be required for sample disposal or storage. Net 30 unless otherwise contracted.

DISTRIBUTION: WHITE - Nautilus Environmental, COLOR - Originator

Appendix C

Sediment and Soil Quality Data

Table C.1: Sediment chemistry data collected at exposed and reference areas, Minto Mine WUL, 2011.

	Analytes	Units	CSQG [a]		Upper McGinty Creek (Reference)					Lower Wolverine Creek (Reference)					Upper Minto Creek (Exposure)					Lower Minto Creek (Exposure)				
					URC-1	URC-2	URC-3	URC-4	URC-5	LWC-1	LWC-2	LWC-3	LWC-4	LWC-5	UMC-1	UMC-2	UMC-3	UMC-4	UMC-5	LMC-1	LMC-2	LMC-3	LMC-4	LMC-5
			ISQG	PEL	10-Sep-11	10-Sep-11	10-Sep-11	10-Sep-11	10-Sep-11	10-Sep-11	10-Sep-11	10-Sep-11	10-Sep-11	10-Sep-11	13-Sep-11	13-Sep-11	13-Sep-11	13-Sep-11	13-Sep-11	12-Sep-11	12-Sep-11	12-Sep-11	12-Sep-11	12-Sep-11
Particle size, TKN, carbon analytes and pH	% Gravel (>2mm)	%			-	-	<0.10	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	-	-	<0.10	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
	% Sand (2.0mm - 0.063mm)	%			-	-	8.72	-	-	41.2	53.1	52.8	53.6	41.1	-	-	49.3	-	-	25.8	30.6	19.1	35.6	28.4
	% Silt (0.063mm - 4um)	%			-	-	69.1	-	-	49.5	40.1	38.0	39.2	46.7	-	-	41.5	-	-	61.7	60.2	67.9	58.1	61.4
	% Clay (<4um)	%			-	-	22.2	-	-	9.32	6.88	9.23	7.22	12.2	-	-	9.21	-	-	12.6	9.21	13.0	6.32	10.2
	Total Kjeldahl Nitrogen (TKN)	%			0.652	0.806	0.565	0.944	0.878	0.182	0.421	0.273	0.174	0.346	0.207	0.242	0.175	0.209	0.169	0.218	0.215	0.251	0.063	0.251
	CaCO3 Equivalent	%			1.62	1.60	1.54	2.39	1.75	2.96	2.60	1.93	2.17	1.76	0.99	1.09	0.94	1.40	0.89	2.26	2.65	1.45	1.58	2.88
	Inorganic Carbon	%			0.19	0.19	0.18	0.29	0.21	0.36	0.31	0.23	0.26	0.21	0.12	0.13	0.11	0.17	0.11	0.27	0.32	0.17	0.19	0.35
	Total Carbon by Combustion	%			12.6	14.8	11.2	19.4	18.4	3.1	8.8	5.1	2.5	5.6	3.6	3.7	2.5	2.8	2.3	4.4	4.5	4.8	1.0	4.8
	Total Organic Carbon	%			12.4	14.6	11.0	19.1	18.2	2.71	8.48	4.92	2.25	5.37	3.50	3.54	2.35	2.67	2.20	4.18	4.17	4.59	0.85	4.50
	pH (1:2 soil:water)	pH units			7.30	6.94	6.86	6.99	7.05	7.52	7.28	6.96	7.17	7.09	7.77	7.92	8.00	7.88	7.95	7.72	7.67	7.65	7.90	7.82
Total ICP-MS Scan	Aluminum (Al)	mg/kg			15,400	17,200	15,900	15,700	15,100	11,700	14,700	15,300	12,500	13,400	13,600	14,800	13,600	12,700	14,900	10,900	11,400	11,100	9,410	12,600
	Antimony (Sb)	mg/kg			0.57	0.65	0.60	0.77	0.66	0.41	0.47	0.58	0.43	0.47	0.51	0.62	0.51	0.52	0.52	0.51	0.45	0.61	0.40	0.50
	Arsenic (As)	mg/kg	5.9	17	6.86	7.95	8.03	9.43	8.49	5.34	6.38	6.46	5.81	6.16	5.97	6.68	6.83	6.73	6.53	6.08	6.07	7.47	4.59	6.86
	Barium (Ba)	mg/kg			327	379	331	417	357	171	229	263	185	238	208	257	236	249	239	213	205	250	154	221
	Beryllium (Be)	mg/kg			0.48	0.58	0.49	0.64	0.52	0.57	0.79	0.83	0.62	0.78	0.52	0.60	0.58	0.49	0.57	0.41	0.44	0.52	0.32	0.47
	Bismuth (Bi)	mg/kg			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Cadmium (Cd)	mg/kg	0.6	3.5	0.254	0.294	0.267	0.443	0.313	0.175	0.242	0.348	0.177	0.287	0.160	0.273	0.242	0.253	0.259	0.200	0.161	0.265	0.120	0.153
	Calcium (Ca)	mg/kg			11,100	13,300	11,600	17,000	12,800	8,690	11,500	13,200	8,670	11,800	9,550	11,000	9,440	8,450	9,360	11,000	9,900	13,600	8,230	9,950
	Chromium (Cr)	mg/kg	37.3	90	34.2	37.7	34.7	37.4	34.8	38.1	45.6	48.4	38.4	42.4	33.8	36.8	33.3	28.1	34.5	26.3	26.7	28.2	23.4	29.5
	Cobalt (Co)	mg/kg			11.5	13.3	12.3	14.5	13.2	11.9	14.2	14.7	13.1	14.1	11.7	13.0	13.3	12.6	13.9	9.62	10.2	10.9	7.89	11.1
	Copper (Cu)	mg/kg	35.7	197	35.5	41.7	35.6	47.6	40.0	22.7	31.7	37.9	24.1	32.8	43.8	120	206	180	174	32.9	28.6	37.1	23.4	30.0
	Iron (Fe)	mg/kg			25,600	29,600	29,000	30,600	28,400	25,800	28,400	28,500	26,100	26,900	23,300	26,600	26,800	25,900	27,000	21,700	22,400	23,500	18,300	24,600
	Lead (Pb)	mg/kg	35	91.3	6.38	7.15	6.63	6.86	6.36	5.28	6.22	6.69	5.52	6.29	5.69	6.94	6.60	6.40	6.71	5.56	5.70	6.18	4.38	5.94
	Lithium (Li)	mg/kg			8.2	9.3	9.2	8.0	7.9	7.9	9.4	9.5	8.4	8.8	9.5	10.5	9.5	9.2	10.3	7.9	8.9	8.5	6.9	9.9
	Magnesium (Mg)	mg/kg			5,050	5,800	5,680	5,490	5,190	8,120	9,580	9,390	8,550	8,900	8,840	9,610	10,100	8,030	10,800	5,840	6,370	6,130	5,440	6,990
	Manganese (Mn)	mg/kg			746	847	923	1,290	1,090	477	579	586	531	755	1,040	1,960	2,230	3,070	2,490	768	693	908	506	696
	Mercury (Hg)	mg/kg	0.17	0.49	0.0769	0.0947	0.0726	0.112	0.0925	0.0318	0.0486	0.0605	0.0331	0.0478	0.0251	0.0313	0.0293	0.0307	0.0276	0.0425	0.0355	0.0544	0.0226	0.0360
	Molybdenum (Mo)	mg/kg			0.67	0.72	0.70	1.01	0.93	0.53	0.59	0.64	0.57	0.58	0.92	1.61	2.17	2.51	2.46	0.57	0.57	0.67	<0.50	0.63
	Nickel (Ni)	mg/kg			21.6	24.7	24.3	24.9	23.6	32.6	41.1	42.9	35.9	40.1	47.3	49.4	51.9	36.6	58.1	25.0	26.7	27.7	21.5	29.0
	Phosphorus (P)	mg/kg			821	970	979	1,050	937	951	1,000	1,030	992	1,030	850	928	986	979	986	836	823	815	842	760
	Potassium (K)	mg/kg			660	690	820	680	710	870	990	950	930	780	980	1,300	1,420	1,590	1,640	820	810	790	710	960
	Selenium (Se)	mg/kg			0.63	0.73	0.68	1.02	0.83	0.29	0.45	0.62	0.29	0.48	0.41	0.61	0.62	0.61	0.51	0.37	0.31	0.51	0.23	0.31
	Silver (Ag)	mg/kg			0.14	0.17	0.13	0.19	0.17	<0.10	0.10	0.14	<0.10	0.11	<0.10	0.14	0.16	0.13	0.13	<0.10	<0.10	0.11	<0.10	<0.10
	Sodium (Na)	mg/kg			170	180	200	190	170	360	440	410	400	350	420	460	530	340	570	250	240	210	250	270
	Strontium (Sr)	mg/kg			85.3	102	88.2	123	99.3	84.0	113	125	79.9	113	93.2	116	97.9	88.0	97.3	86.2	78.8	108	60.9	80.5
	Thallium (Tl)	mg/kg			0.092	0.104	0.097	0.091	0.093	0.069	0.086	0.092	0.070	0.076	0.085	0.102	0.095	0.101	0.108	0.079	0.076	0.081	0.061	0.090
	Tin (Sn)	mg/kg			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
	Titanium (Ti)	mg/kg			647	651	751	647	640	804	893	819	822	656	744	783	714	617	756	621	528	507	562	656
	Uranium (U)	mg/kg			1.50	1.78	1.73	2.33	1.94	1.73	2.26	2.90	1.70	2.39	0.941	0.971	0.907	0.996	0.813	1.19	0.973	1.59	0.731	0.988
	Vanadium (V)	mg/kg			62.0	71.6	64.5	77.4	67.6	66.2	74.6	76.6	67.6	68.4	54.1	61.2	58.6	55.3	57.7	47.7	46.6	51.2	41.0	51.7
	Zinc (Zn)	mg/kg	123	315	49.1	55.6	57.1	50.7	49.6	52.3	58.1	58.6	53.9	56.3	52.0	76.0	97.7	92.6	139	48.8	53.6	51.8	41.9	59.7

[a] Canadian Sediment Quality Guidelines - ISQG = interim sediment quality guideline; PEL = probable effect level (CCME 1999).

Indicates sediment concentration exceeding CSQG ISQG.

Indicates sediment concentration exceeding CSQG PEL.

Table C.2: Chemistry of soil sampled near lower Minto Creek, Minto Mine WUL, 2011.

Analyte	Units	Replicate #1	Replicate #2	Replicate #3	Replicate #4	Replicate #5	Mean
Soluble (2:1) pH	pH Units	8.41	7.99	7.78	7.91	8.32	8.08
Total Aluminum (Al)	mg/kg	9,300	12,400	13,000	13,000	12,700	12,080
Total Antimony (Sb)	mg/kg	0.3	0.5	0.5	0.5	0.5	0.5
Total Arsenic (As)	mg/kg	0.5	5.1	5.1	4.6	4.6	4.0
Total Barium (Ba)	mg/kg	552	266	284	250	276	326
Total Beryllium (Be)	mg/kg	<0.4	0.5	0.5	0.4	0.6	0.5
Total Bismuth (Bi)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Cadmium (Cd)	mg/kg	2.46	0.48	0.59	0.47	0.39	0.88
Total Calcium (Ca)	mg/kg	47,300	10,800	13,800	11,000	14,900	19,560
Total Chromium (Cr)	mg/kg	20	29	28	29	28	27
Total Cobalt (Co)	mg/kg	9.1	10.5	10.6	10.8	10.2	10.2
Total Copper (Cu)	mg/kg	44.5	37.3	37.2	35.3	31.2	37.1
Total Iron (Fe)	mg/kg	18,200	24,400	24,700	25,200	24,400	23,380
Total Lead (Pb)	mg/kg	5.3	6.4	6.4	6.4	6.2	6.1
Total Magnesium (Mg)	mg/kg	6,490	6,630	6,610	7,180	7,390	6,860
Total Manganese (Mn)	mg/kg	1,040	667	696	649	691	749
Total Mercury (Hg)	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Molybdenum (Mo)	mg/kg	0.6	0.7	0.7	0.7	0.7	0.7
Total Nickel (Ni)	mg/kg	21.9	26.7	26.9	27.3	25.8	25.7
Total Phosphorus (P)	mg/kg	2,630	951	1,280	1,060	1,260	1,436
Total Potassium (K)	mg/kg	3,690	2,440	2,460	1,890	2,770	2,650
Total Selenium (Se)	mg/kg	<0.5	<0.5	<0.5	0.6	<0.5	0.5
Total Silver (Ag)	mg/kg	0.19	0.11	0.10	0.09	0.10	0.12
Total Sodium (Na)	mg/kg	207	168	220	285	308	238
Total Strontium (Sr)	mg/kg	306	84.5	96.4	83.6	105	135
Total Thallium (Tl)	mg/kg	0.05	0.08	0.08	0.09	0.09	0.08
Total Tin (Sn)	mg/kg	0.3	0.4	0.4	0.4	0.3	0.4
Total Titanium (Ti)	mg/kg	442	544	547	585	545	533
Total Vanadium (V)	mg/kg	33	50	51	51	49	47
Total Zinc (Zn)	mg/kg	266	96	103	91	97	131
Total Zirconium (Zr)	mg/kg	1.3	3.6	2.5	4.0	3.6	3.0

Appendix D

Periphyton Community Data

Table D.1: Periphyton community sampled at lower Minto Creek (exposure) and lower Wolverine Creek (reference), Minto Mine WUL, 2011.

			Lower Minto Creek (exposure)					Lower Wolverine Creek (reference)				
		Sample Site	LMC-1	LMC-2	LMC-3	LMC-4	LMC-5	LWC-1	LWC-2	LWC-3	LWC-4	LWC-5
		Sampling Date	13-Sep-07	13-Sep-07	13-Sep-07	13-Sep-07	12-Sep-07	10-Sep-07	10-Sep-07	12-Sep-07	12-Sep-07	12-Sep-07
		Area Sampled (cm^2)	165	165	165	165	165	99	99	99	99	99
Phylum	Order	Genera and Species										
Bacillariophycae	Centrales	*Melosira sp.*						√	√	√	√	
	Pennales	*Achnanthes lanceolata*	√	√	254.0				42.9	91.4	169.9	
		Achnanthes laevis						252.6	85.8	274.2	509.8	
		Achnanthes minutissima	√					1,631.2	2,659.7	1,771.0	3,293.5	1,211.8
		Achnanthes spp.			2,032.0	√		2,283.6	1,662.3	354.2	658.7	
		Caloneis/Nedium sp.	35.0		√							
		Caloneis spp.			√		√	√			√	
		Ceratoneis arcus					√	5,546.0	5,651.9	9,209.2	6,587.0	11,130.1
		Cocconeis placentula							√	91.4	339.9	
		Cymbella cistula	√		√						√	
		Cymbella minuta	1,625.8	1,381.4	1,016.0	827.8	350.5	23,853.9	24,308.0	14,993.7	17,743.8	49,740.8
		Cymbella sinuata	135.5	106.3	508.0	71.2	87.6	2,609.9	3,657.1	2,479.4	1,317.4	1,615.7
		Cymbella spp.	69.9	54.8	131.1	35.6	√	84.2	√		√	52.1
		Diatoma elongatum						168.4	85.8	274.2	169.9	104.2
		Diatoma mesodon									85.0	
		Diatomella sp.	√						√			
		Didymosphenia geminata						√				
		Diploneis spp.							√			
		Eunotia spp.	35.0		32.8	√	√			√	√	√
		Fragilaria cf. montana		√				√		√	√	
		Fragilaria vaucheriae	8,341.1	5,316.0	2,794.0	689.8	701.0	17,576.5	7,676.2	24,535.2	25,348.3	13,989.6
		Fragilaria spp.	1,042.6	1,635.7	254.0	413.9	87.6	1,631.2	664.9	1,771.0	658.7	3,231.5
		Frustulia sp.	35.0	√	√				√			
		Gomphonema angustatum/parvulum	1,354.8	1,912.7	15,639.4	16,988.2	2,979.1	32,642.1	20,469.9	25,898.3	5,269.6	24,870.4
		Gomphonema spp.	271.0	531.3	508.0	4,777.9	701.0	16,321.1	14,073.0	32,713.6	13,174.0	21,761.6
		Hantzschia sp.	√	√							√	
		Meridion circulare	104.9	164.5	196.7	320.4	113.0	168.4	858.0	1,005.4	2,549.0	3,542.8
		Navicula mutica	18,246.2	6,951.6	30,301.3	9,025.0	1,927.6	16,321.1	2,327.3	1,771.0	22,813.5	20,207.2
		Navicula radiosa	69.9	54.8	65.6	35.6	√				√	
		Navicula spp.	8,862.4	7,360.6	11,729.5	5,308.8	876.2	26,364.8	14,073.0	12,267.6	32,952.8	13,989.6
		Neidium spp.				√					√	
		Nitzschia dissipata						114,247.5	83,158.8	59,974.9	233,204.7	194,300.0
		Nitzschia spp.	5,213.2	7,769.5	8,697.1	2,654.4	788.6	6,277.3	7,676.2	6,815.3	25,348.3	15,544.0
		Nitzschia sp.A	11,990.4	8,178.4	9,774.6	8,494.1	1,051.4					
		Pinnularia spp.		√	√	√			√	√	√	√
		Rhoicosphenia curvata						84.2	85.8	274.2	679.7	√
		Rhopalodia gibba									√	
		Stauroneis spp.		√		√				√	√	√
		Surirella angusta	139.8	82.3	65.6	106.8	22.6	42.1				
		Surirella spp.	104.9	137.1	131.1	71.2	45.2	84.2	√	√	169.9	√
		Synedra ulna					√	978.7	943.8	1,462.4	1,359.5	3,542.8
		Synedra spp.	3,387.0	106.3	254.0	138.0	87.6	326.2	85.8	91.4	339.9	√
		Tabellaria fenestrata							√		√	
		Tabellaria flocculosa			√	√						√
		UID Pennales[a]	35.0		508.0				332.5	354.2	1,317.4	
		Deformed Diatoms	√						171.6	457.0	√	208.4
Chlorophyta	Chaetophorales	*Stigeoclonium sp.*					√		√		√	
	Ulothricales	*Ulothrix spp.?*	419.5	√	3,212.4	1,673.2		√	6,692.4	548.4	1,869.3	1,042.0
		Ulothrix zonata									√	
	Zygnematales	*Closterium spp.*	√			√		√				
Chlorophyta		UID Chlorophyta colonial			262.2	178.0	350.5			365.6		√
		UID Chlorophyta filamentous										√
		UID Chlorophyta flagellate				√						
		UID Chlorophyta unicellular			254.0		22.6	326.2				
Chrysophyta	Ochromonadales	*Hyalobryon sp.*					√					
		UID Chrysophyta colonial								√		
		UID Chrysophyta cyst[a]	35.0	√		√					169.9	
		UID Chrysophyta unicellular	135.5	106.3		√				274.2	658.7	403.9
Cyanophyta	Chamaesiphonales	*Chamaesiphon spp.*	3,649.2	3,612.8	16,616.8	22,827.8	13,150.0	32,642.1	23,028.6	21,809.1	15,209.0	8,078.7
	Chroococcales	UID Chrooccocales		212.5								
	Oscillatoriales	*Homoeothrix varians*	63,079.7	86,282.1	115,340.3	450,186.2	237,374.7	1,694,880.0	2,075,132.7	684,259.5	1,338,392.0	2,682,894.4
		Lyngbya spp.	559.4	493.6	393.4		1,752.4	15,659.2	43,885.6	2,102.2	21,078.4	121,243.2
		Oscillatoria spp.	1,363.4	2,001.7	27,178.0	12,692.3	5,344.8	85,371.7	107,719.2	5,118.4	83,654.9	158,548.8
		Phormidium sp.	2,027.7	4,551.7	65,786.0	21,659.7	1,943.6	47,303.8	6,692.4	√	63,235.2	35,950.1
		Pseudanabaena spp.	349.6	2,762.8	5,080.0	2,345.3	1,401.9	28,875.7	136,892.2	20,897.8	73,774.4	56,146.7
		Spirulina sp.								√		
		UID Oscillatoriales	2,709.6	3,612.8	4,064.0	6,070.2	1,664.8	6,524.7	20,945.4	3,896.2	61,917.8	73,056.8
Rhodophyta	Nemalionales	*Audouinella sp.*	56,823.9	108,772.7	16,510.0	213.6	2,576.4	16,755.8	√	17,183.2	21,751.5	4,689.0
UID		UID colonial[a]				320.4		505.2				
		UID unicellular[a]	406.4	318.8	254.0	827.8	262.9	326.2		708.4	1,317.4	
		Taxa Total	35	32	35	33	31	36	39	40	48	35

√ = taxa present but abundance could not be reliably quantified
UID = unidentified
cf. = (confertim = close together) = possibly for species
? = possibly for genus
[a] unidentified specimens that were excluded from metric calculations (except density) and summary statistics
Synonyms:
Diatoma mesodon = Diatoma hiemale var. mesodon
Diatoma elongatum = Diatoma tenue var. elongatum

Table D.2: Summary statistics for periphyton collected at lower Minto Creek and lower Wolverine Creek stations, Minto Mine WUL, 2011. All data are presented in number/cm^2.

Phylum	Order	Genera and Species	Lower Minto Creek (exposure)					Lower Wolverine Creek (reference)				
			Mean	Median	Minimum	Maximum	Standard Deviation	Mean	Median	Minimum	Maximum	Standard Deviation
Bacillariophycae	Pennales	*Achnanthes lanceolata*	254	254	254	254		101	91	43	170	64
		Achnanthes laevis						281	263	86	510	174
		Achnanthes minutissima						2,113	1,771	1,212	3,294	845
		Achnanthes spp.	2,032	2,032	2,032	2,032		1,240	1,161	354	2,284	893
		Caloneis/Nedium sp.	35	35	35	35						
		Ceratoneis arcus						7,625	6,587	5,546	11,130	2454
		Cocconeis placentula						216	216	91	340	176
		Cymbella minuta	1,040	1,016	350	1,626	495	26,128	23,854	14,994	49,741	13787
		Cymbella sinuata	182	106	71	508	184	2,336	2,479	1,317	3,657	922
		Cymbella spp.	73	62	36	131	41	68	68	52	84	23
		Diatoma elongatum						161	168	86	274	74
		Diatoma mesodon						85	85	85	85	
		Eunotia spp.	34	34	33	35	2					
		Fragilaria vaucheriae	3,568	2,794	690	8,341	3,276	17,825	17,577	7,676	25,348	7406
		Fragilaria spp.	687	414	88	1,636	642	1,591	1,631	659	3,231	1055
		Frustulia sp.	35	35	35	35						
		Gomphonema angustatum/parvulum	7,775	2,979	1,355	16,988	7,831	21,830	24,870	5,270	32,642	10232
		Gomphonema spp.	1,358	531	271	4,778	1,918	19,609	16,321	13,174	32,714	8050
		Meridion circulare	180	165	105	320	87	1,625	1,005	168	3,543	1381
		Navicula mutica	13,290	9,025	1,928	30,301	11,196	12,688	16,321	1,771	22,814	9985
		Navicula radiosa	56	60	36	70	15					
		Navicula spp.	6,828	7,361	876	11,730	4,068	19,930	14,073	12,268	32,953	9210
		Nitzschia dissipata						136,977	114,247	59,975	233,205	73973
		Nitzschia spp.	5,025	5,213	789	8,697	3,340	12,332	7,676	6,277	25,348	8193
		Nitzschia sp.A	7,898	8,494	1,051	11,990	4,110					
		Rhoicosphenia curvata						281	180	84	680	280
		Surirella angusta	83	82	23	140	44	42	42	42	42	
		Surirella spp.	98	105	45	137	39	127	127	84	170	61
		Synedra ulna						1,657	1,359	944	3,543	1078
		Synedra spp.	795	138	88	3,387	1,451	211	209	86	340	141
		Deformed Diatoms						279	208	172	457	155
Chlorophyta	Ulothricales	*Ulothrix spp.?*	1,768	1,673	420	3,212	1,399	2,538	1,456	548	6,692	2823
Chlorophyta		UID Chlorophyta colonial	264	262	178	350	86	366	366	366	366	
		UID Chlorophyta unicellular	138	138	23	254	164	326	326	326	326	
Chrysophyta		UID Chrysophyta unicellular	121	121	106	135	21	446	404	274	659	196
Cyanophyta	Chamaesiphonales	*Chamaesiphon spp.*	11,971	13,150	3,613	22,828	8,366	20,153	21,809	8,079	32,642	9182
	Chroococcales	UID Chrooccocales	213	213	213	213						
	Oscillatoriales	*Homoeothrix varians*	190,453	115,340	63,080	450,186	159,985	1,695,112	1,694,880	684,259	2,682,894	753194
		Lyngbya spp.	800	526	393	1,752	639	40,794	21,078	2,102	121,243	47432
		Oscillatoria spp.	9,716	5,345	1,363	27,178	10,749	88,083	85,372	5,118	158,549	55365
		Phormidium sp.	19,194	4,552	1,944	65,786	27,311	38,295	41,627	6,692	63,235	23856
		Pseudanabaena spp.	2,388	2,345	350	5,080	1,769	63,317	56,147	20,898	136,892	46259
		UID Oscillatoriales	2,709.6	3,612.8	4,064.0	6,070.2	1,664.8	6,524.7	20,945.4	3,896.2	61,917.8	73,056.8
Rhodophyta	Nemalionales	*Audouinella sp.*	36,979	16,510	214	108,773	46,104	15,095	16,970	4,689	21,751	7296

UID = unidentified
cf. = (confertim = close together) = possibly for species
? = possibly for genus

Synonyms:
Diatoma mesodon = Diatoma hiemale var. mesodon
Diatoma elongatum = Diatoma tenue var. elongatum

Table D.3: Presence/absence of periphyton taxa at lower Minto Creek and lower Wolverine Creek, Minto Mine WUL, 2011.

Phylum	Order	Genera and Species	Lower Minto Creek (exposure)					Lower Wolverine Creek (reference)				
			LMC-1	LMC-2	LMC-3	LMC-4	LMC-5	LWC-1	LWC-2	LWC-3	LWC-4	LWC-5
Bacillariophycae	Centrales	*Melosira sp.*	0	0	0	0	0	1	1	1	1	0
	Pennales	*Achnanthes lanceolata*	1	1	1	0	0	0	1	1	1	0
		Achnanthes laevis	0	0	0	0	0	1	1	1	1	0
		Achnanthes minutissima	1	0	0	0	0	1	1	1	1	1
		Achnanthes spp.	0	0	1	1	0	1	1	1	1	0
		Caloneis/Nedium sp.	1	0	1	0	0	0	0	0	0	0
		Caloneis spp.	0	0	1	0	1	1	0	0	1	0
		Ceratoneis arcus	0	0	0	0	1	1	1	1	1	1
		Cocconeis placentula	0	0	0	0	0	0	1	1	1	0
		Cymbella cistula	1	0	1	0	0	0	0	0	1	0
		Cymbella minuta	1	1	1	1	1	1	1	1	1	1
		Cymbella sinuata	1	1	1	1	1	1	1	1	1	1
		Cymbella spp.	1	1	1	1	1	1	1	0	1	1
		Diatoma elongatum	0	0	0	0	0	1	1	1	1	1
		Diatoma mesodon	0	0	0	0	0	0	0	0	1	0
		Diatomella sp.	1	0	0	0	0	0	1	0	0	0
		Didymosphenia geminata	0	0	0	0	0	1	0	0	0	0
		Diploneis spp.	0	0	0	0	0	0	1	0	0	0
		Eunotia spp.	1	0	1	1	1	0	0	1	1	1
		Fragilaria cf. montana	0	1	0	0	0	1	0	1	1	0
		Fragilaria vaucheriae	1	1	1	1	1	1	1	1	1	1
		Fragilaria spp.	1	1	1	1	1	1	1	1	1	1
		Frustulia sp.	1	1	1	0	0	0	1	0	0	0
		Gomphonema angustatum/parvulum	1	1	1	1	1	1	1	1	1	1
		Gomphonema spp.	1	1	1	1	1	1	1	1	1	1
		Hantzschia sp.	1	1	0	0	0	0	0	0	1	0
		Meridion circulare	1	1	1	1	1	1	1	1	1	1
		Navicula mutica	1	1	1	1	1	1	1	1	1	1
		Navicula radiosa	1	1	1	1	1	0	0	0	1	0
		Navicula spp.	1	1	1	1	1	1	1	1	1	1
		Neidium spp.	0	0	0	1	0	0	0	0	1	0
		Nitzschia dissipata	0	0	0	0	0	1	1	1	1	1
		Nitzschia spp.	1	1	1	1	1	1	1	1	1	1
		Nitzschia sp.A	1	1	1	1	1	0	0	0	0	0
		Pinnularia spp.	0	1	1	1	0	0	1	1	1	1
		Rhoicosphenia curvata	0	0	0	0	0	1	1	1	1	1
		Rhopalodia gibba	0	0	0	0	0	0	0	0	1	0
		Stauroneis spp.	0	1	0	1	0	0	0	1	1	1
		Surirella angusta	1	1	1	1	1	1	0	0	0	0
		Surirella spp.	1	1	1	1	1	1	1	1	1	1
		Synedra ulna	0	0	0	0	1	1	1	1	1	1
		Synedra spp.	1	1	1	1	1	1	1	1	1	1
		Tabellaria fenestrata	0	0	0	0	0	0	1	0	1	0
		Tabellaria flocculosa	0	0	1	1	0	0	0	0	0	1
		Deformed Diatoms	1	0	0	0	0	0	1	1	1	1
Chlorophyta	Chaetophorales	*Stigeoclonium sp.*	0	0	0	0	1	0	1	0	1	0
	Ulothricales	*Ulothrix spp.?*	1	1	1	1	0	1	1	1	1	1
		Ulothrix zonata	0	0	0	0	0	0	0	0	1	0
	Zygnematales	*Closterium spp.*	1	0	0	1	0	1	0	0	0	0
Chlorophyta		UID Chlorophyta colonial	0	0	1	1	1	0	0	1	0	1
		UID Chlorophyta filamentous	0	0	0	0	0	0	0	0	0	1
		UID Chlorophyta flagellate	0	0	0	1	0	0	0	0	0	0
		UID Chlorophyta unicellular	0	0	1	0	1	1	0	0	0	0
Chrysophyta	Ochromonadales	*Hyalobryon sp.*	0	0	0	0	1	0	0	0	0	0
		UID Chrysophyta colonial	0	0	0	0	0	0	0	1	0	0
		UID Chrysophyta unicellular	1	1	0	1	0	0	0	1	1	1
Cyanophyta	Chamaesiphonales	*Chamaesiphon spp.*	1	1	1	1	1	1	1	1	1	1
	Chroococcales	UID Chrooccocales	0	1	0	0	0	0	0	0	0	0
	Oscillatoriales	*Homoeothrix varians*	1	1	1	1	1	1	1	1	1	1
		Lyngbya spp.	1	1	1	0	1	1	1	1	1	1
		Oscillatoria spp.	1	1	1	1	1	1	1	1	1	1
		Phormidium sp.	1	1	1	1	1	1	1	1	1	1
		Pseudanabaena spp.	1	1	1	1	1	1	1	1	1	1
		Spirulina sp.	0	0	0	0	0	0	0	1	0	0
		UID Oscillatoriales	1	1	1	1	1	1	1	1	1	1
Rhodophyta	Nemalionales	*Audouinella sp.*	1	1	1	1	1	1	1	1	1	1

UID = unidentified
cf. = (confertim = close together) = possibly for species
? = possibly for genus

Synonyms:
Diatoma mesodon = Diatoma hiemale var. mesodon
Diatoma elongatum = Diatoma tenue var. elongatum

Table D.4: T-tests between lower Wolverine Creek (reference) and lower Minto Ceek (exposure) areas, Minto Mine WUL, 2011.

Metric	Significant Difference Between Areas? ($p<0.1$)	p-value	Mean Lower Wolverine Creek	Mean Lower Minto Creek	Mean Difference (LWC-LMC)	Power[a]	Magnitude of Difference (# of SDs)[b]	Minimum Detectable Effect Size[a] (# of SDs)[b]
Density (Total)	Yes	0.002	2,273,337	326,318	1,947,019	0.995	2.097	-
Number of Taxa (presence/absence)	Yes	0.030	40.6	34.2	6.4	0.776	1.248	-
Number of Taxa (quantitative)	Yes	0.052	30.4	26.8	3.6	0.668	1.495	-
Simpson's Evenness	Yes	0.087	0.060	0.119	-0.059	0.654	8.751	-
Bray-Curtis Distance	Yes	0.0001	0.192	0.784	-0.592	1.000	4.043	-

[a] power and minimum detectable effects size were calculated using alpha = 0.10

[b] relative to number of reference standard deviations

Note: all data was used to calculate densities. Data used to calculate other metrics was reduced to exclude UID Pennales which were cells not clearly visible under the microscope, UID Chrysophyta cyst which could not be classified as unicellular or colonial due to lifestage, UID colonial, and UID cellular.

Appendix E

Benthic Invertebrate Community Data

Table E.1: Benthic invertebrates collected by Hess sampler. Values reported as number of organisms per m^2, Minto Mine WUL, 2011.

Taxa	Exposure					Reference				
	LMC-1	LMC-2	LMC-3	LMC-4	LMC-5	LWC-1	LWC-2	LWC-3	LWC-4	LWC-5
Phylum: Arthropoda										
Subphylum: Hexapoda										
| Class: Insecta										
| Order: Ephemeroptera										
| Family: Ameletidae										
Ameletus sp.							3			
| Family: Baetidae										
Acentrella sp.							3			
Baetis sp.			10			10	3	40	100	150
Baetis tricaudatus								3		
| Family: Ephemerellidae						3		3	7	
Drunella grandis										10
Ephemerella sp.							7			
| Family: Heptageniidae						57	87	37	133	703
Cinygmula sp.							7		7	
| Order: Plecoptera						3		7		
| Family: Capniidae	7	63	37	13	107	63	67	27	53	290
| Family: Chloroperlidae						20	60	13	53	10
Suwallia sp.										10
| Family: Leuctridae			10							
| Family: Nemouridae	93	207	193	93	173	10	3		13	
Nemoura										
Podmosta sp.	7	127	43	13	13					
Zapada sp.										10
| Family: Perlodidae						7	20	37		220
Isoperla sp.							10	10	53	70
Kogotus nonus										
| Family: Taeniopterygidae							3	3		
| Order: Trichoptera					133					
| Family: Glossosomatidae										
Glossosoma sp.						3	3		7	
| Family: Hydroptilidae										
Agraylea sp.								3		
| Family: Limnephilidae	7					3		7		
Ecclisomyia sp.						17				
| Order: Coleoptera			10							
| Family: Dytiscidae								3		
| Family: Hydrophilidae										
Hydrobius sp.										
| Order: Diptera		10							7	
| Family: Ceratopogonidae		10								
Culicoides sp.				13						
Monohelea sp.						7				
| Family: Chironomidae										
| Subfamily: Diamesinae										
| Tribe: Diamesini										
Diamesa sp.	7		17				7			17
Pagastia sp.				13				73		107
Potthastia longimana group									7	
| Subfamily: Orthocladiinae										
Brillia sp.		17								
Cardiocladius sp.		37		53	40					
Eukiefferiella sp.	1160	1783	1543	2360	3560	63	77	87	140	123
Krenosmittia sp.									7	
Metriocnemus sp.					13					
Orthocladius complex						213	290	523	620	887
Orthocladius lignicola										
Paralimnophyes arcticus										
Paraphaenocladius sp.										
Pseudosmittia sp.			10							
Synorthocladius sp.								17	20	27
Thienemanniella										
| Subfamily: Podonominae										
Trichotanypus sp.		10		27						
| Family: Deuterophlebiidae										
Deuterophlebia sp.								3		
| Family: Empididae			10	27						
Chelifera/ Metachela	7		27	67	53	10	7		27	27
Clinocera sp.			80	40	13					
| Family: Simuliidae		27			13	3		3	20	27
Simulium sp.		17	10	13				3	7	10
| Family: Tipulidae										
Dicranota sp.	13		17	13	27		7	7	13	
Hesperoconopa sp.							3	7		
Ormosia sp.					13					

Table E.1: Benthic invertebrates collected by Hess sampler. Values reported as number of organisms per m^2, Minto Mine WUL, 2011.

Taxa	Exposure					Reference				
	LMC-1	LMC-2	LMC-3	LMC-4	LMC-5	LWC-1	LWC-2	LWC-3	LWC-4	LWC-5
Tipula sp.			10				3			
| Order: Lepidoptera	13									
| Class: Entognatha										
| Order: Collembola										
| Family: Poduridae	387	127	10	67	27		7			
Subphylum: Crustacea										
| Class: Ostracoda			17	67	333	3	3	7	73	
| Class: Copepoda										
| Order: Cyclopoida			10	13		13	3	10		
| Order: Harpacticoida	13	27	17	53	107	23	7	20	27	
| Class: Malacostraca										
| Order: Amphipoda										
| Family: Talitridae										
Daphnia sp.					13	17				
Subphylum: Chelicerata										
| Class: Arachnida										
| Order: Trombidiformes										
| Family: Aturidae										
Aturus sp.								3		
| Family: Feltriidae										
Feltria sp.			10	13		10	7		7	27
| Family: Hygrobatidae										
Hygrobates sp.								3		
| Family: Lebertiidae										
Lebertia sp.						10		3		
| Family: Sperchontidae										
Sperchon sp.			17	27	67			7	7	10
Suborder: Prostigmata		10		27					7	
| Order: Oribatei										
| Family: Hydrozetidae	20	17			53				13	
Phylum: Annelida										
Subphylum: Clitellata										
| Class: Oligochaeta										
| Order: Haplotaxida										
| Family: Haplotaxidae										
Haplotaxis sp.									13	
| Order: Lumbriculida										
| Family: Lumbriculidae	13	53				80	83	50	300	70
Rhynchelmis sp.								7		
| Order: Tubificida										
| Family: Enchytraeidae										
Enchytraeus	107	143			53	130	23	40	140	10
| Family: Naididae		17	177	173	200	57				
Phylum: Nemata	647	217	447	2573	2253	23	20	20	253	53
Phylum: Platyhelminthes										
| Class: Turbellaria			97							
| Order: Tricladida										
| Family: Planariidae										
Polycelis coronata				13						
Phylum: Tardigrada				13						
Totals:	**2501**	**2919**	**2829**	**5784**	**7264**	**858**	**823**	**1086**	**2134**	**2868**

Table E.2: Benthic invertebrates collected by kick-and-sweep. Values reported as number of organisms per sample, Minto Mine WUL, 2011.

Taxa	Lower Minto Creek	Lower Wolverine
Phylum: Arthropoda		
Subphylum: Hexapoda		
| Class: Insecta		
| Order: Ephemeroptera		
| Family: Ameletidae		
Ameletus sp.	12	
| Family: Baetidae		
Acentrella sp.	4	
Baetis sp.	40	4
Baetis tricaudatus	8	4
| Family: Ephemerellidae		
Drunella grandis	4	
Ephemerella sp.	12	
| Family: Heptageniidae	168	
Cinygmula sp.	4	
| Order: Plecoptera	48	
| Family: Capniidae	324	156
| Family: Chloroperlidae	28	
Suwallia sp.		
| Family: Leuctridae		
| Family: Nemouridae		196
Nemoura		8
Podmosta sp.		40
Zapada sp.		
| Family: Perlodidae	104	
Isoperla sp.		
Kogotus nonus	4	
| Family: Taeniopterygidae	4	
| Order: Trichoptera		
| Family: Glossosomatidae		
Glossosoma sp.		
| Family: Hydroptilidae		
Agraylea sp.		
| Family: Limnephilidae		24
Ecclisomyia sp.	4	
| Order: Coleoptera		
| Family: Dytiscidae		
| Family: Hydrophilidae		
Hydrobius sp.		4
| Order: Diptera		4
| Family: Ceratopogonidae		
Culicoides sp.		4
Monohelea sp.	4	
| Family: Chironomidae		
| Subfamily: Diamesinae		
| Tribe: Diamesini		
Diamesa sp.		52
Pagastia sp.		
Potthastia longimana group		
| Subfamily: Orthocladiinae		
Brillia sp.		
Cardiocladius sp.		
Eukiefferiella sp.	16	100
Krenosmittia sp.		
Metriocnemus sp.		
Orthocladius complex	380	552
Orthocladius lignicola		4
Paralimnophyes arcticus		16
Paraphaenocladius sp.		16
Pseudosmittia sp.	4	20
Synorthocladius sp.		
Thienemanniella	8	
| Subfamily: Podonominae		
Trichotanypus sp.		
| Family: Deuterophlebiidae		
Deuterophlebia sp.		
| Family: Empididae		
Chelifera/ Metachela	32	4
Clinocera sp.		8
| Family: Simuliidae		4
Simulium sp.	4	4
| Family: Tipulidae		
Dicranota sp.	12	28
Hesperoconopa sp.		
Ormosia sp.		
Tipula sp.		
| Order: Lepidoptera		

Table E.2: Benthic invertebrates collected by kick-and-sweep. Values reported as number of organisms per sample, Minto Mine WUL, 2011.

Taxa	Lower Minto Creek	Lower Wolverine
| Class: Entognatha		
| Order: Collembola		
| Family: Poduridae	4	20
Subphylum: Crustacea		
| Class: Ostracoda	4	16
| Class: Copepoda		
| Order: Cyclopoida		
| Order: Harpacticoida	4	8
| Class: Malacostraca		
| Order: Amphipoda		
| Family: Talitridae		
Daphnia sp.		
Subphylum: Chelicerata		
| Class: Arachnida		
| Order: Trombidiformes		
| Family: Aturidae		
Aturus sp.	4	
| Family: Feltriidae		
Feltria sp.	20	
| Family: Hygrobatidae		
Hygrobates sp.	12	
| Family: Lebertiidae		
Lebertia sp.	36	
| Family: Sperchontidae		
Sperchon sp.	8	20
Suborder: Prostigmata	8	
| Order: Oribatei		
| Family: Hydrozetidae		12
Phylum: Annelida		
Subphylum: Clitellata		
| Class: Oligochaeta		
| Order: Haplotaxida		
| Family: Haplotaxidae		
Haplotaxis sp.		
| Order: Lumbriculida		
| Family: Lumbriculidae	44	8
Rhynchelmis sp.		
| Order: Tubificida		
| Family: Enchytraeidae		
Enchytraeus	84	
| Family: Naididae		68
Phylum: Nemata	20	228
Phylum: Platyhelminthes		
| Class: Turbellaria	4	
| Order: Tricladida		
| Family: Planariidae		
Polycelis coronata		
Phylum: Tardigrada		
Totals:	**1480**	**1632**

Table E.3a: Percent recovery of benthic invertebrates, Minto Mine Cycle 2 EEM. Shading indicates that the data quality objective of≥90% was not met.

Site	Number of organisms recovered (initial sort)	Number of organisms in re-sort	Percent recovery
LWC Replicate 5	334	342	98
LMC Replicate2	334	340	98
LMC Replicate 4	432	452	95

Table E.3b: Calculation of subsampling error for benthic invertebrate samples, Minto Mine Cycle 2 EEM. Shading indicates that the data quality objective of <20% was not met.

Sample	Number of organisms in fraction 1 (25%)	Number of organisms in fraction 2 (25%)	Number of organisms in fraction 3 (25%)	Number of organisms in fraction 4 (25%)	Actual density	Precision (range of RPD)[a]		Accuracy (range expressed as %)[b]	
LMC Replicate 4	434	385	450	411	1680	6.3	9	8.3	7
LWC K&S	408	441	356	385	1590	7.5	19	10.4	11

[a] relative percent difference among subsamples

[b] range of deviation of abundance estimates derived from sub-samples compared to analysis of entire sample (expressed as % of total organisms present)

Table E.4: Benthic invertebrate community metrics by station for samples collected by Hess sampler, Minto Mine WUL, 2011.

Area	Station	Density (individuals per m^2)	Number of Taxa	Number of EPT Taxa	BC Diss. to LWC Median	Simpson's E[a]	Number of Chironomid Taxa	Ephemeroptera (%)	Plecoptera (%)	Trichoptera (%)	EPT (%)
Lower Minto Creek (Exposure)	LMC-1	2501	14	3	0.882	0.231	2	0	4	0	5
	LMC-2	2919	15	2	0.851	0.166	4	0	14	0	14
	LMC-3	2829	22	4	0.885	0.135	3	0	10	0	10
	LMC-4	5784	22	2	0.943	0.124	4	0	2	0	2
	LMC-5	7264	20	3	0.932	0.147	3	0	4	2	6
Lower Wolverine Creek (Reference)	LWC-1	858	23	8	0.352	0.370	2	8	12	3	23
	LWC-2	823	26	11	0.233	0.224	3	13	20	0	34
	LWC-3	1086	27	8	0.121	0.146	4	8	9	1	17
	LWC-4	2134	25	8	0.317	0.289	5	12	8	0	20
	LWC-5	2868	19	7	0.475	0.287	5	30	21	0	51

[a] calculated as recommnended by Environment Canada 2011.

Table E.4: Benthic invertebrate community metrics by station for samples collected by Hess sampler, Minto Mine WUL, 2011.

Area	Station	Chironomids (%)	Oligochaetes (%)	Nemata (%)	CA Axis-1 (40.4%)	CA Axis-2 (17.2%)	CA Axis-3 (10.3%)	CA Axis-4 (9.9%)
Lower Minto Creek (Exposure)	LMC-1	47	5	26	0.421	0.458	0.601	-0.468
	LMC-2	63	7	7	0.614	0.626	0.200	0.340
	LMC-3	55	6	16	0.553	-0.913	0.105	-0.215
	LMC-4	42	3	44	0.727	-0.166	-0.110	0.446
	LMC-5	50	3	31	0.583	0.192	-0.294	-0.234
Lower Wolverine Creek (Reference)	LWC-1	32	31	3	-0.326	0.205	-0.613	-0.195
	LWC-2	45	13	2	-0.563	-0.040	0.215	-0.304
	LWC-3	64	9	2	-0.718	-0.102	-0.099	0.104
	LWC-4	37	21	12	-0.445	0.125	0.039	-0.007
	LWC-5	40	3	2	-0.741	-0.137	0.229	0.348

[a] calculated as recommnended by Environment Canada 2011.

Table E.5: Statistical characteristics of benthic metrics by area for samples collected by Hess sampler, Minto Mine WUL, 2011.

	Area	n	Median	Mean	Standard Deviation	Standard Error	95% Confidence Interval		Minimum	Maximum
							Lower Bound	Upper Bound		
Density (ind./m2)	Wolverine Ck. Ref.	5	1086.00	1553.800	908.405	406.251	425.870	2681.730	823.000	2868.000
	Minto Ck. Exp.	5	2919.00	4259.400	2138.148	956.209	1604.540	6914.260	2501.000	7264.000
Number of Taxa	Wolverine Ck. Ref.	5	25.00	24.000	3.162	1.414	20.070	27.930	19.000	27.000
	Minto Ck. Exp.	5	20.00	18.600	3.847	1.720	13.820	23.380	14.000	22.000
Number of EPT Taxa	Wolverine Ck. Ref.	5	8.00	8.400	1.517	0.678	6.520	10.280	7.000	11.000
	Minto Ck. Exp.	5	3.00	2.800	0.837	0.374	1.760	3.840	2.000	4.000
Number of Chironomid Taxa	Wolverine Ck. Ref.	5	4.00	3.800	1.304	0.583	2.180	5.420	2.000	5.000
	Minto Ck. Exp.	5	3.00	3.200	0.837	0.374	2.160	4.240	2.000	4.000
EPT (%)	Wolverine Ck. Ref.	5	22.844	29.039	13.897	6.215	11.785	46.294	17.495	51.360
	Minto Ck. Exp.	5	5.865	7.288	4.640	2.075	1.527	13.048	2.057	13.601
Chironomids (%)	Wolverine Ck. Ref.	5	40.481	43.951	12.441	5.564	28.504	59.398	32.168	64.457
	Minto Ck. Exp.	5	49.738	51.516	8.120	3.632	41.433	61.599	42.410	63.275
Oligochaetes (%)	Wolverine Ck. Ref.	5	12.880	15.390	11.048	4.941	1.671	29.108	2.789	31.119
	Minto Ck. Exp.	5	4.798	4.965	1.818	0.813	2.707	7.223	2.991	7.297
Nemata (%)	Wolverine Ck. Ref.	5	2.43	4.131	4.334	1.938	-1.250	9.512	1.842	11.856
	Minto Ck. Exp.	5	25.87	24.921	14.228	6.363	7.254	42.588	7.434	44.485
BC Diss. to WC Median	Wolverine Ck. Ref.	5	0.317	0.299	0.132	0.059	0.135	0.464	0.121	0.475
	Minto Ck. Exp.	5	0.885	0.899	0.038	0.017	0.851	0.946	0.851	0.943
Simpson's D	Wolverine Ck. Ref.	5	0.829	0.827	0.052	0.023	0.762	0.892	0.746	0.882
	Minto Ck. Exp.	5	0.659	0.649	0.035	0.016	0.606	0.692	0.598	0.690
Simpson's E[a]	Wolverine Ck. Ref.	5	0.287	0.263	0.084	0.037	0.159	0.367	0.146	0.370
	Minto Ck. Exp.	5	0.147	0.160	0.042	0.019	0.108	0.213	0.124	0.231
CA Axis-1 (40.4%)	Wolverine Ck. Ref.	5	-0.563	-0.558	0.177	0.079	-0.778	-0.338	-0.741	-0.326
	Minto Ck. Exp.	5	0.583	0.579	0.110	0.049	0.442	0.716	0.421	0.727
CA Axis-2 (17.2%)	Wolverine Ck. Ref.	5	-0.04	0.010	0.148	0.066	-0.174	0.194	-0.137	0.205
	Minto Ck. Exp.	5	0.19	0.040	0.611	0.273	-0.719	0.798	-0.913	0.626
CA Axis-3 (10.3%)	Wolverine Ck. Ref.	5	0.04	-0.046	0.345	0.154	-0.474	0.382	-0.613	0.229
	Minto Ck. Exp.	5	0.11	0.100	0.339	0.152	-0.321	0.522	-0.294	0.601
CA Axis-4 (9.9%)	Wolverine Ck. Ref.	5	-0.01	-0.011	0.256	0.114	-0.328	0.306	-0.304	0.348
	Minto Ck. Exp.	5	-0.21	-0.026	0.397	0.178	-0.519	0.467	-0.468	0.446

[a] calculated as recommnended by Environment Canada 2011.

Table E.6: Summary of benthic invertebrate community characteristics and statistical comparisons among areas for samples collected by Hess sampler Minto Mine WUL, 2011.

	Comparison	ANOVA for Estimation of Effect Size						
Metric	**Planned Comparison**	**Mean Square**	**F (ANOVA)**	**Significant Difference Among Areas? (p-value)[a]**		**Power**	**Magnitude of Difference (# of SDs)[b]**	**Minimum Detectable Effect Size (# of SDs)[c]**
Density (ind./m2)	Wolverine Ck. Reference vs. Minto Ck. Exposure	18300678.4000	6.7820	YES	0.031	0.628	3.0	~
Number of Taxa	Wolverine Ck. Reference vs. Minto Ck. Exposure	72.9000	5.8790	YES	0.042	0.568	-1.7	~
Number of EPT Taxa	Wolverine Ck. Reference vs. Minto Ck. Exposure	78.4000	52.2667	YES	0.000	1.000	-3.7	~
Number of Chironomid Taxa	Wolverine Ck. Reference vs. Minto Ck. Exposure	0.9000	0.7500	NO	0.412	0.119	~	1.8
EPT (%)	Wolverine Ck. Reference vs. Minto Ck. Exposure	1182.8679	11.0218	YES	0.011	0.827	-1.6	~
Chironomids (%)	Wolverine Ck. Reference vs. Minto Ck. Exposure	143.0750	1.2965	NO	0.288	0.172	~	1.8
Crustacea (%)	Wolverine Ck. Reference vs. Minto Ck. Exposure	2.1750	0.3680	NO	0.561	0.084	~	2.1
Oligochaetes (%)	Wolverine Ck. Reference vs. Minto Ck. Exposure	271.6695	4.3338	YES	0.071	0.449	-0.9	~
Nemata (%)	Wolverine Ck. Reference vs. Minto Ck. Exposure	1080.5403	9.7689	YES	0.014	0.781	4.8	~
BC Diss. to WC Median	Wolverine Ck. Reference vs. Minto Ck. Exposure	0.8978	94.3873	YES	0.000	1.000	4.5	~
Simpson's D	Wolverine Ck. Reference vs. Minto Ck. Exposure	0.0792	39.9767	YES	0.000	1.000	-3.4	~
Simpson's E[d]	Wolverine Ck. Reference vs. Minto Ck. Exposure	0.0263	6.0097	YES	0.040	0.577	-1.2	~
CA Axis-1 (40.4%)	Wolverine Ck. Reference vs. Minto Ck. Exposure	3.2358	148.5923	YES	0.000	1.000	6.4	~
CA Axis-2 (17.2%)	Wolverine Ck. Reference vs. Minto Ck. Exposure	0.0022	0.0109	NO	0.919	0.051	~	6.5
CA Axis-3 (10.3%)	Wolverine Ck. Reference vs. Minto Ck. Exposure	0.0536	0.4578	NO	0.518	0.092	~	2.2
CA Axis-4 (9.9%)	Wolverine Ck. Reference vs. Minto Ck. Exposure	0.0006	0.0053	NO	0.944	0.050	~	2.8

[a] p-value obtained from 1-way ANOVA

[b] Magnitude of difference was calculated to reflect the number of reference standard deviations as follows: (exposure mean - reference mean) / standard deviation of the reference mean

[c] Minimum effect size detectable calculated as: $(t\alpha+t\beta)(SQRT(MSE))(SQRT2/n)]/SD_{ref}$. MSE (mean square error) is generated from the ANOVA as an estimate of variability with alpha and beta equal to 0.10,

n is the sample size per area (i.e., 5), and SD_{ref} is the standard deviation for the reference area mean.

[d] calculated as recommnended by Environment Canada 2011.

Table E.7: Benthic taxon scores from Correspondence Analysis for samples collected by Hess sampler, Minto Mine WUL, 2011.

	CA Axis-1 (40.4%)	CA Axis-2 (17.2%)	CA Axis-3 (10.3%)	CA Axis-4 (9.9%)
Baetis sp. + B. tricaudatus	-0.7543	-0.2978	0.0058	0.1224
| Family: Ephemerellidae + Drunella grandis, Ephemerella sp.	-0.9661	-0.0026	0.0322	0.0221
| Family: Heptageniidae + Cinygmula sp.	-0.9669	-0.0001	-0.0251	0.0642
| Family: Capniidae	-0.0909	0.0511	0.0225	-0.0054
| Family: Chloroperlidae + Suwallia sp.	-0.9300	0.0414	-0.0825	-0.1091
| Family: Nemouridae + Podmosta sp., Zapada sp.	0.5111	0.1072	0.1862	-0.0579
| Family: Perlodidae + Isoperla sp.	-1.0114	-0.0525	0.0894	0.1610
| Family: Taeniopterygidae	-1.0874	-0.1866	0.1833	-0.3287
| Order: Trichoptera, including Glossosoma sp. Agraylea sp. Ecclisomyia sp. And unidentified Trichoptera	-0.0776	0.4059	-0.4184	-0.6273
| Order: Coleoptera, including Dytiscidae and unidentified Coleoptera	0.1477	-1.5982	0.1019	-0.3359
| Family: Ceratopogonidae, including Culicoides sp., Monohelea sp., and unidentified ceratopogonids	0.6457	0.5445	-0.5110	0.7648
Diamesa sp.	-0.1430	-0.5654	0.8989	-0.4215
Pagastia sp.	-0.6764	-0.3386	0.1017	0.9596
Cardiocladius sp.	1.0900	0.5339	-0.2374	0.6493
Eukiefferiella sp.	0.2582	0.0722	0.1381	-0.0463
Orthocladius complex	-0.9619	0.0092	-0.0974	0.0216
Synorthocladius sp.	-1.0782	-0.1034	0.2152	0.5313
Trichotanypus sp.	1.1510	0.4309	0.0668	1.3775
Chelifera/ Metachela	0.1628	-0.1829	-0.0242	-0.0860
Clinocera sp.	1.0535	-0.9945	-0.2235	0.0537
| Family: Simuliidae + Simulium sp.	0.0847	0.0326	-0.0203	0.3953
Dicranota sp.	0.2524	-0.1691	0.1769	-0.3553
Hesperoconopa sp.	-1.1111	-0.2010	0.0884	-0.2028
Tipula sp.	0.2441	-1.5396	0.4883	-0.8483
| Family: Poduridae	0.7900	0.3905	0.5596	-0.1784
| Class: Ostracoda	0.2617	-0.1959	-0.3736	-0.0945
| Order: Cyclopoida	-0.0176	-0.5402	-0.4672	-0.0076
| Order: Harpacticoida	0.2617	0.1396	-0.1071	-0.1179
Daphnia sp.	0.1825	0.5167	-1.5465	-0.7337
Feltria sp.	-0.2388	-0.4197	-0.0487	0.1620
Lebertia sp.	-0.7957	0.2406	-1.4256	-0.2938
Sperchon sp.	0.2276	-0.4061	-0.1736	0.1839
Suborder: Prostigmata, incl. O. Oribatei (Family: Hydrozetidae)	0.6799	0.6318	0.2158	0.0483
| Family: Lumbriculidae, incl. Rhynchelmis sp. And unidentified Lumbriculidae.	-0.5161	0.3648	0.1637	-0.0258
Enchytraeus	-0.1385	0.5393	0.0721	-0.2274
| Family: Naididae	0.7614	-0.2207	-0.5187	0.0206
Phylum: Nemata	0.2997	0.0650	0.1290	-0.0461
| Class: Turbellaria, including Polycelis coronata and unidentified Turbellaria	1.0440	-1.6607	0.0897	0.0913

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(blue) Indicates heavy positively-weighted variable on respective CA axis.

(green) Indicates heavy negatively-weighted variable on respective CA axis.

Table E.8: Eigenvalues of Correspondence Analysis for samples collected by Hess sampler, Minto Mine WUL, 2011.

	CA Axis-1 (40.4%)	CA Axis-2 (17.2%)	CA Axis-3 (10.3%)	CA Axis-4 (9.9%)
Eigenvalue	0.348	0.148	0.089	0.085
Relative Inertia (%)	40.440	17.240	10.310	9.860
Cumulative Inertia (%)	40.440	57.680	67.990	77.860

Table E.9: Benthic invertebrate community metrics for samples collected by kick-and-sweep. Values calculated using 2008 and 2010 RCA CABIN models, Minto Mine WUL, 2011.

Model	Metric	Reference Group or Area	Value
2008	Simpson's Evenness	Reference Group 4	-
		Lower Wolverine Creek	0.19
		Lower Minto Creek	0.27
	Total Abundance	Reference Group 4	698.53
		Lower Wolverine Creek	1352
		Lower Minto Creek	1388
	Total No. of Taxa	Reference Group 4	10.23
		Lower Wolverine Creek	14
		Lower Minto Creek	21
	Bray-Curtis Distance	Reference Group 4	-
		Lower Wolverine Creek	0.56
		Lower Minto Creek	0.3
2010	Simpson's Evenness	Reference Group 3	-
		Lower Wolverine Creek	0.19
		Lower Minto Creek	0.27
	Total Abundance	Reference Group 3	1594.35
		Lower Wolverine Creek	1352
		Lower Minto Creek	1388
	Total No. of Taxa	Reference Group 3	11.4
		Lower Wolverine Creek	14
		Lower Minto Creek	21
	Bray-Curtis Distance	Reference Group 3	-
		Lower Wolverine Creek	0.94
		Lower Minto Creek	0.83

Note: metric values marked with a '-' indicate metric could not be calculated (e.g., insufficient data to perform the calculation).

Table E.10: Benthic metrics for samples collected by kick-and-sweep, Minto Mine WUL, 2011.

Area	EPT (%)	Chironomidae (%)	Oligocheata (%)	Nemata (%)
Lower Minto Creek (exposed)	51.9	27.6	8.6	1.4
Lower Wolverine Creek (reference)	26.5	46.6	4.7	14.0

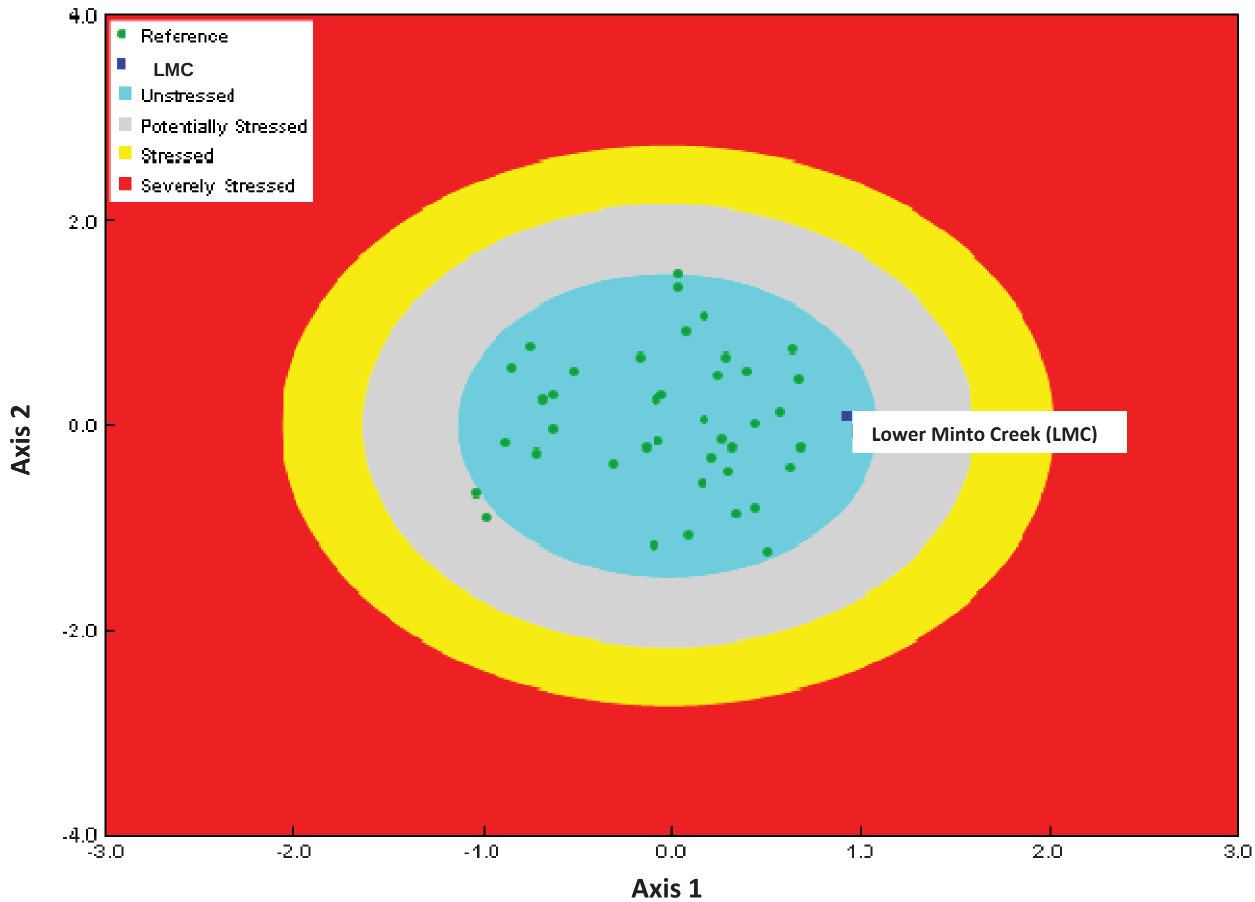

Figure E.1: Scatterplot of Reference Group 4 and lower Minto Creek in ordination space using the 2008 RCA CABIN model. Confidence ellipses shown are 90% (unstressed), 90% to 99% (potentially stressed), 99% to 99.9% (stressed) and >99.9% (severely stressed).

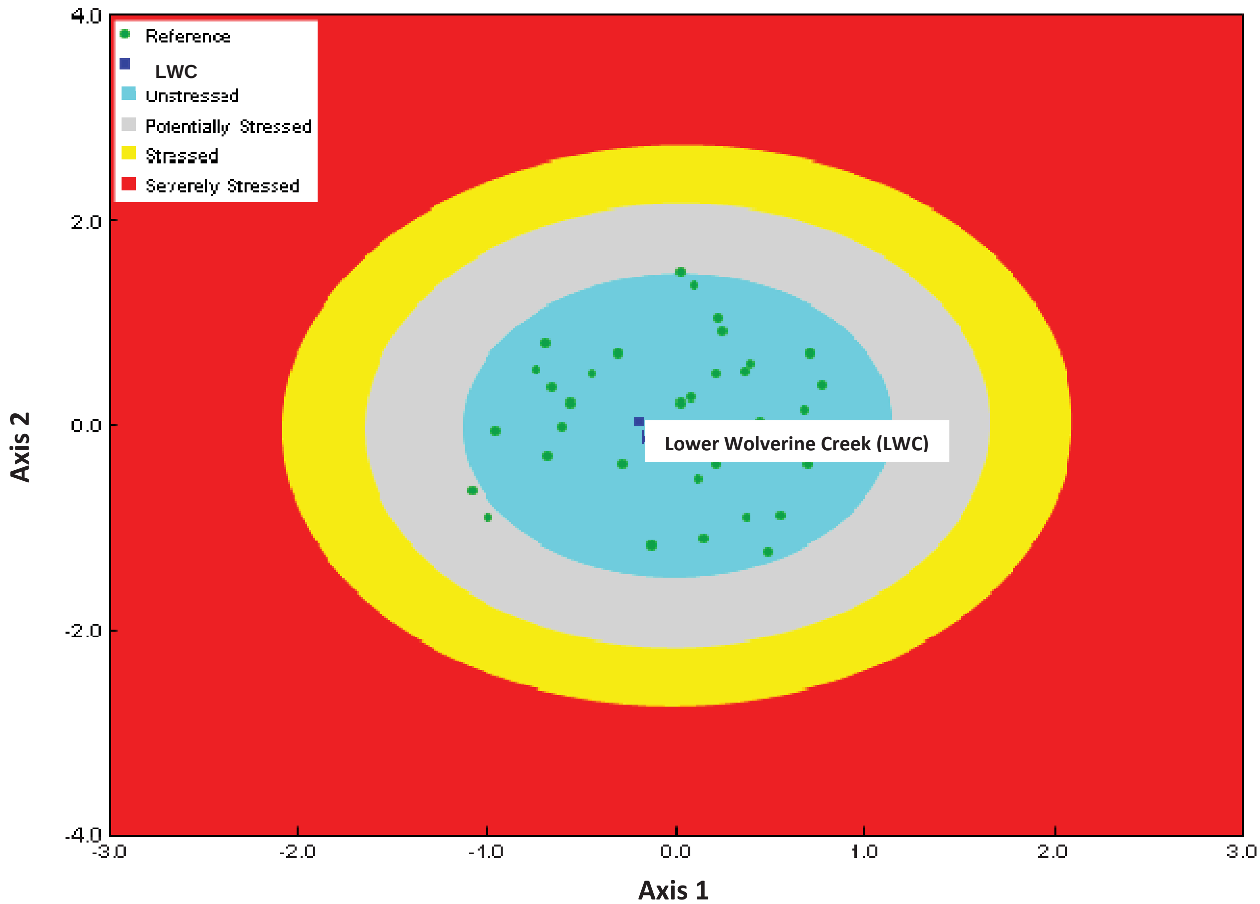

Figure E.2: Scatterplot of Reference Group 4 and lower Wolverine Creek in ordination space using the 2008 RCA CABIN model. Confidence ellipses shown are 90% (unstressed), 90% to 99% (potentially stressed), 99% to 99.9% (stressed) and >99.9% (severely stressed).

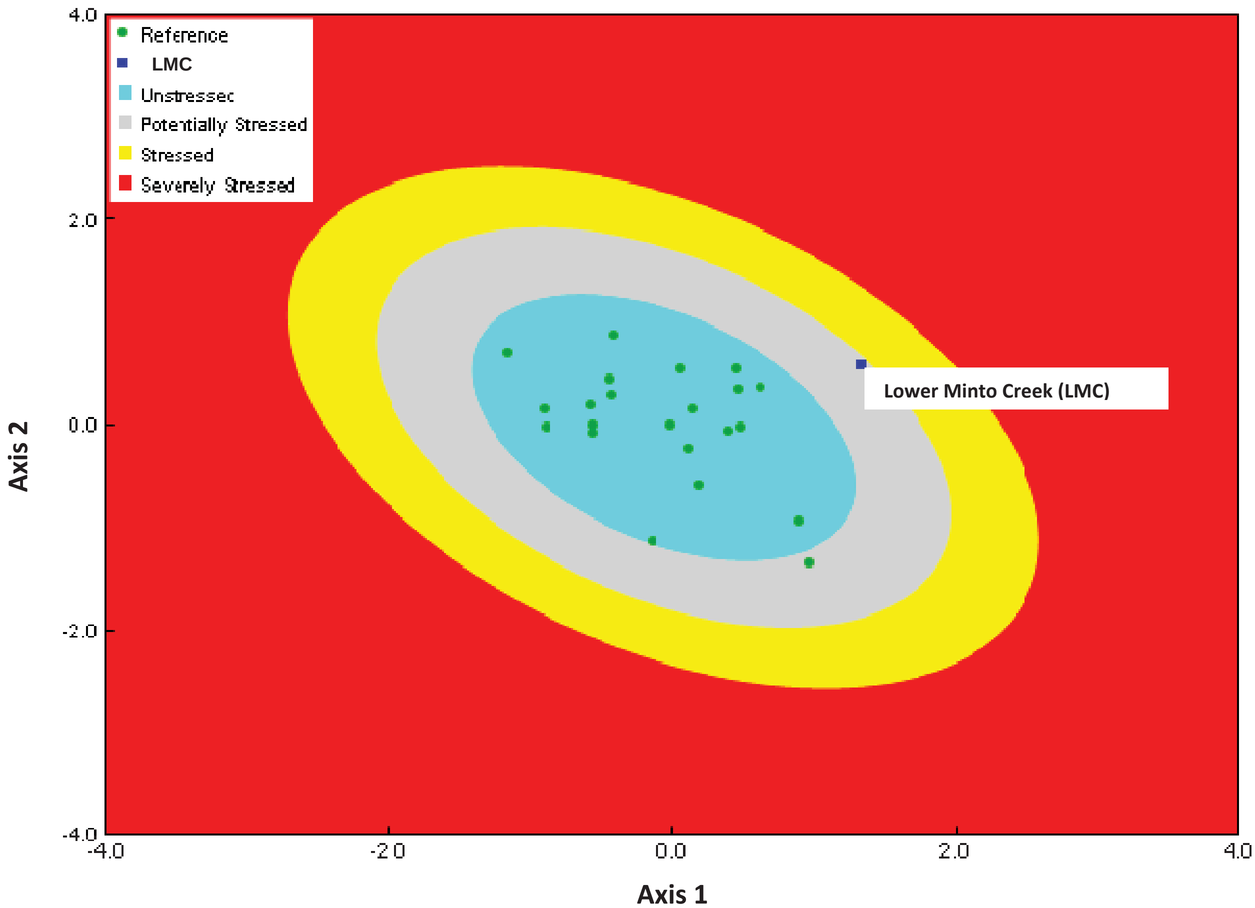

Figure E.3: Scatterplot of Reference Group 4 and lower Minto Creek in ordination space using the 2010 RCA CABIN model. Confidence ellipses shown are 90% (unstressed), 90% to 99% (potentially stressed), 99% to 99.9% (stressed) and >99.9% (severely stressed).

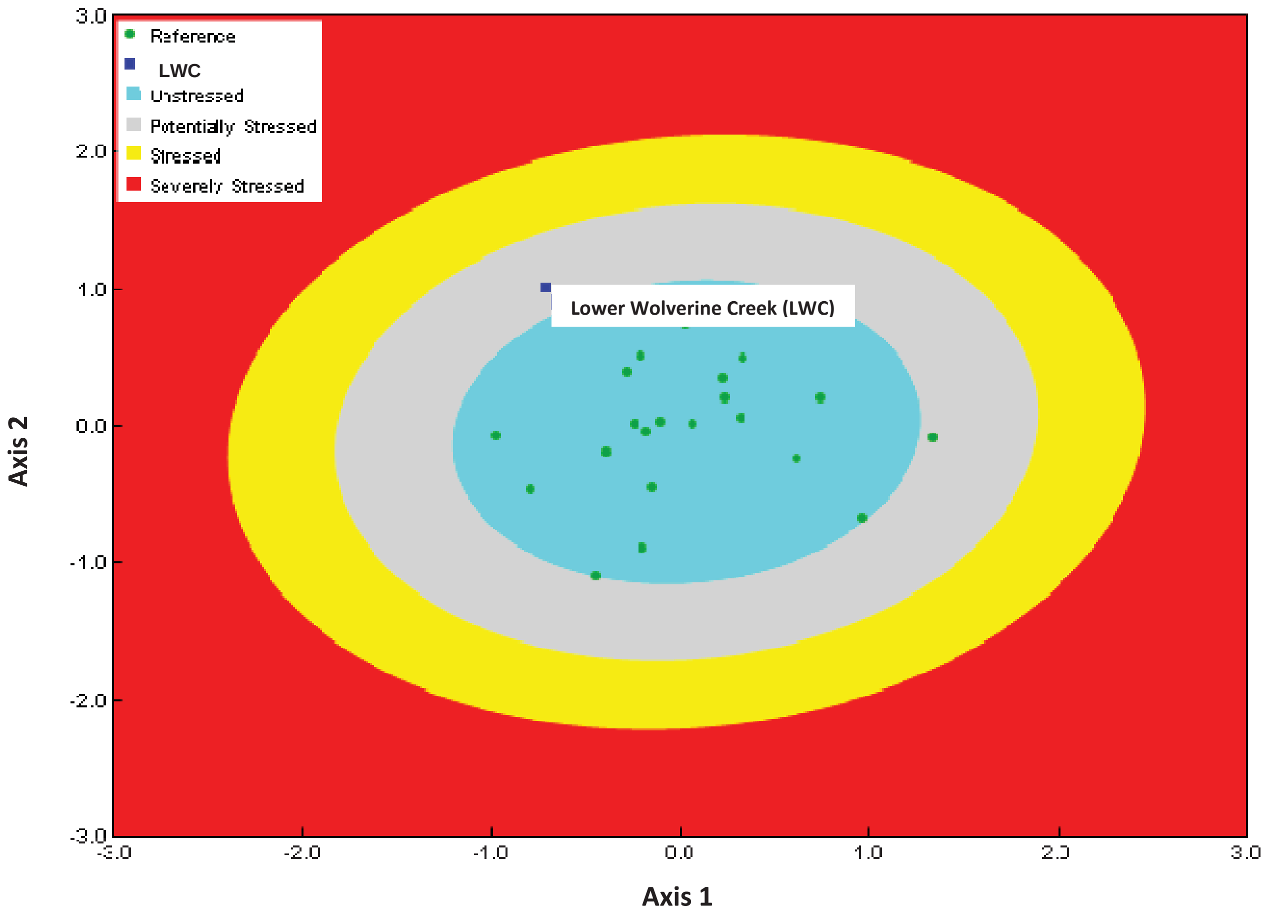

Figure E.4: Scatterplot of Reference Group 4 and lower Wolverine Creek in ordination space using the 2010 RCA CABIN model. Confidence ellipses shown are 90% (unstressed), 90% to 99% (potentially stressed), 99% to 99.9% (stressed) and >99.9% (severely stressed).

Reference Condition Approach (RCA)

REFERENCE CONDITION APPROACH (RCA) METHODS

Description of RCA

The Reference Condition Approach (RCA) was used for analyzing samples collected by kick-and-sweep using protocols established by the Canadian Aquatic Biomonitoring Network (CABIN) as a guide (Environment Canada 2010). The RCA design involved statistically comparing benthic communities of both the lower Minto Creek exposure area and the lower Wolverine Creek reference area to those of a broader set of reference areas to better account for the natural variability that exists among areas (Hughes et al. 1986; Wright et al. 2000; Bailey et al. 2004; Bowman and Somers 2005, 2006). The assessment was accomplished using the online analytical tools package provided on the CABIN website (Environment Canada 2012).

CABIN employs the BEAST (BEnthic Assessment of SedimenT) method for determining whether a site is considered in reference condition or stressed. In general, a CABIN reference model is constructed in the following manner. Hierarchical cluster analysis employing the unweighted pair-group method using arithmetic means (UPGMA) and the Bray-Curtis distance measure is performed on a large dataset of benthic communities that are determined to be in the most pristine state possible. This cluster analysis identifies groups of sites that have similar benthic macroinvertebrate communities. Once specific groups of communities are identified, discriminant function analysis (DFA) is used to determine which environmental variables result in the most accurate prediction of classifying areas to the same groupings as determined by the cluster analysis process using biotic data only (Table 1). The best environmental predictors identified through DFA are then used to determine which reference group a test site should belong to. Predictor environmental variables cannot be affected by the perturbation in question (e.g., pH cannot be used as a predictor variables if acid mine drainage is of concern). The benthic invertebrate community of a test area (e.g., lower Minto Creek exposed area) is then assessed against its predicted reference group using HMDS (hybrid multidimensional scaling) and the Bray-Curtis distance measure. The potential degree of impairment of a test area is determined relative to its distance from the mean reference area grouping in ordination space; this is usually accomplished using confidence ellipses.

Benthic invertebrate and environmental data for lower Minto Creek (effluent exposed) and lower Wolverine Creek (reference) were input into CABIN's database. The Analytical Tools function of the database was then employed to determine whether the CABIN model: a) correctly identified that the benthic community at Wolverine Creek is in reference condition, and b) identified whether or not the benthic community at Minto Creek was of sufficient community structure to be considered non-stressed (i.e., in reference condition). The two sites were run using two models; the "Yukon Reference Model January 2010", and the "Yukon Reference Model July 2008".

Factors Associated with RCA Results

Kick and sweep sample methodology adhered to the CABIN protocol (Environment Canada 2010) with the following exception; sites were sampled for 10 minutes while the CABIN protocol is to sample for 3 minutes. The result of increased sampling time is usually associated with an increased richness count, indeed richness values for the lower Minto Creek and Lower Wolverine Creek were both higher than the reference group mean for both the 2008 and 2010 models. It is also possible that increased sampling will have effects on the other endpoints used in this analysis; therefore, the conclusions and discussion on model results must be interpreted cautiously. Had kick and sweep sampling been limited to 3 minutes the analyses provided by the online CABIN tool pack may have resulted in different conclusions.

Employing the 2008, both sites were designated to a reference group containing 40 sites (Reference Group 4), while the 2010 model designated both sites to a reference group containing only 22 sites (Reference Group 3). While there is still much ambiguity concerning the number of reference sites to use (Bailey et al. 2004), the lower number of reference sites in the 2010 grouping results in large displacement of reference sites in ordination space - as is evident between comparison of the ordination plots of the lower Minto Creek and lower Wolverine Creek (Figures E.1-E.4). Further, there is almost no visible distortion of reference sites between the ordination plots of the 2008 model that uses almost twice as many reference sites.

Error rate is the percentage of reference sites that are not predicted, through DFA of environmental predictors, to belong to the actual reference group to which they belong during the initial reference group creation through cluster analysis of community structure. Error rates associated with both models could be considered poor (Table 2). The overall model error rate for the 2009 model was 45%, while the overall model error rate for 2010 was 50%. Including sites that were not part of model development such as lower Minto Creek and lower Wolverine Creek, would theoretically result in an even higher error rate.

Another prominent difference between models is the use of un-regenerated forest as a predictor variable for the 2010 model (Table 1). Through areal observation via helicopter, the Minto Creek watershed is almost completely reforested; however, the GIS data used in model development predicts that 99% of the Minto Creek watershed is un-regenerated forest. Upon investigation of GIS datum, it was concluded that the GIS layers used in CABIN modeling were collected between 1986 and 2004. This is problematic due to the frequency of forest fires in the Yukon Territory. Therefore, there is a lack of temporal synchronicity between the year benthic samples are taken and landclass datum, particularly with the landclass designation of un-regenerated forest. The 2008 model does not use un-regenerated forest as a model predictor.

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Minto Creek Sediment, Periphyton and Benthic Invertebrate Community Assessment - 2012

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March 2013

Minto Creek Sediment, Periphyton and Benthic Invertebrate Community Assessment - 2012

Report Prepared for:

Minto Explorations Limited

Report Prepared by:

Minnow Environmental Inc.

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1.0 INTRODUCTION

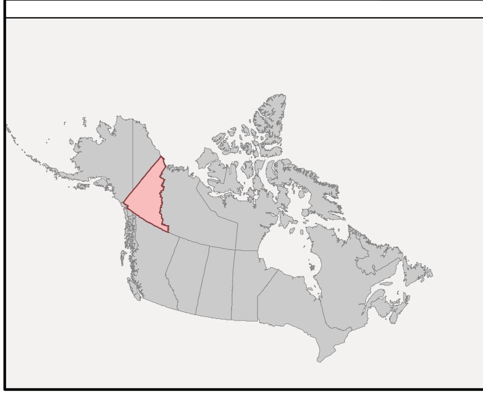
1.1 Site Description

The Minto Mine is a high-grade copper mine located within Selkirk First Nation (SFN) Category A Settlement Land Parcel R-6A approximately 240 km northwest of Whitehorse, Yukon Territory (62°37'N latitude and 137°15'W longitude; Figure 1.1). It is owned and operated by Minto Explorations Ltd. (MintoEx), a wholly owned subsidiary of Capstone Mining Corporation (Capstone). Development of the mine was initiated in 1997, commercial operations started in October 2007 and the anticipated operating life is to the year 2020. The facility is permitted to conduct open pit mining and milling at a rate of 3,600 tonnes of copper/gold/silver ore per day, which is currently expected to produce a total of approximately 6.1 million tonnes (Mt) of ore and 30.5 Mt of waste (e.g., waste rock and tailings) during the mine's operating life. Mine-impacted seepage from the Tailings Storage Facility and under the Mill Valley Fill Expansion (MVFE) is collected at the Minto Creek Detention Structure at the toe of the MVFE (Figure 1.2) and pumped to the water treatment plant or the open pit. Non-impacted water and treated mine-impacted water are collected in a Water Storage Pond (WSP; Figure 1.2). Effluent from the WSP is periodically discharged to Minto Creek under conditions specified in Water Use Licence (WUL) QZ96-006 (Amendment 7, April 2011 and Amendment 8, September 2012). Minto Creek, in turn, discharges to the Yukon River approximately 12 km south-east of the mine site (Figure 1.2).

1.2 Background

Under the WUL, the Minto Mine implements a routine water quality surveillance program in Minto Creek and reference tributaries at sampling frequencies that vary from weekly to monthly during the ice-free period (typically from April to October or November). In accordance with the WUL, the Minto Mine submits water quality data as original laboratory reports and monthly summary reports within 30-days of month-end. Water quality monitoring data have indicated that total suspended solids concentrations can increase dramatically during high flow events and that concentrations of a number of metals (including aluminum, chromium, copper and iron) are generally concurrently higher than national water quality guidelines for the protection of aquatic life even under background and reference conditions (e.g., HKP 1994; Minnow 2009a, 2010a, 2010b).

Recent interpretations of water quality data have documented an influence of the Minto Mine on Minto Creek even in the absence of mine effluent discharge (Minnow/Access



MINTO PROJECT

Minto Explorations Ltd.

A SUBSIDIARY OF CAPSTONE MINING LTD.

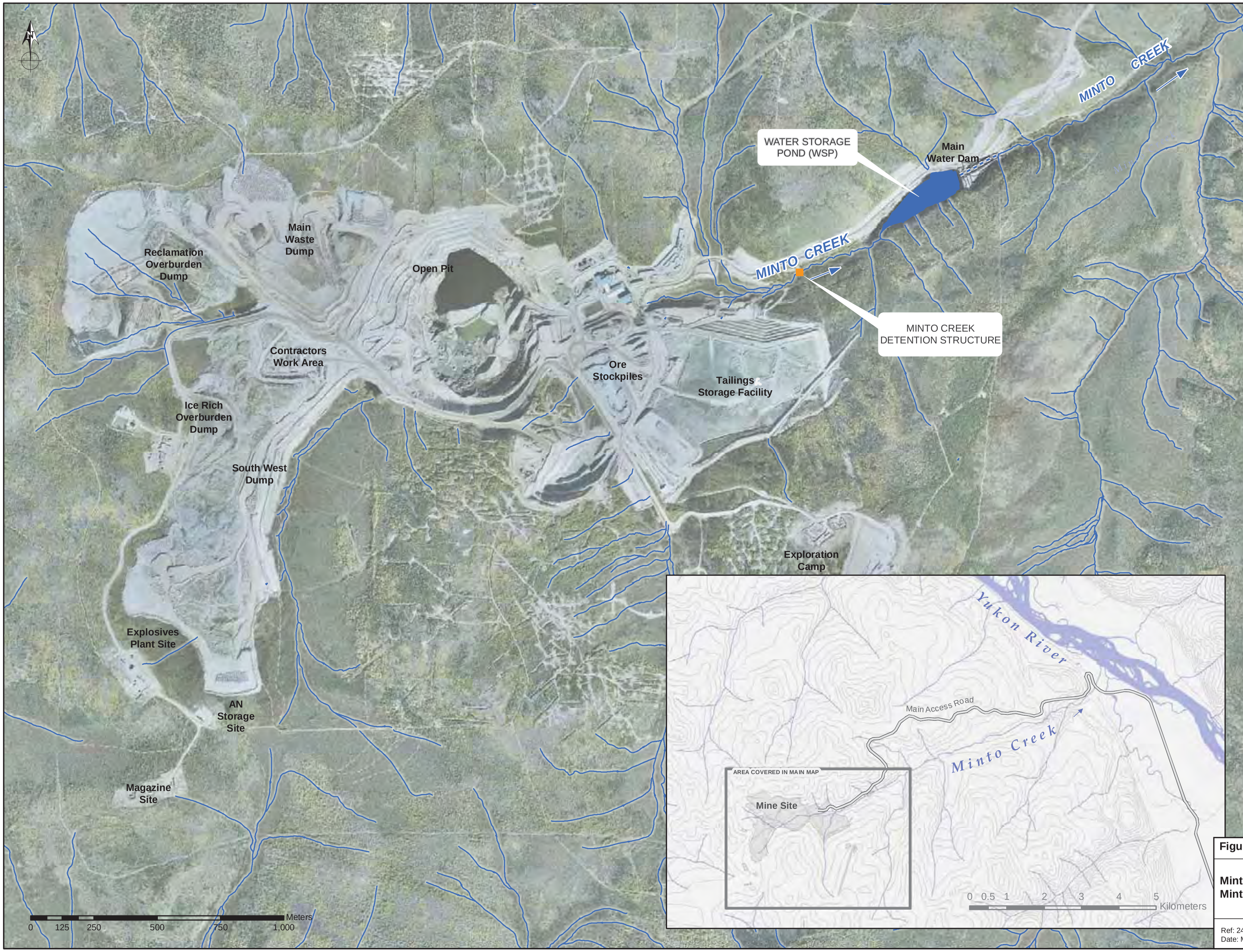
ACCESS CONSULTING GROUP

Figure 1.1

minnow environmental inc.

Location of the Minto Mine

Ref: 2461YWB - July 16, 2014 - QZ14-031
Date: March 2013
Source: Access Consulting Group



MINTO MINE

Minto Explorations Ltd.

Minto Creek Detention Structure
Watercourse
Intermittent Flow
Water Storage Pond

ACCESS

Aerial imagery obtained from Challenger Geomatics.
Imagery acquired September 9th 2011.
Hydrology data provided by Minto Explorations Ltd, May 2010.

Inset topography compiled by Natural Ressource Canada.

Projection : UTM Zone 8N
Datum: NAD 83

Figure 1.2

minnow

Minto Mine Site and Receiving Environment, Minto Mine WUL, 2013

Ref: 2461 YWB - July 16, 2014 - QZ14-031
Date: March 2013
Source: Access Consulting

2012). This influence was evident in conductivity and in concentrations of nitrate, sulphate, chloride, molybdenum and sodium that were greater in Minto Creek than at reference areas. During effluent discharge, concentrations of bromide and nitrite, and to a lesser extent, selenium and total Kjeldahl nitrogen (TKN), were also elevated in Minto Creek relative to reference concentrations. Although mean concentrations of a number of analytes were greater than water quality guidelines in Minto Creek over the 2009-2011 period, only nitrate and selenium were consistently greater than both guidelines and reference (Minnow/Access 2012).

The Minto Mine also implements annual biological monitoring under the WUL, which includes monitoring of sediment, periphyton, benthic invertebrates, fish and fish habitat. The biological monitoring program has been modified over time, but data from 1994 (baseline) and 2006-2011 have been reported previously. The sediment and benthic program conducted in September 2011 demonstrated that a few analytes measured in sediments of Minto Creek had concentrations that were greater than Interim Sediment Quality Guidelines (ISGQs) for the protection of aquatic life (Minnow 2012a). However, only copper in upper Minto Creek was elevated to concentrations greater than ISQGs, baseline and reference. In lower Minto Creek, no sediment analytes were elevated to concentrations greater than ISQGs, baseline and reference. Sediments of lower Minto Creek were also non-toxic to *Hyalella azteca* (an amphipod) and *Chironomus dilutus* (a midge larva). The periphyton community of lower Minto Creek differed from that of the reference creek (lower Wolverine Creek), but general taxonomic dominance was similar. Subtle differences in depositional benthic invertebrate community composition between Minto Creek and the reference area (lower Wolverine Creek) were apparent, but interpretation of erosional benthic community composition based on control-impact comparisons and the reference condition approach indicated no clear evidence of mine-related impact to the erosional benthic invertebrate community of lower Minto Creek.

1.3 Objectives

The objectives of this study and report are to characterize and interpret current sediment quality, the periphyton community and the benthic invertebrate community of Minto Creek relative to reference conditions and conditions documented in previous years. Additional data on the quality of biological tissues (periphyton, benthic invertebrates and slimy sculpin) are also reported. At the time of preparation of this report, periphyton community data were not available due to a backlog at the taxonomy laboratory. These data, and associated interpretation, will be provided under separate cover when they become available.

1.4 Report Overview

This report is presented in eight sections, the first of which is this introduction. Section 2.0 presents the methods used in sample collection, sample analysis and data analysis. Section 3.0 provides a description of the sampling areas and a summary of supporting physical and chemical data collected in the field. Section 4.0 provides the sediment quality results. Benthic invertebrate community results are presented in Section 5.0. Tissue chemistry results are presented in Section 6.0. Conclusions and recommendations of the study are provided in Section 7.0. All the references cited throughout this report are listed in Section 8.0.

2.0 METHODS

Minnow Environmental Inc. implemented the Minto Creek sediment, periphyton and benthic invertebrate community assessment from September 5th to 8th, 2012 with the assistance of Minto Mine staff. The study design was consistent with the design submitted to the Yukon Water Board in June 2011 in accordance with the Minto Mine Water Use Licence (QZ06-006 - Amendment 7). Sediment sampling was undertaken in upper Minto Creek, lower Minto Creek and corresponding reference areas (Table 2.1; Figure 2.1). Periphyton and benthic invertebrate community sampling were undertaken in erosional habitat of lower Minto Creek and a corresponding reference area (Table 2.1; Figure 2.1). Tissue sampling (periphyton, benthic invertebrate and slimy sculpin) was also undertaken in lower Minto Creek and corresponding reference areas (Table 2.1; Figure 2.1). Supporting measures (e.g., habitat characteristics, field meter measures, water quality samples, etc.) were collected at all sampling stations.

2.1 Supporting Measures

2.1.1 Field Collection

A number of environmental variables were measured to support the sediment quality, periphyton and benthic invertebrate community data collected for the Minto Creek assessment. The location of each station was recorded using a Geographic Positioning System (GPS) with coordinates recorded in latitudes and longitudes (degrees, minutes and decimal seconds using the North American Datum of 1983).

Supporting measures collected concurrent with sediment sampling (i.e., at depositional areas) included sediment redox potential, core penetration depth (lower creek areas only), sample texture, and the presence or absence of organic detritus. *In situ* measurements of temperature, dissolved oxygen, conductivity, and pH were also taken at each station using either a YSI 650 MDS (Multiparameter Display System) field meter equipped with a YSI 6600 Sonde (Yellow Springs Instruments, Yellow Springs, OH) or a Hanna 4M multiparameter meter (Woonsocket, RI).

At each periphyton and benthic invertebrate community station, *in situ* measurements were taken using a field meter (described above), water depth was measured using a meter stick and water velocity was measured using a Marsh-McBirney Flo-Mate 2000 portable flow meter (Marsh-McBirney Ltd., Frederick, MD). Creek wetted and bankfull widths were measured at each sampling station using a tape measure. Additional data collected to characterize each periphyton and benthic invertebrate sampling station

Table 2.1: Minto Mine Water Use License program summary, September 2012.

Area Type	Area	Station	Water	Sediment by Spoon [1]	Sediment by Hand Corer [2]	Periphyton Chlorophyll 'a'	Periphyton Community	Benthic Community by Hess Sampler [3]	Tissue Chemistry
Lower Creek Areas	Lower Minto Creek (Exposed)	LMC-1	X		X	X	X	X	X [4]
		LMC-2			X	X	X	X	
		LMC-3			X	X	X	X	
		LMC-4			X	X	X	X	
		LMC-5			X	X	X	X	
	Lower Wolverine Creek (Reference)	LWC-1	X		X	X	X	X	X [5]
		LWC-2			X	X	X	X	
		LWC-3			X	X	X	X	
		LWC-4			X	X	X	X	
		LWC-5			X	X	X	X	
	Lower Big Creek (Reference)	LWC-1	X						X [4]
		LWC-2							
		LWC-3							
		LWC-4							
		LWC-5							
Upper Creek Areas	Upper Minto Creek (Exposed)	UMC-1	X	X					
		UMC-2		X					
		UMC-3		X					
		UMC-4		X					
		UMC-5		X					
	Upper McGuinty Creek (Reference)	URC-1	X	X					
		URC-2		X					
		URC-3		X					
		URC-4		X					
		URC-5		X					

[1] top 2 centimeters collected; minimum 3-grab composite
[2] top 2 centimeters collected; 3-grab composite
[3] 500 um mesh; 3-grab composite
[4] periphyton, benthic invertebrates and slimy sculpin; target sample sizes 5, 5 and 8, respectively.
[5] periphyton and benthic invertebrates; target sample sizes 5 and 5, respectively.

3,000 0 3,000
Meters

MAP INFORMATION
Map Projection: NAD 1983
Data Source: Department of Natural Resources Canada. All rights reserved.
Created By: J.Wilson
Creation Date: March 2013
Project No.: 2461

Features

Mine Site

SAMPLES COLLECTED

- Water
- Sediment
- Periphyton
- Benthos
- Fish

- Water Quality Station
- Fish Barrier
- Water Flow
- Contours (30m interval)
- Roads

Figure 2.1: Monitoring Areas for the Minto Creek Sediment, Periphyton, and Benthic Invertebrate Community Assessment – 2012

Created by:
minnow environmental inc.

included: elevation, gradient, water appearance, creek morphology, bank condition, substrate texture, instream cover, residual pool depth, instream features, overhead canopy, aquatic vegetation, riparian vegetation, surrounding land use and anthropogenic disturbance. In addition, at each benthic invertebrate station, the intermediate axis length of 100 rocks that were washed during the benthic invertebrate sampling were measured and recorded, and the percent embeddedness of ten randomly selected rocks was also evaluated and recorded. This type of substrate characterization is similar to the Canadian Aquatic Biomonitoring Network (CABIN) protocol (CABIN 2010) for characterizing benthic invertebrate habitat and provided additional information to assess and standardize habitat conditions among sampling stations. Summary statistics of intermediate axis lengths were calculated for each station including the median and geometric mean as per CABIN protocol.

Water samples for chemical analysis were collected at each periphyton and benthic sampling area. Samples were collected into pre-labeled sample bottles that were triple rinsed and preservatives were added to the sample bottles, as required. Water samples for dissolved organic carbon (DOC) and for dissolved ICP-MS (Inductively Coupled Plasma-Mass Spectrometry) analytes were filtered in the field using 0.45 µm polypropylene filters.

The productivity of lower Minto Creek and lower Wolverine Creek was evaluated through measurements of chlorophyll *a*, in addition to collection of periphyton (Section 2.3), at each periphyton and benthic station. Chlorophyll *a* is the primary photosynthetic pigment of all oxygen-evolving photosynthetic organisms (Wetzel 2001) and therefore provides an indicator of the standing stock of photosynthetic organisms representing the lowest trophic level. In 2012, chlorophyll *a* was measured in periphyton instead of water. Minto Creek is a lotic system, so measuring chlorophyll *a* in periphyton is considered to be more representative of productivity. A stainless steel razor blade was used to scrape periphyton from rocks and transfer it to labeled sampling jars. The surface area sampled at each station was carefully recorded. All samples were maintained in coolers with ice packs during transportation and then at 4°C in a refrigerator on site until submission to the ALS Group Environmental Laboratory (ALS; Whitehorse, Yukon). Chlorophyll a samples arrived at the laboratory within one day of collection.

2.1.2 Data Analysis

Water chemistry data quality was assessed prior to data analysis and interpretation, and was judged to be acceptable (Appendix A). Water quality of Minto Creek was evaluated relative to WUL standards, concentrations measured in reference areas, applicable water quality guidelines, and previous water quality (e.g., water quality results included in previous annual reports).

Supporting field measures (temperature, dissolved oxygen, pH and specific conductivity) and chlorophyll *a* results were tested for differences in the lower creek areas using by t-testing. Prior to t-testing, data were transformed as necessary to meet assumptions of normality and homogeneity of variance. Statistical comparisons were conducted using SPSS software (SPSS 2011). Creek productivity was also characterized by comparing chlorophyll *a* concentration against the Dodds et al. (1998) classification system for temperate streams.

2.2 Sediment Quality

2.2.1 Sample Collection and Laboratory Analysis

Sediment samples were collected for analysis of particle size and for chemical analysis at depositional areas within Minto Creek and reference creeks (Table 2.1; Figure 2.1). At lower Minto Creek and lower Wolverine Creek, sediment samples for particle size analysis were collected using a 15.24 cm x 15.24 cm (6" x 6") stainless steel ponar grab (0.023 m^2 sampling area). A composite sample was created by collecting the surficial two centimeters of sediment from each of three acceptable grabs (i.e., full to each edge of the sampler) using a stainless steel spoon. Sediment samples for physical characterization were then placed into pre-labeled 500 mL PET (polyethylene) jars. Sediment samples for chemical analyses were collected using a 4.7 cm (2") (inside diameter) Lexan® core tube, which was carefully inserted into sediment deposits, capped using a fitted plastic cap and retrieved by hand. From each acceptable core (i.e., each core containing an intact, representative sediment-water interface), the surficial two centimeters of sediment was manually extruded upwards into a graded core collar, cut with a stainless steel core knife, and placed into a pre-labeled 250 mL glass jar. Samples from three cores treated in this manner were composited to form a single sample from each station. At upper Minto Creek and upper McGinty Creek, sediment deposits were rare and were typically very shallow (i.e., deposits were less than three centimeters in depth). Accordingly, collection by ponar or by coring, as described above, was not effective in the upper creek areas and sediments were collected using a stainless steel spoon. Specifically, at locations of sediment deposition, surficial sediment was carefully collected by slowly spooning the sediment into a sample jar, with care taken to avoid the loss of fine material. In order to be as consistent as possible with the sediment collected in the lower Creek areas, samples included only the top 2 centimeters of deposited sediment. Immediately after collection, sediment samples were placed in a cooler, and later placed in a refrigerator at approximately 4°C until they were submitted to the ALS Group Environmental Laboratory in Burnaby, BC, for analysis of particle size, total organic carbon, metals (by ICP-MS and ICP-OES [Inductively Coupled Plasma-Mass Spectrometry and Inductively Coupled Plasma-Optical Emission Spectroscopy] scans) and mercury.

2.2.2 Data Analysis

Sediment data quality was assessed prior to data analysis and interpretation, and was judged to be acceptable (Appendix A). Sediment quality data were evaluated relative to sediment quality guidelines (SQGs) for the protection of aquatic life (e.g., CCME 1999) and reference concentrations to identify metals with the potential to adversely affect aquatic life and/or whose concentrations were elevated due to mine activity. Sediment quality data were also evaluated by comparison to results obtained in previous years of sampling (1994 and 2006-2011). However, interpretation was conducted with careful consideration of a significant methodological change made in 2010 and carried through to 2012 (sediments collected as described above) relative to previous years. When calculating descriptive statistics and a value was reported as less than method detection limit (i.e., <0.1 mg/kg) a value of the method detection limit (i.e., 0.1 mg/kg) was used for calculation purposes. Sediments collected in all years previous to 2010 were collected within the active channel of the creek using an aluminum or Teflon scoop. Samples were submitted whole for analysis of particle size distribution, which generally included significant quantities of gravel and sand. Only material passing through a 230 mesh sieve (<63 um; silt and clay) was digested and analyzed for metals. While this approach does result in the analysis of geochemically-relevant fine sediment (e.g., Horowitz 1991), it represents an impediment to the interpretation of the biological significance of sediment chemistry as organisms are exposed to whole sediment, and sediment quality guidelines (SQGs) for the protection of aquatic life (e.g., CCME 1999) apply to whole sediment.

2.3 Periphyton Community

2.3.1 Sample Collection and Laboratory Analysis

Periphyton is the assemblage of algae, bacteria, fungi, and meiofauna attached to submerged substrate in freshwaters. However, periphyton communities are generally characterized on the basis of the attached algae community. Attached algal communities are representative of the lowest trophic level and are indicators of productivity. Periphyton was collected from randomly selected rocks at each station with the use of a stainless steel razor blade. The surface area sampled was inversely proportional to the periphyton coverage in order to provide a consistent sample weight for analysis (2-5 grams). Samples were preserved with Lugol's iodine solution and shipped to Fraser Environmental Services (Surrey, BC) for analysis to species/variant level.

2.3.2 Data Analysis

Data from Fraser Environmental Services laboratory are pending due to a backlog. Use of an alternate lab may be explored next year. An update letter report will be provided once data are available.

2.4 Benthic Invertebrate Community

2.4.1 Sample Collection and Laboratory Analysis

Benthic invertebrate community samples were collected in erosional habitat of lower Minto Creek and lower Wolverine Creek as required under the WUL. Benthic invertebrate community samples were collected from riffle/run habitat with cobble and gravel substrate using a Hess sampler (0.1 m^2) outfitted with 250 µm mesh. Five replicate samples were collected at each monitoring location and consisted of a three-grab composite (0.3 m^2 of bottom area in total). For each grab, the substrate within the sampler was disturbed and scrubbed (by hand and nail brush) with care taken to ensure that all dislodged organic material was swept into the sampler collection net. The substrate was disturbed to a depth of approximately 10 cm over a period of approximately five minutes. This procedure was repeated for the second and third grab, following which all of the material contained in the collection net was carefully transferred to a pre-labeled 2 litre wide-mouth plastic jar using a stainless steel spoon and a wash bottle while working over a plastic tub to avoid any potential loss of organisms. Any organisms that adhered to the sieve bag were removed by hand and added to the sample. All samples were labeled internally (using wooden sticks) and externally with the station number, area identifier, Minnow project number, date and field personnel in order to ensure correct identification at the laboratory. Samples were preserved within six hours of collection using buffered formalin solution to a nominal concentration of 10% in ambient water.

All benthic invertebrate samples were shipped to Cordillera Consulting in Summerland, BC. At the laboratory, samples were split using sieves to allow separate evaluation of >250 µm and >500 µm size fractions. Each sample was elutriated to remove sand, gravel and clay, and the remaining organic material was preserved in 70% ethanol. The elutriate was examined for any mollusc or trichopteran cases then each sample was examined to estimate the total number of invertebrates. If the estimated number was greater than 600 individuals and the sample was fine and non-clumping, a subsample was taken using a

Folsom Plankton Splitter (Motodo 1959; Van Guelpen et al. 1982). Empty snail or bivalve shells, empty caddisfly cases, invertebrate fragments such as legs, gills, antennae etc. were not removed or counted. When organism fragments were encountered, only the heads were counted towards the total. Larval and pupa exuviae were not counted while terrestrial stages and terrestrial drop-ins were indicated as such and do not contribute to the total count. Benthic invertebrates were identified to the "lowest practicable taxonomic level" (which in most cases was genus) and counted. Following identification and counting, representative specimens of each taxon were preserved in a museum quality vial with a polyseal lid to create a voucher collection. The interior labels were used to identify the taxa, the client, date collected, site code and the project. Laboratory quality assurance/quality control (QA/QC) included an assessment of sub-sampling error and sorting efficiency on at least 10% of the samples.

2.4.2 Data Analysis

Benthic invertebrate community data quality was assessed prior to data analysis and interpretation, and was judged to be acceptable (Appendix A). Benthic invertebrate communities were evaluated using summary metrics including invertebrate density (number of organisms per m^2 calculated based on a sample area of 0.3 m^2), number of taxa, Simpson's Diversity, Simpson's Evenness and Bray-Curtis Index. For each benthic invertebrate sample, total organism density (individuals/m^2) was calculated. The diversity metric "number of taxa" (also known as taxon richness) included all separate taxa identified to the species/variant level, excluding any organisms that could not be conclusively identified as separate taxa. Simpson's Diversity ("D") and Simpson's Evenness ("E") indices were computed according to formulae presented by Smith and Wilson (1996) and recommended by Environment Canada (2012). These indices take into account both the relative abundance of taxa, and the number of taxa, with values ranging from 0 (low diversity or evenness) to 1 (high diversity or evenness). Bray-Curtis (B-C) index was also calculated according to Environment Canada (2012). This metric takes into account the abundance of each taxon at each station compared to the median abundance computed from the reference stations (lower Wolverine Creek), to compute an index of the relative "dissimilarity" of each station from the hypothetical reference median station. Larger B-C index values indicate greater dissimilarity from reference.

The relative proportions of the most abundant taxa were calculated relative to the total number of organisms in the sample. Dominant taxon groups were defined as those groups representing greater than 10% of total organism abundance in one or more areas or any groups considered to be important indicators of environmental stress. In this study, relative proportions of oligochaetes (worms), chironomids (non-biting midges), nematans (roundworms), and EPT taxa (Ephemeroptera [mayfly], Plecoptera [stonefly], Trichoptera [caddisfly] taxa) were examined. It is often possible to relate low relative abundance of sensitive taxonomic groups (e.g., EPT taxa) to environmental stress (e.g., Taylor and Bailey 1997). Similarly, high relative abundance of tolerant taxonomic groups (e.g., oligochaetes) may indicate higher environmental stress (Chapman et al. 1982a; 1982b).

All benthic invertebrate community endpoints were summarized by reporting mean, median, minimum, maximum, standard deviation, standard error and sample size for each study area. Differences among effluent-exposed and reference areas were tested using ANOVA. Prior to ANOVA, all data were transformed as necessary to meet assumptions of normality and homogeneity of variance. All statistical comparisons were conducted using SPSS software (SPSS 2011). Following the statistical comparisons, the magnitude of difference between effluent-exposed and reference area means was calculated for each benthic invertebrate community metric where a significant difference was detected. If a significant difference between areas was not detected, then the minimum effect size that could be detected was calculated.

Community structure was also assessed by examining the proportions of key taxonomic groups using a multivariate ordination technique known as Correspondence Analysis (CA). CA is used to calculate axes, which can be thought of as new variables summarizing variation in the relative abundance of benthic taxa. When depicted in two-dimensional plots, taxa that tend to co-occur will have similar CA axis scores and will plot together, while those that rarely co-occur plot farther apart. Similarly, stations sharing many taxa plot closest to one another, while those with little in common plot farther apart. The greatest variation among either taxa or stations is explained by the first axis, with other axes accounting for progressively less variation. This type of multivariate analysis describes not only which stations have distinct benthic communities but also how these benthic communities differ among stations (i.e., which particular taxa differ). CA is influenced by rare species, so those taxa occurring at only one of the ten stations were removed. After screening and data reduction, abundances were log (x+1) transformed. Scores for both stations and taxa were calculated using the ADE-4 package (Thioulouse et al. 1997) to evaluate the associations of organisms and stations.

Benthic invertebrate community data were also evaluated in comparison to results obtained in previous years of sampling (1994, 2006, 2008, 2010 and 2011). Prior to making comparisons, summary metrics from earlier years were re-calculated (Minnow 2011) to ensure consistency and appropriate comparisons over time.

2.5 Tissue Chemistry

2.5.1 Sample Collection and Laboratory Analysis

Periphyton and benthic invertebrate samples were collected from lower Minto Creek (exposed), lower Wolverine Creek (reference) and lower Big Creek (reference), and slimy sculpin samples were collected from lower Minto Creek (exposed), lower Wolverine Creek (reference; Table 2.1; Figure 2.1). Periphyton samples were collected by scraping submerged cobble-size rocks using a stainless steel razor blade. A total of five samples were targeted per area, but due to very low periphyton coverage at lower Minto Creek and lower Big Creek, only one sample could be obtained from these areas. Scraped material (periphyton) was placed in pre-labelled sample jars. Benthic invertebrate tissue samples were collected in areas with cobble substrate using a kick-net and by overturning rocks and collecting organisms by hand. A total of five samples were targeted per area, but due to very low productivity, only one sample could be obtained per area. Benthic invertebrate samples were placed into pre-labelled Whirl-Pak™ bags until the desired sample size (2-5 grams) was achieved. Slimy sculpin tissue samples were collected by the Access Consulting Group using a Smith-Root LR-24 battery-powered backpack electrofisher. The operator was supported by a dip netter dedicated to capturing fish shocked by the electrofisher. Upon capture, fish were placed in buckets containing aerated water. At the completion of each electrofishing run, total shocking time was recorded. Slimy scuplin were then dispatched followed by measurement of length using digital calipers, weight using a portable electronic balance and removal of head for ageing. The remaining headless carcasses were placed into pre-labelled Whirl-Pak™ bags.

Immediately after collection, all tissue samples were placed in a cooler, and later in a freezer until they were submitted to the ALS Laboratory Group in Burnaby, BC. Samples were analyzed for wet and dry weight for metals by High-Resolution ICP-MS.

2.5.2 Data Analysis

The primary objective of the tissue collections was to support a selenium assessment reported under separate cover (Minnow 2013). Accordingly, data are reported within this report for future reference with limited interpretation. Data interpretation was limited to qualitative comparison of metal concentration in samples collected from lower Minto Creek to those collected from reference creeks. Only were slimy sculpin collected at a level of replication (n=7) sufficient to support statistical analysis and these data were interpreted by statistically comparing metal concentrations in fish collected at the exposed area to those collected at the reference area using the student's t-test.

3.0 SUPPORTING MEASURES

3.1 Field Measures

Mean temperature in lower Minto Creek (5.7°C) was significantly higher than in lower Wolverine Creek (4.1°C; Figure 3.1; Appendix Table B.3). Specific conductance followed a gradient from the mine downstream and was slightly greater in upper Minto Creek (285 μS/cm) than in lower Minto Creek (207 μS/cm). Water in all areas was well oxygenated with a slightly alkaline pH; both dissolved oxygen and pH were well within water quality guidelines as well as the WUL standard for pH.

3.2 Water Chemistry and Chlorophyll *a*

At lower Minto Creek five analytes (aluminum, cadmium, chromium, copper and iron) were present at concentrations that did not meet guidelines and WUL standards. Furthermore, total suspended solids (TSS) concentration was greater than guideline levels and total phosphorus was at concentrations greater than the WUL standard (Table 3.1). Concentrations of phosphorus and iron were higher than WUL standards at the reference area, upper McGinty Creek. Since phosphorus concentration was greater than guidelines at both reference and exposure areas it appears to be naturally elevated. The analytes noted above also tend to be positively correlated with TSS (Minnow 2012b). Concentrations of TSS were greater than guideline levels at both lower Minto Creek and lower Wolverine Creek but levels at lower Minto Creek were considerably elevated above guidelines (Table 3.1). Of the analytes greater than water quality guidelines, only concentrations of cadmium and copper were also greater than reference (lower Wolverine Creek. Conversely, fluoride was the only analyte with concentrations greater than guidelines in reference areas and not at the exposure areas, indicating natural elevation due to differences in source geology. Interestingly, the water quality of upper Minto Creek was better than the water quality of lower Minto Creek, indicating that the Minto Mine had a limited influence on water quality at the time of sampling.

Comparisons of analyte concentrations that were higher than WUL standards and/or guidelines in the receiving environment in 2012 against 2011 data (Minnow 2012) indicate that mean TSS, aluminum, chromium and iron concentrations were higher in lower Minto Creek in 2012 than in 2011 (Appendix Table B.6). Concentrations of aluminum, chromium and iron were likely relatively elevated in 2012 because of the elevated levels of TSS in lower Minto Creek. Copper and cadmium concentrations were greater than guidelines in 2012 in lower Minto Creek but were not in 2011 and this could be due to the fact TSS

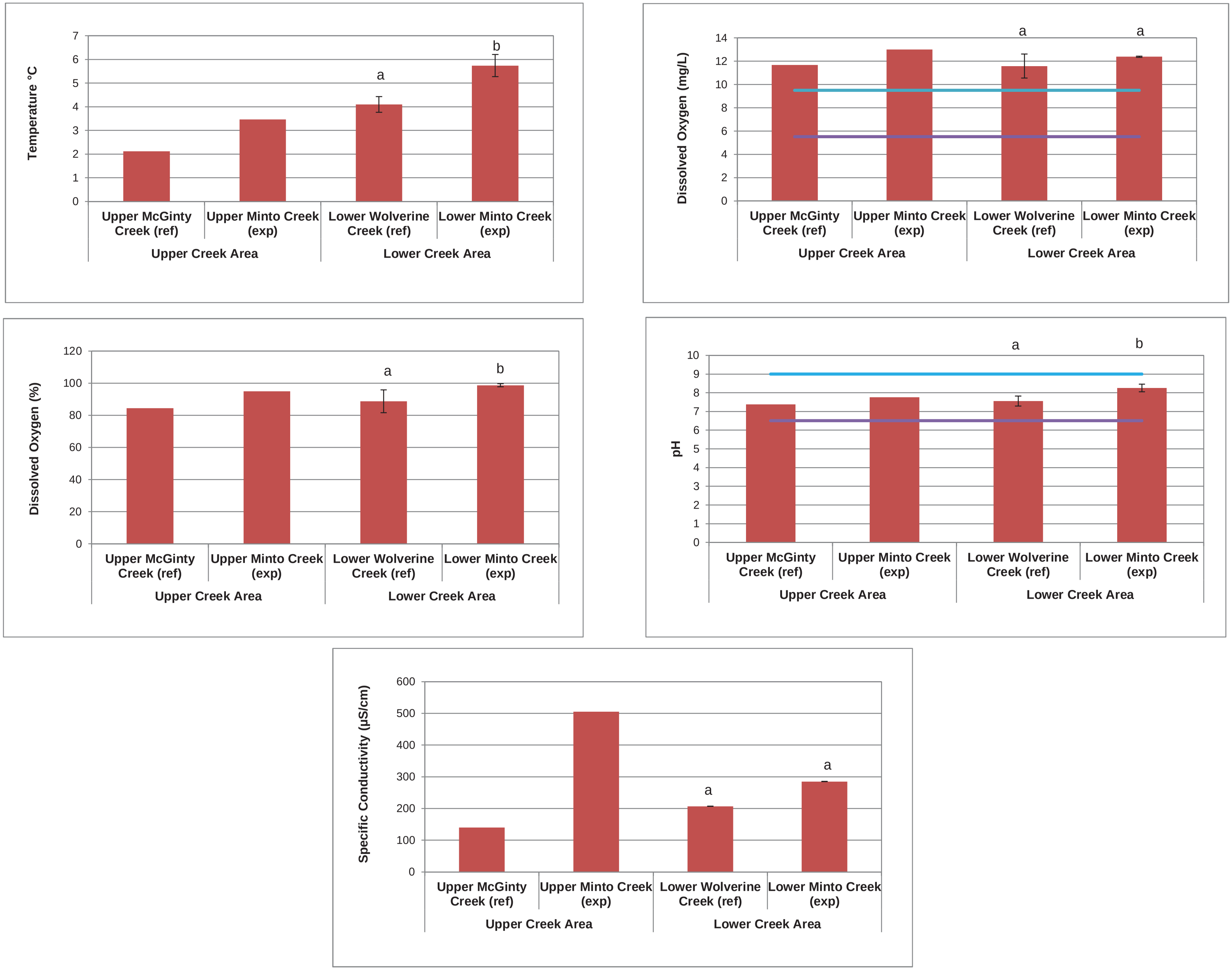


Figure 3.1: Physico-chemical measurements in depositional areas of upper and lower Minto Creek relative to reference areas. Data presented as mean ± standard deviation. Sample sizes were n = 5 in lower areas and n = 1 in upper areas.

Table 3.1: Water quality results at exposure and reference, Minto Mine WUL, September 2012.

	Analyte	Units	CCME Water Quality[a]		WUL Limits at W2	Lower Minto Creek (exposure)	Lower Wolverine Creek (reference)	Upper Minto Creek (exposure)	Upper McGinty Creek (reference)	Lower Big Creek (reference)
			30	Max						
Physical Tests	Conductivity	µS/cm	-	-	-	275	197	482	139	191
	Hardness (as $CaCO_3$)	mg/L	-	-	-	146	104	239	78	92
	pH	ph Units	-	-	6.0 - 9.0	8.25	8.00	7.97	7.93	8.14
	Total Suspended Solids	mg/L	17.7	-	-	425.0	22.0	< 3.0	4.7	12.7
	Total Dissolved Solids	mg/L	-	-	-	158	123	253	92	116
	Turbidity	NTU	6.85	-	-	-	6.11	-	3.58	-
Anions and Nutrients	Anion Sum	meq/L	-	-	-	2.82	2.06	4.72	1.44	2.06
	Cation Sum	meq/L	-	-	-	3.29	2.40	5.65	1.80	2.21
	Cation - Anion Balance	%	-	-	-	7.8	7.6	9.0	11.2	3.5
	Alkalinity, Total	mg/L	-	-		140	87	223	64	91
	Ammonia, Total (as N)	mg/L	0.5		0.35	0.036	0.010	< 0.005	0.007	< 0.005
	Chloride (Cl)	mg/L	120	640	-	< 0.5	< 0.5	< 0.5	< 0.5	0.8
	Fluoride (F)	mg/L	0.12	-	-	< 0.02	0.13	0.06	0.23	0.15
	Nitrate (as N)	mg/L	13	550	2.9	< 0.005	< 0.005	0.097	< 0.005	0.079
	Nitrite (as N)	mg/L	0.197	-	0.06	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	Phosphorus (P)-Total dissolved	mg/L	-	-	-	-	0.021	-	0.033	-
	Phosphorus (P)-Total	mg/L	-	-	0.02	0.298	0.032	0.005	0.031	0.014
	Sulfate (SO4)	mg/L	-	-	-	0.7	15.6	12.2	7.1	10.4
Other	Cyanide, Total	mg/L	-	-	-	-	< 0.005	-	< 0.005	-
	Cyanide, Free	mg/L	0.005	-	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	Dissolved Organic Carbon	mg/L	-	-	-	11.3	13.1	6.2	11.6	9.3
	Total Organic Carbon	mg/L	-	-	-	13.2	13.8	5.9	13.3	9.8
Total Metals	Total Aluminum (Al)	mg/L	0.1	-	0.62	6.76	0.56	0.01	0.11	0.30
	Total Antimony (Sb)	mg/L	-	-	-	0.0003	0.0002	< 0.0001	0.0002	0.0002
	Total Arsenic (As)	mg/L	0.005	-	0.005	0.0045	0.0009	0.0003	0.0012	0.0014
	Total Barium (Ba)	mg/L	-	-	-	0.242	0.053	0.083	0.048	0.071
	Total Beryllium (Be)	mg/L	-	-	-	0.0003	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Total Bismuth (Bi)	mg/L	-	-	-	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
	Total Boron (B)	mg/L	1.5	2.9	-	0.01	0.01	0.03	< 0.01	0.01
	Total Cadmium (Cd)	mg/L	0.00004	-	0.00004	0.00012	0.00002	< 0.00001	< 0.00001	0.00001
	Total Calcium (Ca)	mg/L	-	-	-	45.3	22.2	55.7	20.3	23.6
	Total Chromium (Cr)	mg/L	0.001 Cr(VI)	-	0.002	0.0126	0.0020	0.0002	0.0013	0.0008
	Total Cobalt (Co)	mg/L	-	-	-	0.0050	0.0005	< 0.0001	0.0005	0.0002
	Total Copper (Cu)	mg/L	0.003	-	0.013	0.017	0.003	0.002	0.002	0.003
	Total Iron (Fe)	mg/L	0.3	-	1.1	11.80	0.97	0.02	1.46	0.49
	Total Lead (Pb)	mg/L	0.005	-	0.004	0.00314	0.00021	< 0.00005	0.00006	0.00018
	Total Lithium (Li)	mg/L	-	-	-	0.0051	0.0019	0.0025	< 0.0005	0.0013
	Total Magnesium (Mg)	mg/L	-	-	-	14.4	11.5	25.1	5.9	9.5
	Total Manganese (Mn)	mg/L	-	-	-	0.42	0.05	0.05	0.14	0.03
	Total Mercury (Hg)	mg/L	-	-	-	0.00002	< 0.00001	< 0.00001	< 0.00001	< 0.00001
	Total Molybdenum (Mo)	mg/L	0.073	-	0.073	0.0013	0.0007	0.0049	0.0011	0.0011
	Total Nickel (Ni)	mg/L	0.12	-	0.11	0.014	0.003	0.001	0.002	0.002
	Total Phosphorus (P)	mg/L	-	-	-	0.41	< 0.05	< 0.05	< 0.05	< 0.05
	Total Potassium (K)	mg/L	-	-	-	1.67	0.90	2.19	0.48	0.84
	Total Selenium (Se)	mg/L	0.001	-	0.001	0.0003	0.0002	0.0004	0.0003	< 0.0001
	Total Silicon (Si)	mg/L	-	-	-	19.20	6.77	5.71	6.93	7.49
	Total Silver (Ag)	mg/L	0.0001	-	-	0.00006	0.00017	< 0.00001	0.00001	< 0.00001
	Total Sodium (Na)	mg/L	-	-	-	7.59	6.98	18.70	3.94	7.48
	Total Strontium (Sr)	mg/L	-	-	-	0.351	0.187	0.611	0.120	0.250
	Total Thallium (Tl)	mg/L	0.0008	-	-	0.00006	< 0.00001	< 0.00001	< 0.00001	< 0.00001
	Total Tin (Sn)	mg/L	-	-	-	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Total Titanium (Ti)	mg/L	-	-	-	0.22	0.02	< 0.01	< 0.01	0.01
	Total Uranium (U)	mg/L	0.015	0.033	-	0.0015	0.0007	0.0028	0.0003	0.0019
	Total Vanadium (V)	mg/L	-	-	-	0.023	0.003	< 0.001	0.002	0.002
	Total Zinc (Zn)	mg/L	0.03	-	0.03	0.026	0.003	< 0.003	< 0.003	< 0.003

Water use licence standard not met

Water quality guideline not met

[a] CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. 1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg. See Appendix Table B.5 for explanatory notes on selected water quality guidelines.

concentrations were much greater in 2012 than in 2011 and/or because there was discharge from the WSP in 2012 but not in 2011 (Appendix Table B.6). Total phosphorus was above WUL standards in both 2011 and 2012 at both exposure and reference areas.

In 2012, chlorophyll *a* concentration was measured in periphyton whereas in previous years it was measured in water. Concentration of chlorophyll *a* was lower at lower Minto Creek than at lower Wolverine Creek but the difference was not statistically significant (Figure 3.2). The observed difference was likely due to greater light penetration to the substrate at lower Wolverine Creek than with water quality. Chlorophyll *a* concentrations at both areas were well below the British Columbia Water Quality Guideline of 100 mg/m^2 for the protection of aquatic life (BCMOE 1985). The production of both creeks could be considered low (oligotrophic) based on the classification by Dodds et al. (1998) which sets the oligotrophic-mesotrophic boundary for benthic chlorophyll at 20 mg/m^2. This differs from the classification based on only total phosphorus which would define both areas as mesotrophic (Dodds et al. 1998). The lower concentrations of chlorophyll *a* despite relatively high phosphorus may be due to environmental factors associated with a northern system such as low water temperatures and a short growing season.

3.3 Summary

Temperature and specific conductivity were higher at the exposure areas (upper and lower Minto Creek) than at the reference areas (upper McGinty Creek and lower Wolverine Creek). Other field water quality measures (dissolved oxygen and pH) were similar at the exposure and reference areas. Conditions observed in 2012 were generally consistent with those observed in 2011.

Overall, water quality results demonstrated that seven analytes (phosphorus, TSS, aluminum, cadmium, chromium, copper, and iron) did not meet WUL standards and/or water quality guidelines in at least one exposure area. Phosphorus was higher than the WUL standard in lower Minto Creek and reference areas suggesting naturally elevated concentrations and indicating that the WUL standard is not appropriate. Total suspended solids at lower Minto Creek in 2012 were much higher than in any other sampling year and could explain why aluminum, chromium and iron were elevated in 2012 at lower Minto Creek (Minnow 2010c; Minnow 2012a). A key finding was that, in lower Minto Creek, only cadmium and copper were greater than both guidelines/standards and reference concentrations. Furthermore, at the time of sampling in 2012, the water quality of upper Minto Creek was better than the water quality of lower Minto Creek, indicating that the Minto Mine had a limited influence on water quality at that time. Differences in chlorophyll

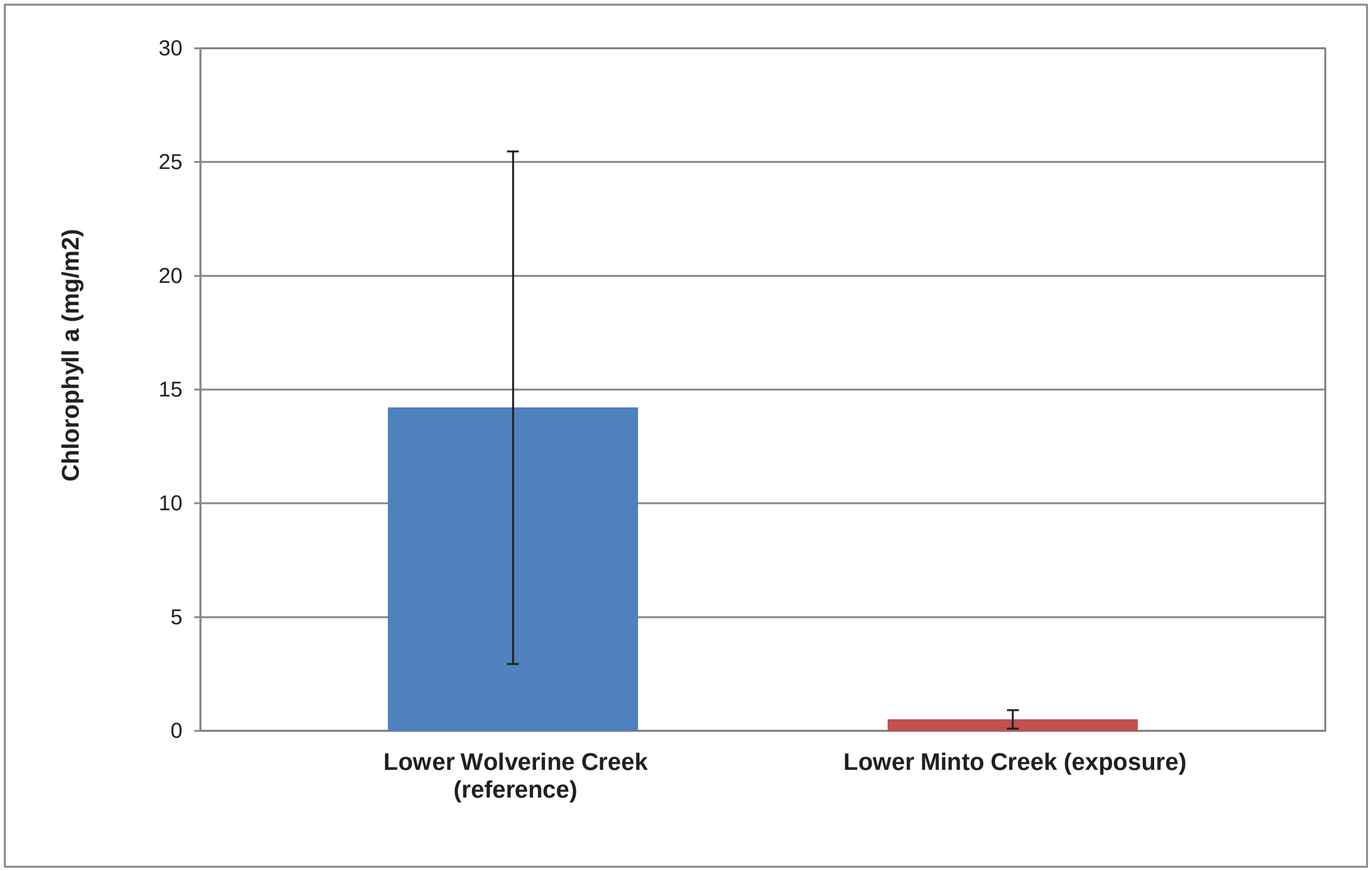


Figure 3.2: Concentrations of chlorophyll *a* in periphyton measured at five benthic stations in lower Wolverine and lower Minto Creeks, Minto Mine WUL, 2012. Data presented as mean ± standard deviation.

a between areas were likely not related to water quality but rather to natural differences. Regardless, the concentrations of chlorophyll a found at both areas were well below the guideline of 100 mg/m^2 for the protection of aquatic life and both indicate low productivity (oligotrophic) based on the classification system of Dodds et al. (1998).

4.0 SEDIMENT QUALITY

4.1 Sediment Particle Size and Chemistry

Sediments collected in 2012 were largely composed of fine particles in the silt/clay and sand size categories (Figure 4.1; Appendix Table C.1). Mean total organic carbon content of sediment collected from lower Minto Creek was approximately three times greater than in lower Wolverine Creek (Table 4.1). Arsenic and copper were the only analytes with mean concentrations greater than the Interim Sediment Quality Guideline (ISQG; CCME 1999) in an exposure area (upper and lower Minto Creek; Table 4.1; Appendix Table C.1). However, arsenic was also greater than ISQG at reference areas indicating that levels might be natural. Therefore, only mean copper concentrations at upper Minto Creek were greater than ISQG and reference, indicating a mine related influence on sediment quality at a concentration with the potential to adversely affect aquatic life. Mean chromium concentration was higher than the applicable ISQG, but only in the reference area of lower Wolverine Creek.

Due to the predominantly erosional habitat in upper Minto Creek, there are relatively few areas where sediment is deposited and this only in small quantities that likely wash away each year during freshet. Therefore, elevated sediment copper in fine sediment in the upper reaches of Minto Creek may be of limited importance in terms of exposure and potential toxicity to biota. In lower Minto Creek where fine sediment deposits were more common, sediment metal concentrations were below sediment quality guidelines and/or reference concentrations.

4.2 Temporal Comparisons

Sediment particle size distribution in 2012 was similar to 2010 and 2011 but was notably different from earlier sample year data (Figure 4.1). The disparity between 2010-2012 and 1994-2009 data reflects the change in sediment sampling methodology initiated in 2010 (Minnow 2011). Mean analyte concentrations higher than guideline in Minto Creek were compared to earlier data to detect any increasing or decreasing trends in sediment quality. In 2011, arsenic was elevated above guideline at all areas whereas in 2012 it was elevated at all areas except for upper Minto Creek (Figure 4.2). Chromium was again elevated at the reference area, lower Wolverine Creek, but not at other areas. Copper was greater than the guideline in 1994 and continued to be elevated above the guideline in 2012 in upper Minto Creek but not at lower Minto Creek (Figure 4.3; Table 4.1; Appendix Table C.1). Lower concentrations of copper at lower Minto Creek relative to

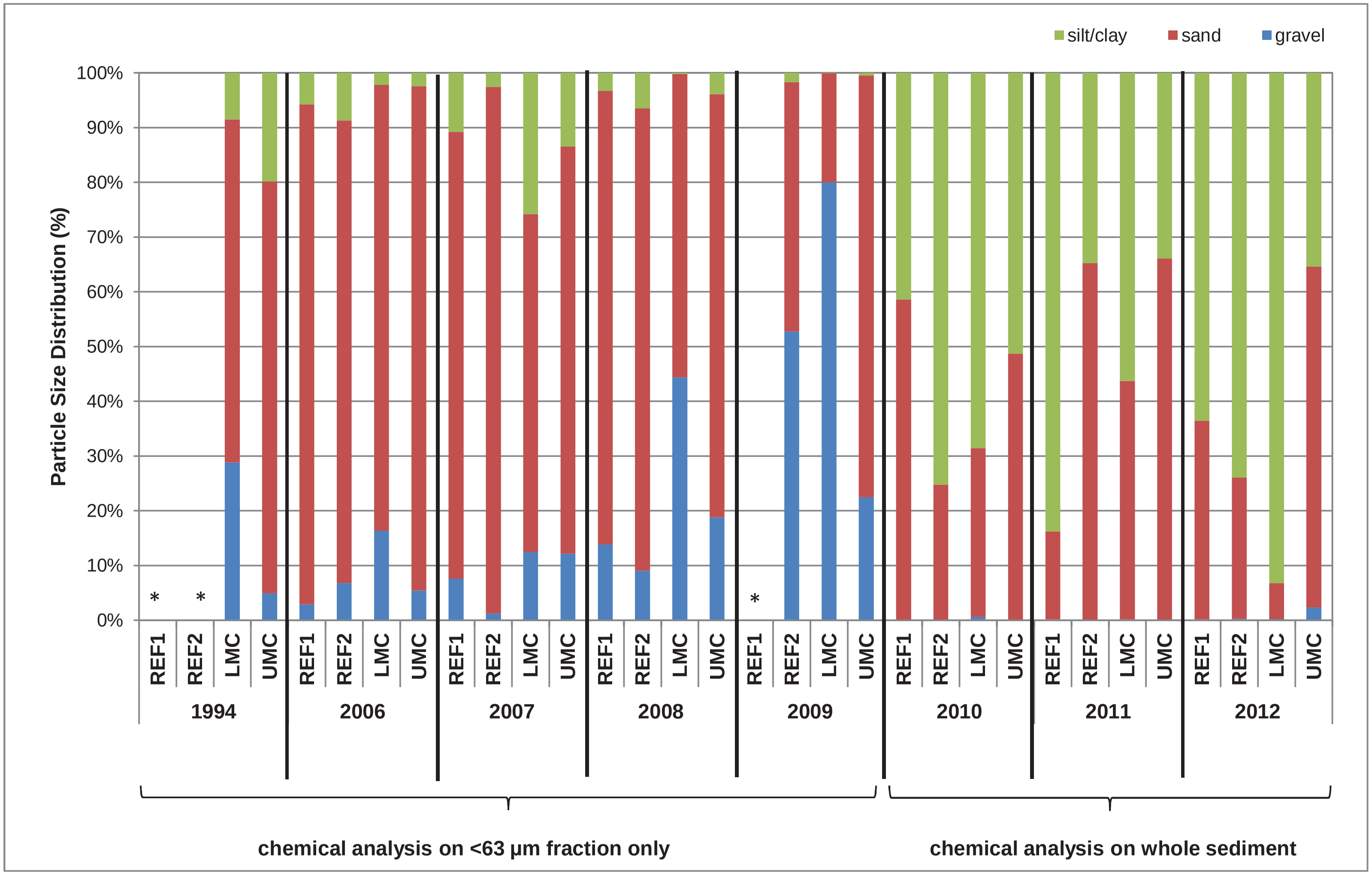


Figure 4.1: Particle size distribution of sediment collected in Minto Creek and reference locations, 1994 - 2012[1]

[1] UMC = Upper Minto Creek; LMC = Lower Minto Creek; REF1 = Station W6 (south-flowing tributary) in 2006 to 2008 and McGinty Creek in 2010 to 2012; REF2 = Station W7 (north-flowing tributary) in 2006 to 2009 and Wolverine Creek in 2010 to 2012; * - no data

Table 4.1: Sediment chemistry data collected at exposed and reference areas, Minto Mine WUL, 2012.

	Analytes	Units	CSQG [a]		Upper McGinty Creek (Reference)				Lower Wolverine Creek (Reference)				Upper Minto Creek (Exposure)				Lower Minto Creek (Exposure)			
			ISQG	PEL	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum
Particle size, TKN, carbon analytes and pH	Loss on Ignition	%			-	-	-	-	21	4	14	24	-	-	-	-	8	3	5	12
	pH (1:2 soil:water)	pH units			7.04	0.20	6.83	7.29	7.27	0.33	6.93	7.71	7.98	0.21	7.72	8.19	8.08	0.08	7.99	8.19
	% Gravel (>2mm)	%			-	-	-	-	0.15	0.18	0.01	0.46	-	-	-	-	< 0.1	0.0	< 0.1	< 0.1
	% Sand (2.0mm - 0.063mm)	%			-	-	-	-	14.86	16.99	0.97	42.40	-	-	-	-	3.41	2.21	0.95	5.91
	% Silt (0.063mm - 4um)	%			-	-	-	-	74.1	14.7	50.9	85.8	-	-	-	-	86.6	2.1	85.2	90.2
	% Clay (<4um)	%			-	-	-	-	10.9	2.5	6.7	13.4	-	-	-	-	10.02	2.34	8.13	13.9
	Total Kjeldahl Nitrogen	%			0.48	0.13	0.31	0.67	0.50	0.13	0.32	0.65	0.09	0.03	0.07	0.13	0.17	0.06	0.10	0.25
	Total Organic Carbon	%			-	-	-	-	9.6	2.1	6.1	11.3	-	-	-	-	3.41	1.54	1.71	5.71
Total Metals	Aluminum (Al)	mg/kg			14,960	1,222	13,400	16,700	17,780	2,091	14,800	20,700	11,206	1,274	9,830	13,000	10,758	1,082	9,290	12,100
	Antimony (Sb)	mg/kg			0.54	0.05	0.45	0.57	0.56	0.03	0.53	0.59	0.36	0.08	0.27	0.47	0.47	0.07	0.40	0.56
	Arsenic (As)	mg/kg	5.9	17	9.78	1.72	7.77	12.2	6.43	0.48	6.1	7.27	5.65	0.41	5.25	6.31	6.11	1.12	4.85	7.44
	Barium (Ba)	mg/kg			348	40	287	399	300	28	260	335	194	26	175	238	195	36	151	240
	Beryllium (Be)	mg/kg			0.49	0.05	0.41	0.52	0.86	0.06	0.80	0.94	0.42	0.08	0.32	0.54	0.40	0.07	0.32	0.49
	Bismuth (Bi)	mg/kg			< 0.2	0	< 0.2	< 0.2	< 0.2	0	< 0.2	< 0.2	< 0.2	0.0	< 0.2	< 0.2	< 0.2	0	< 0.2	< 0.2
	Cadmium (Cd)	mg/kg	0.6	3.5	0.24	0.05	0.17	0.31	0.34	0.03	0.30	0.37	0.17	0.03	0.15	0.22	0.14	0.04	0.10	0.20
	Calcium (Ca)	mg/kg			12,000	1,808	9,500	14,300	12,340	940	11,600	13,900	6,676	1,373	5,200	8,870	9,542	1,835	7,810	12,200
	Chromium (Cr)	mg/kg	37.3	90	31.4	2.3	28.6	34.4	53.9	5.7	44.8	60.4	26.3	2.8	23.8	30.7	21.7	2.7	18.2	24.9
	Cobalt (Co)	mg/kg			13.8	1.5	12.5	16.3	14.8	0.9	13.3	15.9	10.7	0.9	10.0	12.3	7.9	1.2	6.5	9.5
	Copper (Cu)	mg/kg	35.7	197	33.3	4.4	25.9	37.8	38.2	3.1	33.6	42.1	**113.8**	14.3	**96.8**	**133.0**	20.1	3.9	15.8	25.4
	Iron (Fe)	mg/kg			31,140	3,230	27,300	35,500	29,520	1,836	26,500	31,300	23,180	1,128	22,500	25,100	19,200	2,508	16,100	22,100
	Lead (Pb)	mg/kg	35	91.3	6.11	0.29	5.77	6.52	8.10	1.35	6.88	10.4	5.26	0.82	4.22	6.49	5.28	0.61	4.42	5.91
	Lithium (Li)	mg/kg			9.1	0.9	7.9	10.3	11.9	1.2	10.3	13.7	7.4	1.2	5.9	9.2	8.0	0.9	6.8	9.0
	Magnesium (Mg)	mg/kg			5,178	294	4,900	5,640	9,606	700	8,560	10,300	7,918	866	7,360	9,430	4,930	570	4,220	5,630
	Manganese (Mn)	mg/kg			1,616	537	1,090	2,430	768	49	716	827	1,612	370	1,050	2,010	457	132	320	631
	Mercury (Hg)	mg/kg	0.17	0.49	0.071	0.018	0.050	0.099	0.060	0.003	0.056	0.063	0.019	0.004	0.015	0.024	0.033	0.008	0.025	0.044
	Molybdenum (Mo)	mg/kg			0.73	0.23	0.53	1.13	0.52	0.01	0.52	0.53	1.23	0.26	0.92	1.59	0.55	0.07	0.50	0.66
	Nickel (Ni)	mg/kg			22.4	1.5	20.0	23.6	41.5	2.7	37.4	45.0	36.4	5.8	31.9	46.5	18.6	2.4	15.8	21.7
	Phosphorus (P)	mg/kg			971	74	877	1,050	981	26	941	1,010	994	30	958	1,040	792	41	758	860
	Potassium (K)	mg/kg			708	55	630	780	856	80	730	950	1,254	118	1,120	1,350	800	121	620	940
	Selenium (Se)	mg/kg			0.65	0.14	0.47	0.8	0.60	0.04	0.54	0.64	0.35	0.09	0.28	0.49	0.25	0.07	0.20	0.36
	Silver (Ag)	mg/kg			0.13	0.01	0.12	0.14	0.14	0.01	0.13	0.15	< 0.1	0	< 0.1	< 0.1	< 0.1	0	< 0.1	< 0.1
	Sodium (Na)	mg/kg			202	8	190	210	310	12	300	330	378	54	310	450	244	27	210	280
	Strontium (Sr)	mg/kg			98	16	78	119	123	10	114	139	67.9	16.6	48.3	94.0	75.6	17.6	58.8	101
	Thallium (Tl)	mg/kg			0.081	0.003	0.076	0.084	0.097	0.012	0.078	0.108	0.066	0.012	0.052	0.082	0.073	0.015	0.055	0.094
	Tin (Sn)	mg/kg			< 2.0	0	< 2.0	< 2.0	< 2.0	0	< 2.0	< 2.0	< 2.0	0	< 2.0	< 2.0	< 2.0	0	< 2.0	< 2.0
	Titanium (Ti)	mg/kg			655	78	537	738	695	52	611	749	653	59	578	738	564	63	476	644
	Uranium (U)	mg/kg			1.57	0.27	1.28	1.97	2.72	0.07	2.66	2.83	0.63	0.17	0.53	0.93	0.83	0.18	0.65	1.06
	Vanadium (V)	mg/kg			59.8	3.6	54.0	62.9	70.7	4.3	63.9	76.0	52.2	2.8	50.2	56.9	41.8	4.7	35.5	46.6
	Zinc (Zn)	mg/kg	123	315	52.6	2.8	49.3	56.4	62.6	4.0	56.5	67.4	65.8	4.1	61.3	71.4	43.8	5.0	37.7	49.1

[a] Canadian Sediment Quality Guidelines - ISQG = interim sediment quality guideline; PEL = probable effect level (CCME 1999).

(blue) Indicates sediment concentration exceeding CSQG ISQG.

(green) Indicates sediment concentration exceeding CSQG PEL.

bold Indicates sediment concentration exceeding the higher reference mean by more than 2 times

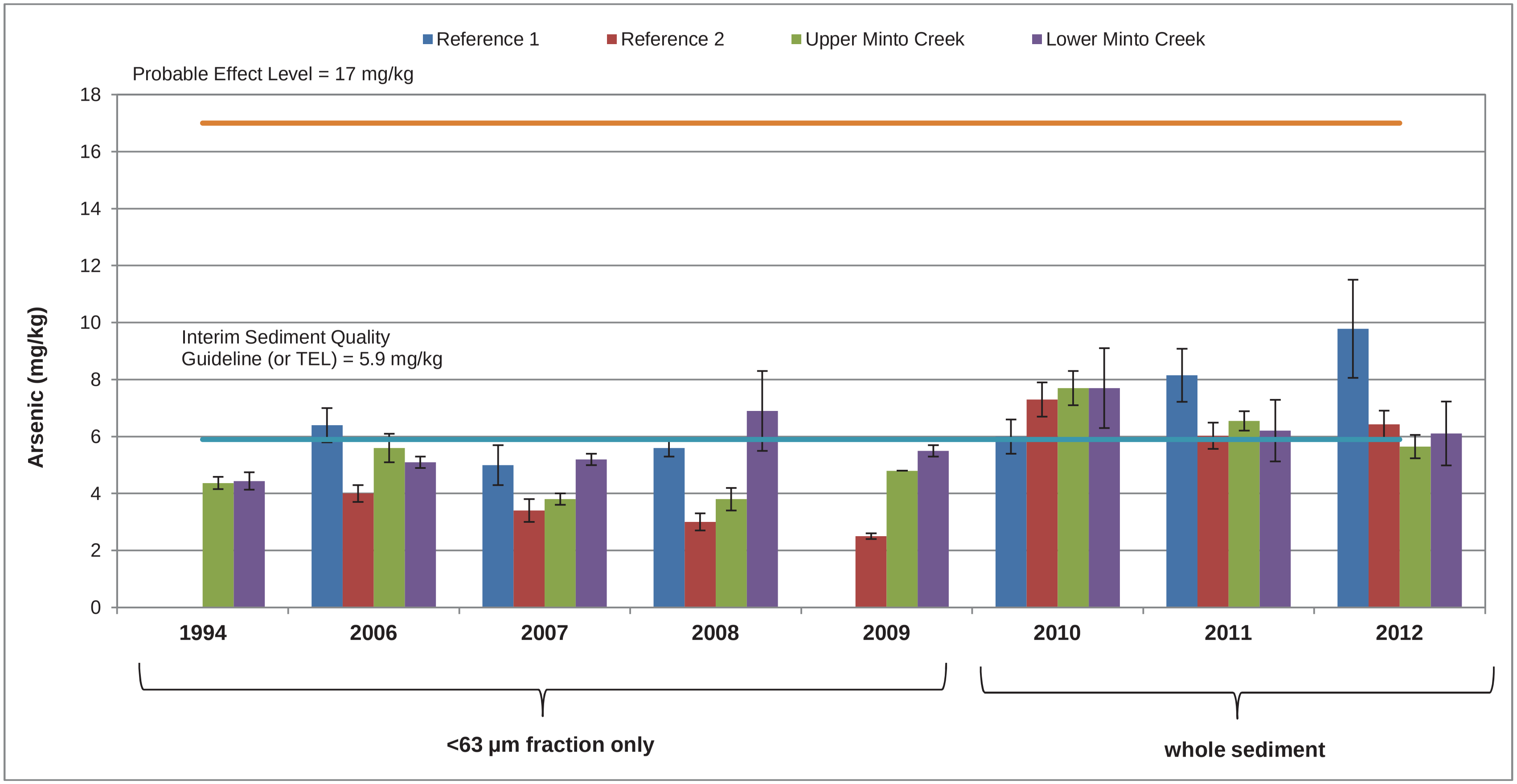


Figure 4.2: Mean arsenic concentrations in sediment collected in Minto Creek and reference locations, 1994-2012 (mean ± standard deviation)

Note: Reference 1 = Station W6 (south-flowing tributary) in 2006 to 2008 and McGinty Creek in 2010 to 2012; Reference 2 = Station W7 (north-flowing tributary) in 2006 to 2009 and Wolverine Creek in 2010 to 2012; * = no data. TEL: Threshold Effect Levels

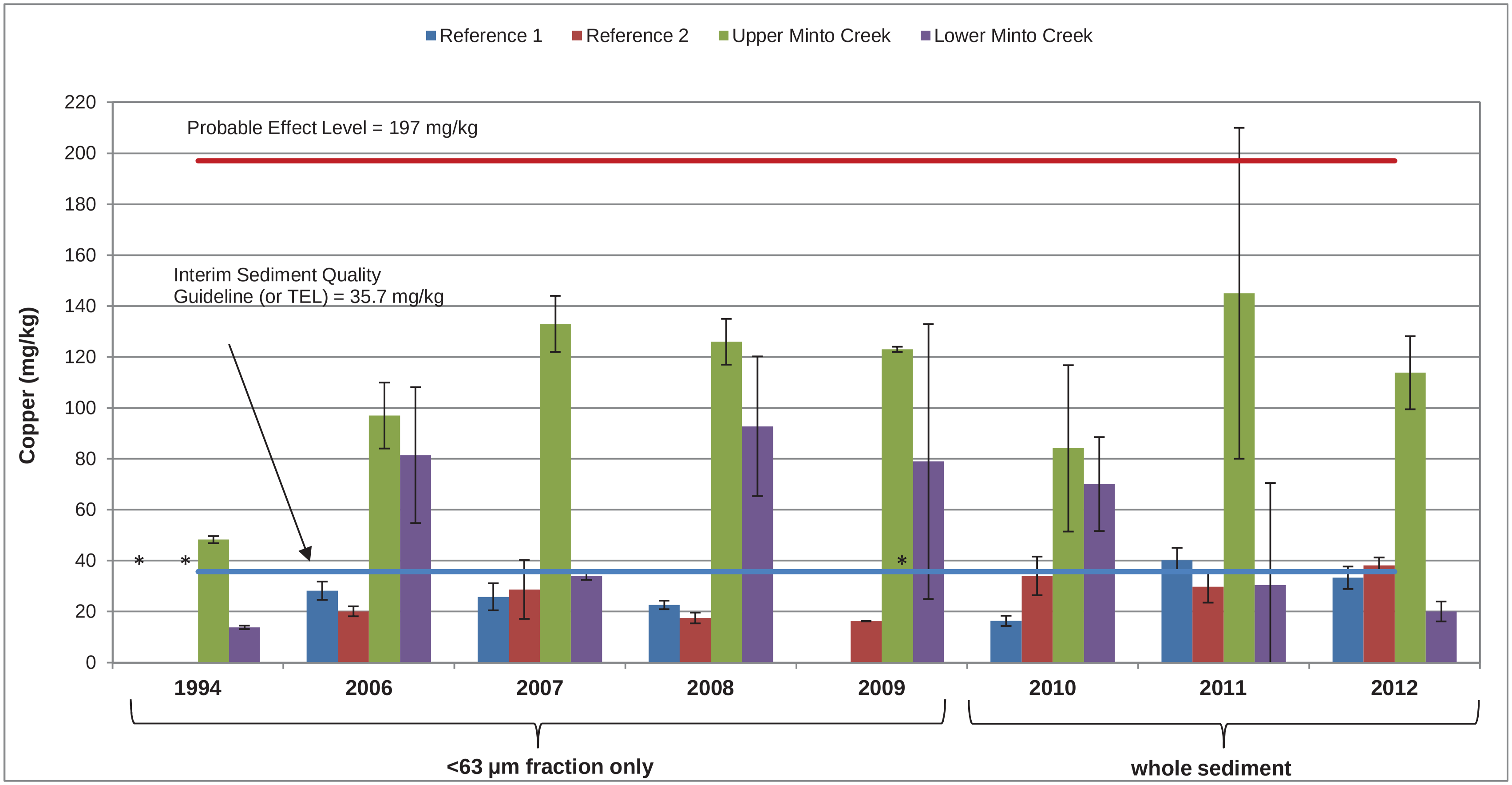


Figure 4.3: Mean copper concentrations in sediment collected in Minto Creek and reference locations, 1994-2012 (mean ± standard deviation)[1]

[1]Reference 1 = Station W6 (south-flowing tributary) in 2006 to 2008 and McGinty Creek in 2010 to 2012; Reference 2 = Station W7 (north-flowing tributary) in 2006 to 2009 and Wolverine Creek in 2010 to 2012; * = no data. TEL: Threshold Effect Levels

reference differs from the observations of previous sampling years and could be due to inputs from non-mineralized areas within the catchment (e.g. bank instability in several tributaries).

4.3 Summary

Overall, concentrations of metals in receiving environment sediments were lower than reference and/or sediment quality guidelines with the exception of copper at upper Minto Creek. Arsenic concentration was greater than the sediment quality guideline at both exposure and reference areas (as it was in previous sampling years), indicating naturally elevated arsenic concentrations. In lower Minto Creek, where sediment is less sparsely distributed and some depositional habitat is supported, sediment metal concentrations were below reference and/or sediment quality guidelines. In 2012, concentrations of many analytes in lower Minto Creek were lower than in 2010 and 2011 possibly due to contribution of sediment from bank erosion in several tributaries.

5.0 BENTHIC INVERTEBRATE COMMUNITY

Benthic invertebrate community samples were processed separately using 250 µm and 500 µm sieve sizes. In comparisons of lower Minto Creek to lower Wolverine Creek, the same trends were evident for both 250 µm and 500 µm sieve sizes (Appendix D). Due to the similarity in results associated with the two mesh sizes, the 500 µm fraction results (Appendix Tables D.1-D.6) are discussed herein. Results for 250 µm mesh size are provided in Appendix D (Appendix Tables D.7-D.13).

5.1 Primary Metrics and Community Composition

Lower Minto Creek had significantly lower density (individuals/m^2; 856 versus 7,579; Figure 5.1a; Table 5.1) and significantly higher mean number of benthic invertebrate taxa than at lower Wolverine Creek (20.4 versus 12.6; Figure 5.1b; Table 5.1). Consistent with the greater number of taxa in lower Minto Creek, Simpson's Diversity was also significantly greater; whereas there was no difference in Simpson's Evenness (Figure 5.1c; Table 5.1). Bray-Curtis index (distance from the reference median) was significantly higher at lower Minto Creek than at lower Wolverine Creek (Figure 5.1d; Table 5.1), indicating a difference in community composition.

Dominant taxonomic groups in lower Minto and Wolverine creeks included EPT taxa (Ephemeroptera, Plecoptera and Trichoptera or mayflies, stoneflies and caddisflies, respectively), chironomids (non-biting midges), oligochaetes (worms) and nematodes (roundworms). There were no significant differences between areas in the relative abundance of oligochaetes, nematodes or organisms from the pollution and enrichment intolerant EPT order (Figure 5.2a,c,d; Table 5.1, Appendix Table D.5). However, percent chironomids was significantly lower at lower Minto Creek than at lower Wolverine Creek (Figure 5.2b; Table 5.1, Appendix Table D.5).

Correspondence Analysis (CA) summarized 64.4 percent of the community variance in the first three axes (Appendix Table D.4). The first CA axis explained 38.2 percent of the variation and significantly separated lower Minto Creek from the reference area, lower Wolverine Creek. There were no area differences for subsequent axes (Appendix Table D.5). The exposure area had extreme negative scores on CA Axis-1, in contrast to the extreme positive scores for the reference area (Figure 5.3; Appendix Table D.4). Low CA axis scores were associated with higher relative abundance of negative scoring taxa such as naidid worms, *Sphaeromias* No-See-Ums, cyclopoid copepods, *Psectrocladius* chironomids, and flatworms (Appendix Table D.4). The large positive scores for the reference stations indicated peak abundances of *Taenioma* and perlodid stoneflies, the

Table 5.1: Summary of benthic invertebrate community metrics and statistical comparisons, Minto Mine WUL, 2012.

Metric	Area Means		Statistical Contrasts		
	Lower Wolverine Creek (Reference)	Lower Minto Creek (Exposed)	Significant Difference between areas?	Direction	p-value
Density (organisms/m^2)	7,579	856	Yes	Minto < Wolverine	0.001
Number of Taxa	12.6	20.4	Yes	Minto > Wolverine	0.000
Simpson's Diversity [1]	0.51	0.74	Yes	Minto > Wolverine	0.050
Simpson's Evenness [1]	0.20	0.20	No	-	0.981
Bray-Curtis Distance	0.25	0.91	Yes	Minto > Wolverine	0.000
EPT (%) [2]	11.4	23.5	No	-	0.103
Chironomidae (%)	75.1	51.5	Yes	Minto < Wolverine	0.014
Oligochaetae (%)	11.1	7.8	No	-	0.558
Nemata (%)	0.7	4.9	No	-	0.272
CA Axis-1 (38.2%)	0.60	-0.87	Yes	non-directional	0.000
CA Axis-2 (14.1%)	0.01	-0.09	No	-	0.749
CA Axis-3 (12.1%)	0.07	0.02	No	-	0.885

(yellow shading) indicates a statistically significant difference between exposed and reference areas

[1] Calculated as recommended by Environment Canada 2012

[2] Percent Ephemeroptera, Plecoptera, Trichoptera

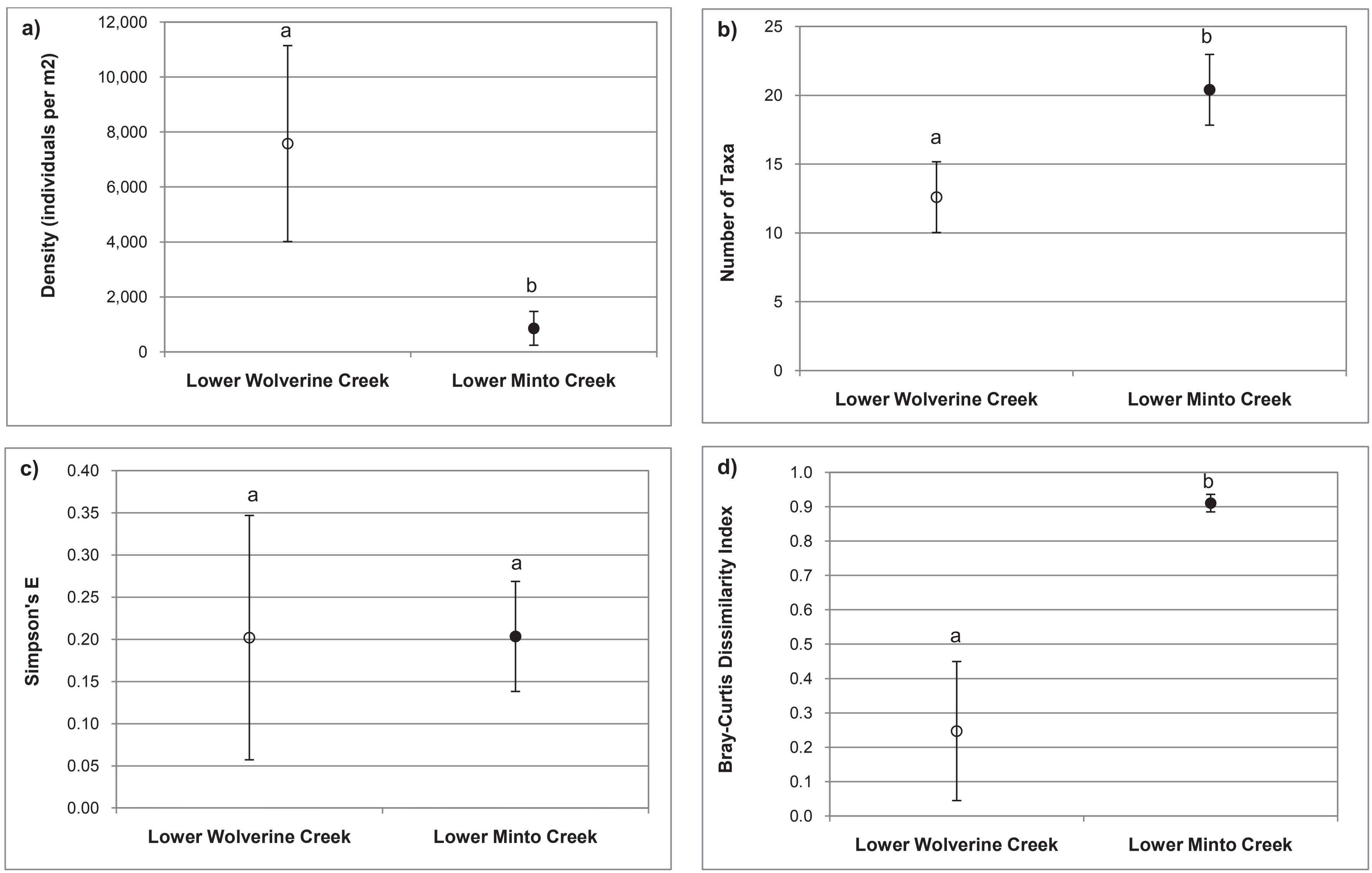


Figure 5.1: Comparison of a) benthic invertebrate density, b) number of taxa, c) Simpson's Eveness and d) Bray-Curtis Dissimilarity at the lower Minto Creek exposure area compared to the lower Wolverine Creek reference area (500 µm mesh). Data represents area means and 95% confidence intervals (n=5 in all areas). Different letters above data points indicate areas that were significantly different ($p < 0.1$).

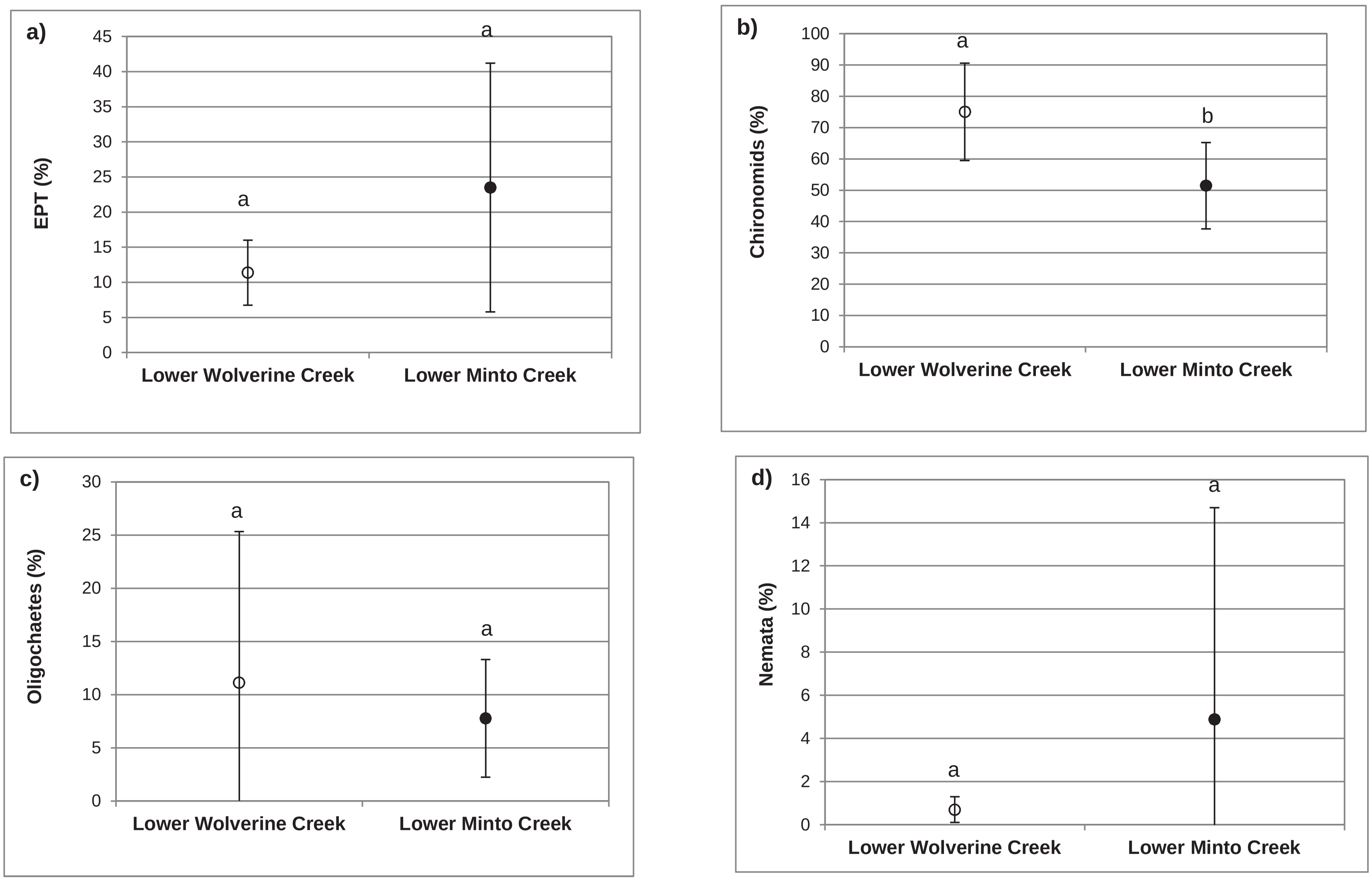


Figure 5.2: The relative abundance as percent of total organisms in an area for a) EPT, b) Chironomids, c) Oligochaetes and d) Nemata (500 µm mesh). Data represents area means and 95% confidence intervals (n=5 in all areas). Different letters above 95% confidence interval bars indicate areas that were significantly different (p<0.1).

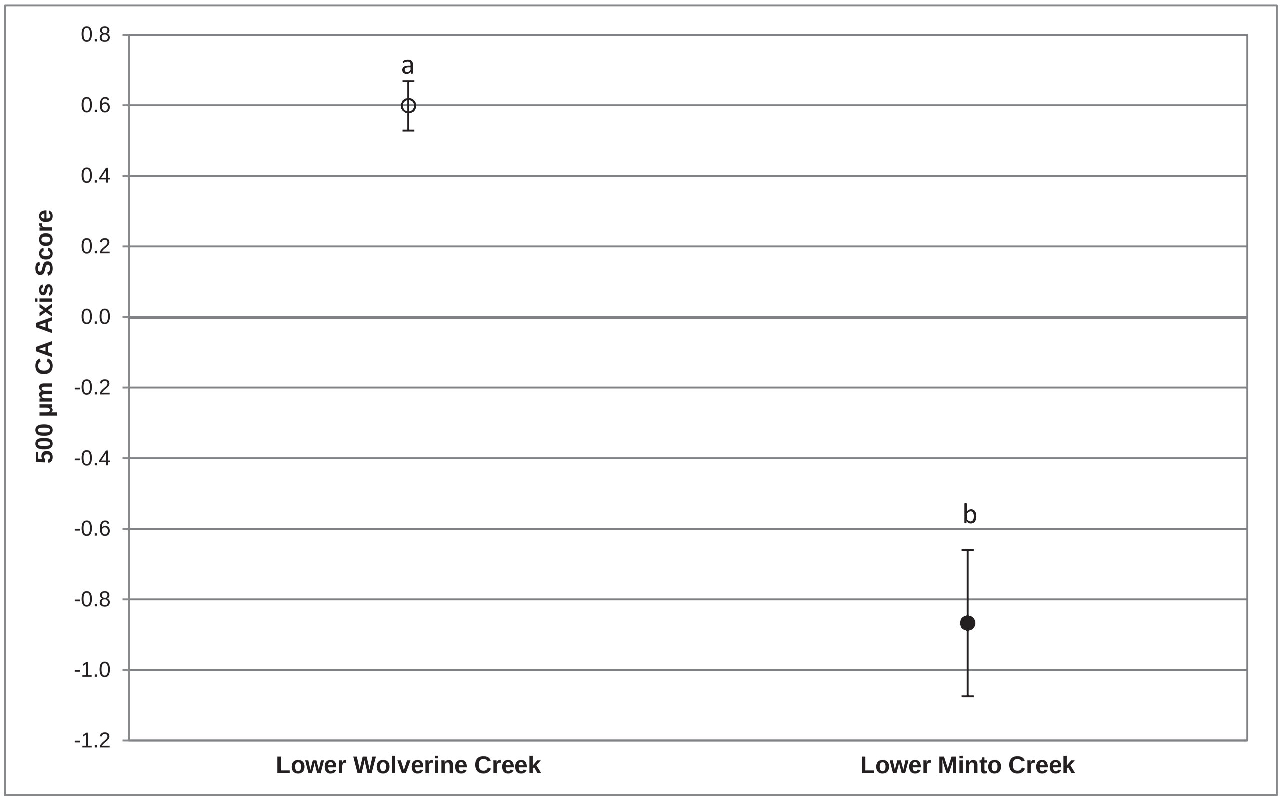


Figure 5.3: Comparison of CA Axis-1 at lower Minto Creek to lower Wolverine Creek

mayfly *Drunella spinifera*, and chironomids of the genus *Orthocladius*. The taxa listed above occurred in most cases at only exposure stations (-ve scoring taxa) or reference stations (+ve scoring taxa).

The absence of *Orthocladius* chironomids and of some stonefly taxa (Family Perlodidae, and *Taenioma*) at exposure stations identified key, extreme-scoring taxa that led to significant reference-exposure differences on the first CA axis. Stoneflies are, in general, associated with unpolluted, clear water with alkaline-to-neutral pH (Burdick and Gaufin 1978). Specific taxa in the order do vary somewhat in tolerance, but the presence of nemourid stoneflies at the slightly more alkaline exposure area suggest that water quality differences are minor, and that habitat differences may play a role in determining which stonefly families are present. *Orthocladius* is a genus of chironomids represented by more than 20 different species, some of which are variously reported to be acidophilous or tolerant of eutrophication (Beck 1977). The absence of *Orthocladius* at exposure stations cannot clearly be ascribed to the slightly more basic pH in this area without knowing more about the tolerances of the species of *Orthocladius* found at reference stations.

5.2 Correlation Analysis

Most significant correlations between benthic invertebrate community metrics and physical-chemical conditions were related to temperature and specific conductivity (Table 5.2). With higher temperature and specific conductivity at lower Minto Creek relative to reference, there were lower density, more taxa/diversity, greater Bray-Curtis distance and lower CA Axis-1 score (Table 5.2, Figure 5.4). However, the relationships were highly leveraged rather than a continuously distributed. These correlations suggest that lower density, higher taxon richness and greater Bray-Curtis dissimilarity could be mine related as higher temperatures and specific conductivity are related to mine discharges. However, correlation is not causation and inference of cause is not strong due to the observed leveraging. Other significant correlations are presented in Appendix D (Appendix Figures D.2-D.4).

5.3 Temporal Comparisons

Temporal comparisons of the benthic invertebrate community condition of lower Minto Creek were made in order to augment data interpretation, but their power is tempered by temporal changes in sampling location, sampling methodology, level of replication and analytical processing techniques. For example, 1994 baseline data were collected near the mouth of Minto Creek as three single grab samples, 2006 data were collected at Station W2 in the same manner, 2008 and 2010 data were collected at Station W2 as

Table 5.2: Correlations between benthic metrics and environmental supporting measurements at Minto Mine WUL Stations, 2012.

		Median Intermediate Axis Length (cm)	Median Embeddedness (%)	Water Velocity (m/s)	Depth (m)	Temperature (°C)	DO (%)	Specific Conductivity (µS/cm)	pH	% cobble	% gravel	% sand and finer
Density (organisms/m^2)	Pearson Correlation	-0.32	-0.53	0.24	-0.25	-0.79	-0.82	-0.86	-0.88	-0.17	-0.04	0.22
	Sig. (2-tailed)	0.375	0.145	0.508	0.510	0.007	0.004	0.002	0.001	0.635	0.915	0.536
	N	10	9	10	9	10	10	10	10	10	10	10
Number of Taxa	Pearson Correlation	0.10	0.31	-0.22	0.53	0.82	0.72	0.87	0.73	-0.28	0.07	-0.12
	Sig. (2-tailed)	0.776	0.416	0.547	0.140	0.003	0.019	0.001	0.016	0.441	0.840	0.750
	N	10	9	10	9	10	10	10	10	10	10	10
Simpson's Diversity	Pearson Correlation	0.06	0.54	-0.01	0.12	0.67	0.44	0.61	0.52	-0.31	0.17	0.00
	Sig. (2-tailed)	0.860	0.132	0.985	0.754	0.032	0.203	0.061	0.122	0.382	0.632	1.000
	N	10	9	10	9	10	10	10	10	10	10	10
Simpson's Evenness	Pearson Correlation	-0.13	0.72	0.26	-0.32	0.20	-0.26	0.01	-0.12	-0.45	0.10	0.22
	Sig. (2-tailed)	0.730	0.028	0.473	0.398	0.583	0.470	0.986	0.748	0.193	0.776	0.537
	N	10	9	10	9	10	10	10	10	10	10	10
Bray-Curtis Distance	Pearson Correlation	-0.21	0.40	-0.17	0.22	0.91	0.56	0.95	0.70	-0.38	0.20	-0.32
	Sig. (2-tailed)	0.568	0.289	0.645	0.572	0.000	0.094	0.000	0.024	0.278	0.581	0.374
	N	10	9	10	9	10	10	10	10	10	10	10
EPT (%) [1]	Pearson Correlation	0.14	0.40	0.12	0.27	0.59	0.40	0.54	0.45	-0.54	0.00	0.32
	Sig. (2-tailed)	0.697	0.283	0.735	0.481	0.070	0.251	0.108	0.190	0.104	0.996	0.361
	N	10	9	10	9	10	10	10	10	10	10	10
Chironomidae (%)	Pearson Correlation	-0.26	-0.63	-0.04	-0.28	-0.72	-0.65	-0.72	-0.70	0.30	-0.21	-0.02
	Sig. (2-tailed)	0.473	0.071	0.914	0.463	0.020	0.042	0.019	0.025	0.399	0.561	0.958
	N	10	9	10	9	10	10	10	10	10	10	10
Oligochaetae (%)	Pearson Correlation	0.20	0.30	0.03	-0.31	-0.11	0.07	-0.20	0.10	0.25	0.35	0.30
	Sig. (2-tailed)	0.571	0.425	0.930	0.415	0.770	0.840	0.586	0.792	0.483	0.314	0.408
	N	10	9	10	9	10	10	10	10	10	10	10
Nemata (%)	Pearson Correlation	0.09	0.36	0.39	0.08	0.13	0.21	0.36	0.17	0.03	-0.15	-0.99
	Sig. (2-tailed)	0.812	0.335	0.268	0.832	0.716	0.561	0.310	0.637	0.945	0.681	0.000
	N	10	9	10	9	10	10	10	10	10	10	10
CA Axis-1 (38.2%)	Pearson Correlation	-0.08	-0.49	0.13	-0.37	-0.86	-0.75	-0.97	-0.82	0.17	-0.15	0.39
	Sig. (2-tailed)	0.819	0.184	0.724	0.332	0.001	0.012	0.000	0.004	0.641	0.679	0.261
	N	10	9	10	9	10	10	10	10	10	10	10
CA Axis-2 (14.1%)	Pearson Correlation	0.07	-0.03	0.20	-0.01	-0.32	-0.17	-0.16	-0.27	0.33	0.00	-0.79
	Sig. (2-tailed)	0.854	0.930	0.583	0.982	0.369	0.643	0.662	0.450	0.356	0.992	0.006
	N	10	9	10	9	10	10	10	10	10	10	10
CA Axis-3 (12.1%)	Pearson Correlation	0.17	0.03	-0.10	-0.31	-0.01	0.01	-0.02	0.10	0.44	-0.68	-0.01
	Sig. (2-tailed)	0.644	0.935	0.774	0.414	0.977	0.975	0.946	0.776	0.198	0.032	0.974
	N	10	9	10	9	10	10	10	10	10	10	10

(grey) correlation scatterplot inspected: $p < 0.0100$

(yellow) significant after Bonferroni correction; $p < 0.00035$ ($p = 0.05$ adjusted for 143 comparisons)

[1] Percent Ephemeroptera, Plecoptera, Trichoptera

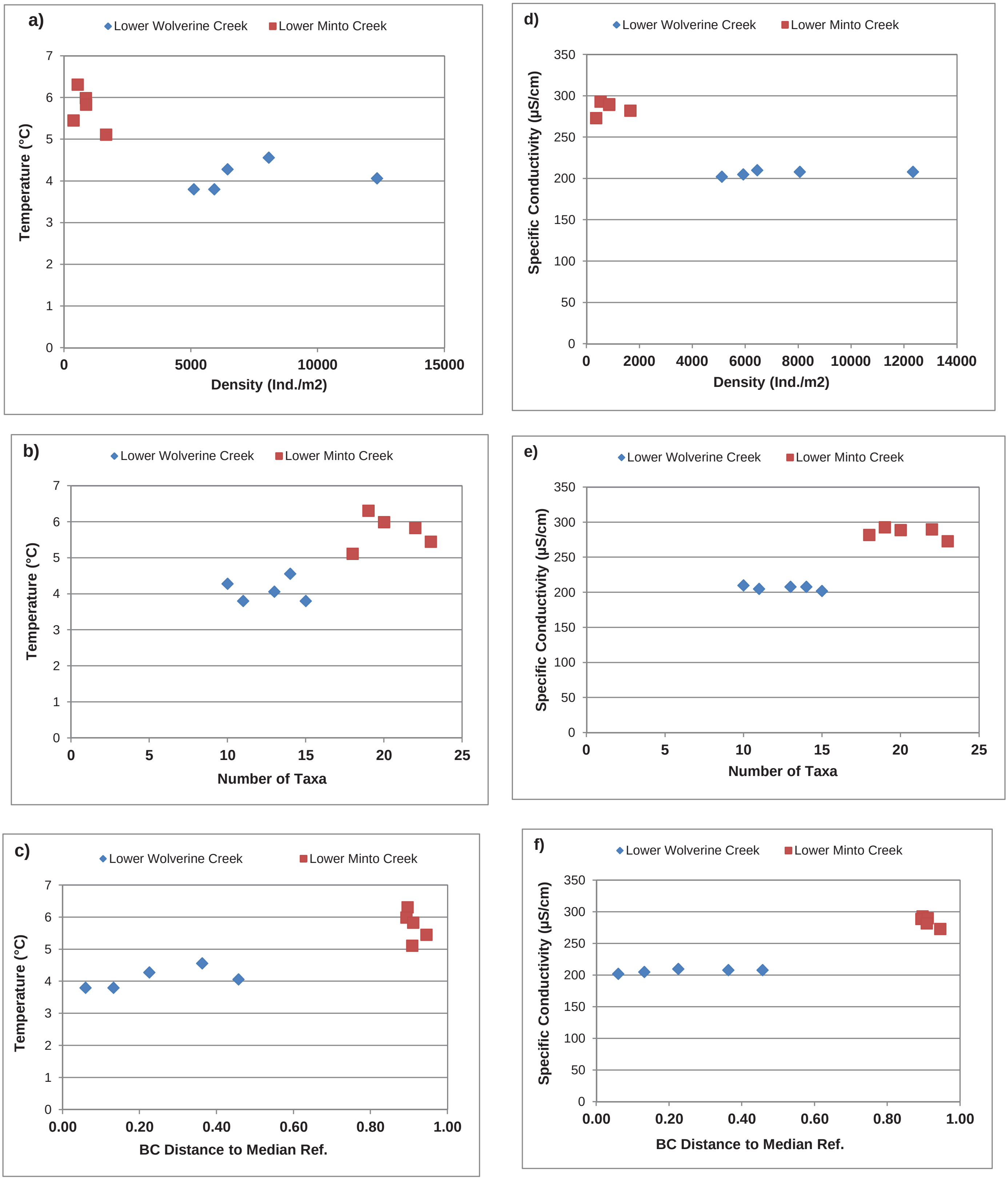


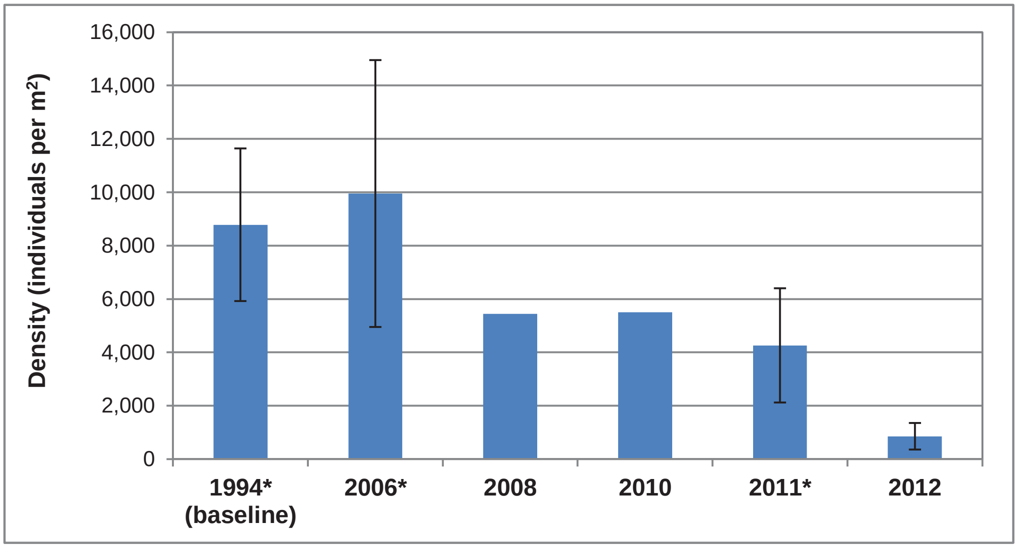
Figure 5.4: Scatterplots of significant relationships between selected benthic invertebrate community metrics and temperature and conductivity

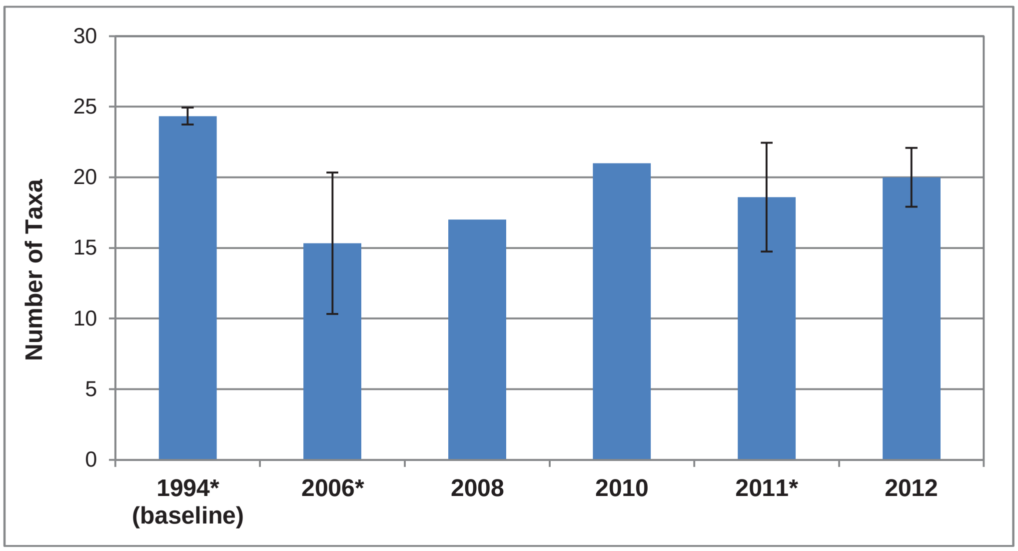
three-grab composites whereas 2011 and 2012 data were collected as five replicate three-grab samples from a large area upstream of Station W2. Only in the later years (2011 and 2012) do data represent an area (i.e., lower Minto Creek) rather than a station.

Benthic invertebrate density in 2012 was lower than in all previous collections (Figure 5.5). This could be due to the unusually high sediment loads associated with erosion in non-mine impacted tributaries. Mean number of taxa in lower Minto Creek in 2012 (20.4 taxa) was lower than the 1994 baseline (HPK 1994) but similar to collections in 2008 and 2010, when the mine was discharging effluent (Figure 5.5). In comparisons of lower Minto Creek to the lower Wolverine Creek reference, differences in density and number of taxa/diversity observed in 2012 were opposite from those observed in 2011. As in 2011, evenness was lower at the exposure area compared to other sampling years; however, in 2012, the difference was not statistically significant (Table 5.1; Figure 5.1c; Figure 5.5; Appendix Tables D.3-D.6). Changes in density and evenness over time likely reflected high temporal variability of benthic invertebrate communities in the region, also evident at reference areas (Minnow 2009b; 2011). High inter-annual variability in environmental conditions such as flow, deep freezing, and occasional pulses of very high sediment loads can, in turn, influence benthic invertebrate community composition features among years.

5.4 Summary

Based on control-impact comparison of benthic invertebrate community data collected by Hess sampling, the benthic invertebrate community of lower Minto Creek differed from that of lower Wolverine Creek on the basis of density (lower), taxon richness (higher), Simpson’s Diversity (higher), Bray-Curtis dissimilarity (greater), percent chironomids (lower), as well as for the first axis of Correspondence Analysis. Greater taxon richness/diversity and lower dominance by chironomids are typically considered indicative of a healthy erosional benthic invertebrate community, whereas lower density can be equivocal. The lower density, higher number of taxa and greater Bray-Curtis dissimilarity at the lower Minto Creek was correlated with higher temperature and specific conductivity, but the relationships were highly leveraged and therefore do not strongly infer cause. Percent chironomids was significantly lower and percent EPT taxa was higher (but not significantly so) at lower Minto Creek than at lower Wolverine Creek. Given that chironomids are generally considered to be tolerant of pollutants and EPT taxa are generally considered to be sensitive to pollutants, this pattern suggests limited influence of the mine on the benthic invertebrate community of lower Minto Creek. High temporal variability has been observed at the exposure and reference area (Minnow 2009b; 2011, 2012a), presumably due to inter-annual variability in environmental conditions (e.g., flow,





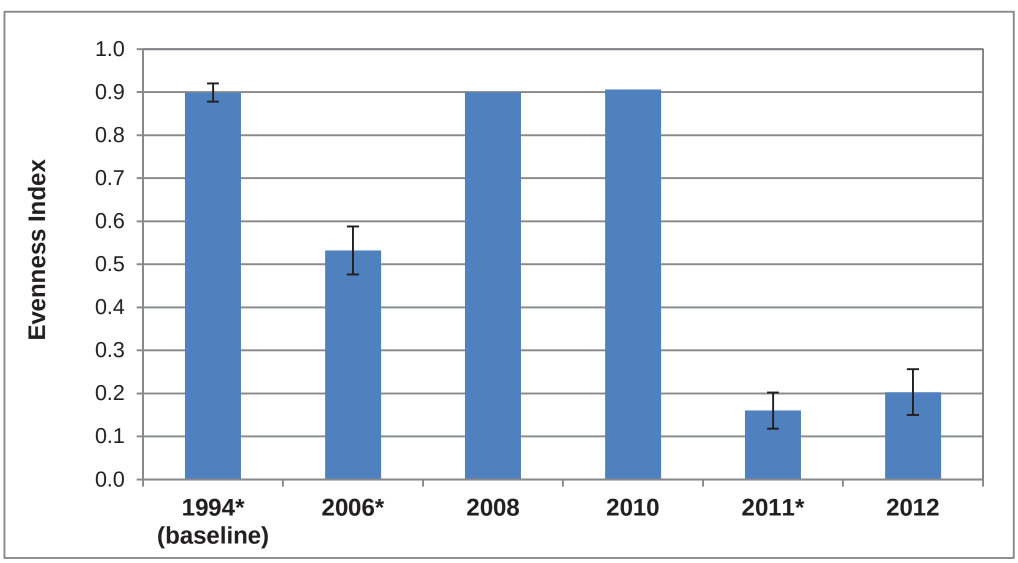


Figure 5.5: Primary benthic invertebrate community metrics at lower Minto Creek, 1994 - 2012. Data presented as mean ± standard deviation where replicated. Asterisk (*) indicates a year the mine was not discharging.

ice scour). This variability may also be related to changes in sampling method/replication, making it difficult to distinguish any mine-related influences.

6.0 TISSUE CHEMISTRY

As indicated in Section 2.5, tissue chemistry data are provided here simply to report the ancillary data that were collected along with the selenium data reported under separate cover (Minnow 2013). Data interpretation is therefore limited to basic comparisons of metal concentrations in tissue collected at the exposure area (lower Minto Creek) to those collected at reference creeks.

6.1 Periphyton Tissue

Metal concentrations in periphyton tissue collected from lower Minto Creek were lower than in periphyton tissue collected from lower Wolverine Creek and similar to lower Bog Creek (Table 6.1; Appendix Table C.2). In the absence of the periphyton community data (pending), it is unclear whether the differences may be related to differences in community composition.

6.2 Benthic Invertebrate Tissue

Metal concentrations in benthic invertebrate tissue collected from lower Minto Creek were generally similar to concentrations in samples collected from lower Wolverine Creek and lower Big Creek, with no evidence of consistently greater concentrations in lower Minto Creek than in reference. However, at least one mine-related metal (copper) was present at a greater concentration in benthic invertebrate samples from lower Minto Creek than reference (Appendix Table C.3).

6.3 Fish Tissue

Selenium and sodium were the only analytes present at significantly greater concentrations in slimy sculpin collected from Minto Creek relative to those collected from lower Big Creek (Table 6.1; Appendix Table C.4). Conversely, concentrations of six metals (arsenic, beryllium, bismuth, boron, silver and strontium) were significantly lower in slimy sculpin collected from Minto Creek than in those collected from lower Big Creek (Table 6.1; Appendix Table C.4). Of the analytes observed to differ among areas, selenium is noteworthy, and comparison of selenium concentrations in other fish tissues and to additional areas is planned for 2013 (Minnow 2013).

Table 6.1: Tissue chemistry results, Minto Mine WUL, September 2012.

Analyte	Units	Periphyton				Benthic Invertebrates			Slimy Sculpin			
		Lower Wolverine Creek (Reference)		Lower Big Creek (Reference)	Lower Minto Creek (Exposed)	Lower Wolverine Creek (Reference)	Lower Big Creek (Reference)	Lower Minto Creek (Exposed)	Lower Big Creek (Reference)		Lower Minto Creek (Exposed)	
		n = 5		n=1	n=1	n = 1	n=1	n = 1	n = 8		n = 7	
		Mean	Standard Deviation	Mean	Mean	Mean	Mean	Mean	Mean	Standard Deviation	Mean	Standard Deviation
Moisture	%	82.1	4.5	59.3	51.9	80.1	85.4	90.7	-	-	-	-
Aluminum (Al)	mg/kg dw	31,440	2,207	21,500	21,100	4,890	2,440	8,720	91.8	81.9	61.8	63.4
Antimony (Sb)	mg/kg dw	0.04	0.00	0.03	0.02	< 0.01	0.05	0.08	0.027	0.014	0.019	0.012
Arsenic (As)	mg/kg dw	8.20	1.21	13.90	4.24	2.05	2.86	5.32	0.435	0.084	0.308	0.130
Barium (Ba)	mg/kg dw	361	26	260	284	71	48	196	15.3	2.2	13.5	6.1
Beryllium (Be)	mg/kg dw	1.23	0.09	0.692	0.664	0.23	0.09	0.35	0.142	0.017	0.095	0.005
Bismuth (Bi)	mg/kg dw	0.143	0.008	0.451	0.125	0.03	0.07	0.07	0.142	0.017	0.095	0.005
Boron (B)	mg/kg dw	17.5	20.3	5.6	4.9	< 2.0	< 3.0	20.3	2.84	0.35	1.90	0.10
Cadmium (Cd)	mg/kg dw	0.38	0.05	0.24	0.18	0.27	0.37	0.31	0.197	0.117	0.171	0.109
Calcium (Ca)	mg/kg dw	15,400	997	11,500	16,200	3,040	3,630	9,450	30,886	4,632	32,509	4,497
Chromium (Cr)	mg/kg dw	81.7	5.5	43.6	51.4	12.4	17.2	16.9	0.388	0.144	0.266	0.128
Cobalt (Co)	mg/kg dw	19.5	1.6	10.6	10.3	3.94	2.44	5.38	0.154	0.094	0.178	0.109
Copper (Cu)	mg/kg dw	44.4	3.5	30.9	26.3	17.3	18.5	33.2	4.468	0.912	4.555	1.096
Iron (Fe)	mg/kg dw	37,400	3,102	26,000	28,000	7,640	5,400	13,500	222	138	190	136
Lead (Pb)	mg/kg dw	8.30	0.47	7.32	6.72	1.32	1.30	3.34	0.249	0.124	0.178	0.059
Magnesium (Mg)	mg/kg dw	13,540	1,361	8,460	7,230	3,120	2,160	3,440	1,847	264	1,704	234
Manganese (Mn)	mg/kg dw	1,526	373	653	1,130	360	256	782	27	8	49	32
Mercury (Hg)	mg/kg dw	0.09	0.05	0.07	0.06	0.07	0.06	0.08	0.198	0.045	0.176	0.065
Molybdenum (Mo)	mg/kg dw	0.49	0.04	0.68	0.43	0.72	1.64	3.21	0.109	0.023	0.138	0.040
Nickel (Ni)	mg/kg dw	50.2	3.9	25.1	23.9	8.88	5.19	11.3	0.539	0.242	0.302	0.185
Phosphorus (P)	mg/kg dw	1,390	203	1,190	1,060	5,750	5,030	4,250	24,404	3,394	25,953	2,202
Potassium (K)	mg/kg dw	3,340	740	2,600	2,400	6,200	7,300	5,400	15,874	3,651	14,612	2,226
Selenium (Se)	mg/kg dw	0.87	0.12	0.3	0.21	1.01	0.83	1.14	3.4	0.7	5.2	1.1
Silver (Ag)	mg/kg dw	-	-	-	-	-	-	-	0.028	0.003	0.019	0.001
Sodium (Na)	mg/kg dw	< 1,000	-	< 1,000	< 1,000	4,300	6,100	3,000	4,265	812	6,101	764
Strontium (Sr)	mg/kg dw	133	8	91	104	26.0	34.3	74.3	87	24	62	9
Thallium (Tl)	mg/kg dw	0.21	0.02	0.15	0.14	0.04	0.02	0.07	0.019	0.003	0.015	0.008
Tin (Sn)	mg/kg dw	0.23	0.04	0.04	< 0.02	< 0.02	0.03	0.35	0.142	0.017	0.237	0.127
Titanium (Ti)	mg/kg dw	1,472	73	1,000	1,020	28	102	404	7.8	4.2	7.1	4.3
Uranium (U)	mg/kg dw	2.52	0.22	1.08	1.32	0.60	1.28	1.29	0.043	0.017	0.032	0.018
Vanadium (V)	mg/kg dw	105	8	75	81	21.5	14.7	37.5	-	-	-	-
Yttrium (Y)	mg/kg dw	15.7	0.7	13.3	17.1	2.70	1.76	7.37	0.777	0.241	0.869	0.302
Zinc (Zn)	mg/kg dw	97	7	79	73	93.0	74.0	96.1	111	18	112	11

(green) indicates a mean concentration in lower Minto Creek that is significantly lower than the mean concentration in lower Big Creek (t-test; p=0.05)

(orange) indicates a mean concentration in lower Minto Creek that is significantly greater than the mean concentration in lower Big Creek (t-test; p=0.05)

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The Minto Mine sediment, periphyton and benthic assessment undertaken from September 5th to 8th, 2012 served to quantitatively compare water quality (field measures and chemistry), sediment quality and benthic invertebrate community condition of Minto Creek relative to reference creeks and also drew on previous data for interpretation.

Temperature and specific conductivity were higher at the exposure areas (upper and lower Minto Creek) than at the reference areas (upper McGinty Creek and lower Wolverine Creek). At the time of water sampling (September 5th to 8th, 2012), a total of seven analytes (phosphorus, TSS, aluminum, cadmium, chromium, copper, and iron) did not meet WUL standards and/or water quality guidelines in at least one exposure area. Phosphorus was higher than the WUL standard in lower Minto Creek and reference areas suggesting naturally elevated concentrations and indicating that the WUL standard is not appropriate. Total suspended solids at lower Minto Creek in 2012 were much higher than in any other sampling year and could explain why aluminum, chromium and iron were elevated in 2012 at lower Minto Creek (Minnow 2010c; Minnow 2012a). A key finding was that, in lower Minto Creek, only cadmium and copper were greater than both guidelines/standards and reference concentrations. Furthermore, at the time of sampling in 2012, the water quality of upper Minto Creek was better than the water quality of lower Minto Creek, indicating that the Minto Mine had a limited influence on water quality at that time. Differences in chlorophyll *a* between areas were likely not related to water quality but rather to natural differences. Regardless, the concentrations of chlorophyll a found at both areas were well below the guideline of 100 mg/m^2 for the protection of aquatic life and both indicate low productivity (oligotrophic) based on the classification system of Dodds et al. (1998).

Sediment metal concentrations in the exposure area were lower than reference and/or sediment quality guidelines with the exception of copper at upper Minto Creek. Arsenic concentration was greater than the sediment quality guideline at exposure and reference areas (as it was in previous sampling years), indicating naturally elevated arsenic concentrations. In lower Minto Creek, where sediment is less sparsely distributed and some depositional habitat is supported, sediment metal concentrations were below reference and/or sediment quality guidelines. In 2012, concentrations of many analytes in lower Minto Creek were lower than in 2010 and 2011 possibly due to contribution of sediment from bank erosion in several tributaries.

Based on control-impact comparison of benthic invertebrate community data collected by Hess sampling, the benthic invertebrate community of lower Minto Creek differed from that of lower Wolverine Creek on the basis of density (lower), taxon richness (higher), Simpson's Diversity (higher), Bray-Curtis dissimilarity (greater), percent chironomids (lower), as well as for the first axis of Correspondence Analysis. Greater taxon richness/diversity and lower dominance by chironomids are typically considered indicative of a healthy erosional benthic invertebrate community, whereas lower density can be equivocal. The lower density, higher number of taxa and greater Bray-Curtis dissimilarity at the lower Minto Creek was correlated with higher temperature and specific conductivity, but the relationships were highly leveraged and therefore do not strongly infer cause. Percent chironomids was significantly lower and percent EPT taxa was higher (but not significantly so) at lower Minto Creek than at lower Wolverine Creek. Given that chironomids are generally considered to be tolerant of pollutants and EPT taxa are generally considered to be sensitive to pollutants, this pattern suggests limited influence of the mine on the benthic invertebrate community of lower Minto Creek. High temporal variability has been observed at the exposure and reference area (Minnow 2009b; 2011, 2012a), presumably due to inter-annual variability in environmental conditions (e.g., flow, ice scour).

The chemical quality of biological tissues (periphyton, benthic invertebrates and slimy sculpin) collected at mine-exposed lower Minto Creek and reference areas was reported. Simple comparisons did not indicate any consistent exposed area-reference area differences indicative of a mine-related influence.

7.2 Recommendations

Based on the results and conclusions of the 2012 Minto Mine sediment, periphyton and benthic assessment, it is recommended that the program is repeated in 2013 with the sole modification being that only >500 μm sampling is used for benthic invertebrate community monitoring. The use of the 500 μm cutoff for benthic invertebrate community sampling and analysis is the industry standard (e.g., Environment Canada 2012) and reduces the collection of small organisms/life stages that are difficult to identify precisely. This is now also supported by the 2012 comparison of 250 μm and 500 μm fraction results, which yielded similar findings.

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APPENDIX A

DATA QUALITY ASSESSMENT

APPENDIX A: DATA QUALITY ASSESSMENT

LIST OF TABLES

After Page…

A1.0 INTRODUCTION

Data Quality Assessment (DQA) was conducted on data collected as part of the 2012 Minto Creek Periphyton and Benthic Invertebrate Community Assessment Report. The objective of DQA is to define the overall quality of the data presented in the report, and, by extension, the confidence with which the data can be used to derive conclusions.

A1.1 Background

A variety of factors can influence the chemical and biological measurements made in an environmental study and thus affect the accuracy and/or precision of the data. Inconsistencies in sampling or laboratory methods, use of instruments that are inadequately calibrated or which cannot measure to the desired level of accuracy or precision, and contamination of samples in the field or laboratory are just some of the potential factors that can lead to the reporting of data that do not accurately reflect actual environmental conditions. Depending on the magnitude of the problem, inaccuracy or imprecision have the potential to affect the reliability of any conclusions made from the data. Therefore, it is important to ensure that monitoring programs incorporate appropriate steps to control the non-natural sources of data variability (i.e., minimize the variability that does not reflect natural spatial and temporal variability in the environment) and thus assure the quality of the data.

Data quality as a concept is meaningful only when it relates to the intended use of the data. That is, one must know the context in which the data will be interpreted in order to establish a relevant basis for judging whether or not the data set is adequate. DQA involves comparison of actual field and laboratory measurement performance to data quality objectives (DQOs) established for a particular study, such as evaluation of method detection limits, blank sample data, data precision (based on field and laboratory duplicate samples), and data accuracy (based on matrix spike recoveries and/or analysis of standards or certified reference materials).

DQOs were established at the outset of the field program that reflect reasonable and achievable performance expectations (Table A.1). Programs involving a large amount of samples and analytes usually result in some results that exceed the DQOs. This is particularly so for multi-element scans (e.g., ICP scans for metals) since the analytical conditions are not necessarily optimal for every element included in the scan. Generally, scan results may be considered acceptable if no more than 20% of the parameters fail to meet the DQOs. Overall, the intent of comparing data to DQOs was

Table A.1: Data quality objectives for environmental samples.

Quality Control Measure	Quality Control Sample Type	Study Component			
		Water Quality	Sediment Quality	Benthic Invertebrate Community	Tissue Chemistry
Method Detection Limits (MDL)	Comparison actual MDL versus target MDL	MDL for each parameter should be at least as low as applicable guidelines, ideally ≤1/10th guideline value[a]	MDL for each parameter should be at least as low as applicable guidelines, ideally ≤1/10th guideline value[a]	n/a	MDL as requested based on laboratory's stated performance
Blank Analysis	Laboratory Blank	≤two-times the laboratory MDL	≤two-times the laboratory MDL	n/a	≤two-times the laboratory MDL
Field Precision	Field Duplicates	n/a	n/a	n/a	n/a
Laboratory Precision	Laboratory Duplicates	≤25% RPD	≤35% RPD	n/a	≤35% RPD
	Sub-Sampling Error	n/a	n/a	20% difference between sub-samples	n/a
Accuracy	Recovery of Blank Spikes	80-120%	n/a	n/a	n/a
	Recovery of Matrix Spikes	75-125%	n/a	n/a	n/a
	Recovery of Certified Reference Materials (CRMs)	85-115%	70-130%	n/a	70-130%
	Organism Recovery	n/a	n/a	≥ 90%	n/a

[a] or below predictions, if applicable and no guideline exists for the substance.
[b] RPD - Relative Percent Difference
n/a - not applicable

not to reject any measurement that did not meet the DQO, but to ensure that any questionable data received more scrutiny to determine what effect, if any, this had on interpretation of results within the context of this project.

A1.2 Types of Quality Control Samples

Several types of quality control (QC) samples were assessed based on samples collected (or prepared) in the field and laboratory. These samples, and a description of each, include the following:

- **Blanks** are samples of de-ionized water and/or appropriate reagent(s) that are handled and analyzed the same way as regular samples. These samples will reflect any contamination of samples occurring in the field (in the case of field or travel blanks) or the laboratory (in the case of laboratory or method blanks). Analyte concentrations should be non-detectable although a data quality objective of twice the method detection limit allows for slight “noise” around the detection limit.

- **Laboratory Duplicates** are replicate sub-samples created in the laboratory from randomly selected field samples which are sub-sampled and then analyzed independently using identical analytical methods. The laboratory duplicate sample results reflect any variability introduced during laboratory sample handling and analysis and thus provide a measure of laboratory precision.

- **Spike Recovery Samples** are created in the laboratory by adding a known amount/concentration of a given analyte (or mixture of analytes) to a randomly selected test sample previously divided to create two sub-samples. The spiked and regular sub-samples are then analyzed in an identical manner. The spike recovery represents the difference between the measured spike amount (total amount in spiked sample minus amount in original sample) relative to the known spike amount (as a percentage). Two types of spike recovery samples are commonly analyzed. Spiked blanks (or blank spikes) are created using laboratory control materials whereas matrix spikes are created using field-collected samples. The analysis of spiked samples provides an indication of the accuracy of analytical results.

- **Certified Reference Materials** are samples containing known chemical concentrations that are processed and analyzed along with batches of environmental samples. The sample results are then compared to target results to provide a measure of analytical accuracy. The results are reported as the percent of the known amount that was recovered in the analysis.

The following QC was applied to benthic invertebrate community samples as follows:

- **Organism Recovery Checks** for benthic invertebrate community samples involve the re-processing of previously sorted material from a randomly selected sample to determine the number of invertebrates that were not recovered during the original sample processing. The reprocessing is conducted by an analyst not involved during the original processing to reduce any bias. This check allows the determination of accuracy through assessment of recovery efficiency.

A2.0 WATER SAMPLES

A2.1 Method Detection Limits

Most reported MDLs were at or below the target concentrations with the exception of five analytes: cadmium, copper, mercury, vanadium and fluoride (Table A.2). Even though these MDLs were higher than requested, they were all lower than guideline levels except for fluoride. Therefore, data for this project can be reliably interpreted relative to the guidelines.

A2.2 Laboratory Blank Sample Analysis

All blank samples contained non-detectable analyte concentrations indicating no inadvertent contamination of samples within the laboratory during analysis (Table A.3).

A2.3 Data Precision

Close agreement was generally achieved between laboratory duplicate samples indicating that reported sample results were associated with good analytical precision (Table A.4).

A2.4 Data Accuracy

A2.4.1 Blank Spike Recovery Samples

Analyte recoveries for spiked blanks all met the data quality objectives indicating excellent analytical accuracy for the water sample analyses (Table A.3).

A2.4.2 Matrix Spike Recovery Samples

All analytes measured met the data quality objective of 75 - 125% recovery, but recovery of some analytes could not be calculated (Table A.3). The laboratory reported a qualifier (MS-B) for matrix spike results for phosphorus, dissolved organic carbon, total organic carbon, barium, manganese, sodium, strontium and uranium. For sodium and strontium, over 50% of the samples had the qualifier MS-B. The qualifier MS-B indicated analyses for which recoveries could not be calculated as the spike used had concentrations much lower than the concentration in the sample.

A2.4.3 Certified Reference Materials

Most analyte recoveries from certified reference materials met the data quality objectives (Tables A.3) except for many of the dissolved metal samples. The following samples did not meet the data quality objective of 85 - 115% recovery: aluminum,

Table A.2: Laboratory method detection limits (MDLs) relative to targets and water quality guidelines, Minto Mine, 2012.

Analyte		Units	CCME Water Quality[a]		Method Detection Limit	
			30 Day	Max	Target	Achieved
Physical Tests	Conductivity	µS/cm	-	-	-	2.0
	Hardness (as CaCO3)	mg/L	-	-	-	0.5
	pH	pH units	-	-	-	0.1
	Total Suspended Solids	mg/L	12.7	-	1.27	3.0
	Total Dissolved Solids	mg/L	-	-	-	1.0
	Turbidity	NTU	4.85	-	0.485	0.1
Anions and nutrients	Alkalinity, Total	mg/L	-	-	-	2.0
	Ammonia, Total (as N)	mg/L	0.5[b]		0.05	0.005
	Chloride (Cl)	mg/L	120	640	12	0.5
	Fluoride (F)	mg/L	0.12	-	0.012	0.02
	Nitrate (as N)	mg/L	13	550	1.3	0.01
	Nitrite (as N)	mg/L	0.197	-	0.0197	0.001
	Phosphorus (P)-Total dissolved	mg/L	-	-	-	0.02
	Phosphorus (P)-Total	mg/L	-	-	-	0.02
	Sulfate (SO4)	mg/L	-	-	-	0.5
Cyanides	Cyanide, Total	mg/L	-	-	-	0.005
	Cyanide, Free	mg/L	0.005	-	0.0005	0.001
Organic / inorganic carbon	Dissolved Organic Carbon	mg/L	-	-	-	0.5 - 1.0
	Total Organic Carbon	mg/L	-	-	-	0.5 - 1.0
Total Metals	Total Aluminum (Al)	mg/L	0.1[c]	-	0.01	0.003
	Total Antimony (Sb)	mg/L	-	-	-	0.0001
	Total Arsenic (As)	mg/L	0.005	-	0.0005	0.0001
	Total Barium (Ba)	mg/L	-	-	-	0.00005
	Total Beryllium (Be)	mg/L	-	-	-	0.0001
	Total Bismuth (Bi)	mg/L	-	-	-	0.0005
	Total Boron (B)	mg/L	1.5	2.9	0.15	0.01
	Total Cadmium (Cd)	mg/L	0.00004d	-	0.000004	0.00001
	Total Calcium (Ca)	mg/L	-	-	-	0.05
	Total Chromium (Cr)	mg/L	0.001 Cr(VI)	-	0.0001	0.0001
	Total Cobalt (Co)	mg/L	-	-	-	0.0001
	Total Copper (Cu)	mg/L	0.003[d]	-	0.0003	0.0005
	Total Iron (Fe)	mg/L	0.3	-	0.03	0.01
	Total Lead (Pb)	mg/L	0.005[d]	-	0.0005	0.00005
	Total Lithium (Li)	mg/L	-	-	-	0.0005
	Total Magnesium (Mg)	mg/L	-	-	-	0.1
	Total Manganese (Mn)	mg/L	-	-	-	0.00005
	Total Mercury (Hg)	mg/L	0.00003	-	0.000003	0.00001
	Total Molybdenum (Mo)	mg/L	0.07	-	0.007	0.00005
	Total Nickel (Ni)	mg/L	0.12[d]	-	0.0126	0.0005
	Total Phosphorus (P)	mg/L	-	-	-	0.05
	Total Potassium (K)	mg/L	-	-		0.1
	Total Selenium (Se)	mg/L	0.001	-	0.0001	0.0001
	Total Silicon (Si)	mg/L	-	-	-	0.05
	Total Silver (Ag)	mg/L	0.0001		0.00001	0.00001
	Total Sodium (Na)	mg/L	-	-	-	0.05
	Total Strontium (Sr)	mg/L	-	-	-	0.0002
	Total Thallium (Tl)	mg/L	0.0008	-	0.00008	0.00001
	Total Tin (Sn)	mg/L	-	-	-	0.0001
	Total Titanium (Ti)	mg/L	-	-	-	0.01
	Total Uranium (U)	mg/L	0.015	0.033	0.0015	0.00001
	Total Vanadium (V)	mg/L	-	-	-	0.001
	Total Zinc (Zn)	mg/L	0.03	-	0.003	0.003

* Working guideline

[a] CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. 1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg.

[b] Based on lowest guideline using highest temperature and pH

[c] Based on lowest guideline using highest pH

[d] Based on lowest guideline using lowest hardness

(shaded) value greater than DQO

Table A.3: Laboratory QAQC for water quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Spiked Blank			Matrix Spike			Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Material
Physical tests	Conductivity	µS/cm	< 2.0	< 2.0	-	-	-	-	-	-	147	143	97%	VA-EC-PCT-CONTROL
		µS/cm	< 2.0	< 2.0	-	-	-	-	-	-	147	160	109%	VA-EC-PCT-CONTROL
		µS/cm	< 2.0	< 2.0	-	-	-	-	-	-	147	142	97%	VA-EC-PCT-CONTROL
		µS/cm	< 2.0	< 2.0	-	-	-	-	-	-	147	145	99%	VA-EC-PCT-CONTROL
		µS/cm	< 2.0	< 2.0	-	-	-	-	-	-	147	144	98%	VA-EC-PCT-CONTROL
		µS/cm	< 2.0	< 2.0	-	-	-	-	-	-	147	143	97%	VA-EC-PCT-CONTROL
		µS/cm	< 2.0	< 2.0	-	-	-	-	-	-	147	160	109%	VA-EC-PCT-CONTROL
		µS/cm	< 2.0	< 2.0	-	-	-	-	-	-	147	142	97%	VA-EC-PCT-CONTROL
		µS/cm	< 2.0	< 2.0	-	-	-	-	-	-	147	145	99%	VA-EC-PCT-CONTROL
		µS/cm	< 2.0	< 2.0	-	-	-	-	-	-	147	144	98%	VA-EC-PCT-CONTROL
	pH	pH units	-	-	7.00	6.98	100%	-	-	-	7.00	7.05	101%	VA-PH7-BUF
		pH units	-	-	-	-	-	-	-	-	7.00	6.99	100%	VA-PH7-BUF
		pH units	-	-	-	-	-	-	-	-	7.00	6.97	100%	VA-PH7-BUF
		pH units	-	-	-	-	-	-	-	-	7.00	6.95	99%	VA-PH7-BUF
		pH units	-	-	-	-	-	-	-	-	7.00	6.96	99%	VA-PH7-BUF
		pH units	-	-	-	-	-	-	-	-	7.00	6.95	99%	VA-PH7-BUF
		pH units	-	-	-	-	-	-	-	-	7.00	6.94	99%	VA-PH7-BUF
		pH units	-	-	-	-	-	-	-	-	7.00	6.94	99%	VA-PH7-BUF
	Total Suspended Solids	mg/L	< 3.0	< 3.0	75.0	68.7	92%	-	-	-	-	-	-	-
		mg/L	< 3.0	< 3.0	75.0	81.3	108%	-	-	-	-	-	-	-
		mg/L	< 3.0	< 3.0	75.0	74.3	99%	-	-	-	-	-	-	-
		mg/L	< 3.0	< 3.0	75.0	70.3	94%	-	-	-	-	-	-	-
		mg/L	< 3.0	< 3.0	75.0	68.7	92%	-	-	-	-	-	-	-
	Turbidity	NTU	< 0.1	< 0.1	-	-	-	-	-	-	8.00	8.07	101%	VA-TURB-SPK-8
		NTU	< 0.1	< 0.1	-	-	-	-	-	-	8.00	8.00	100%	VA-TURB-SPK-8
Anions and nutrients	Alkalinity (as $CaCO_3$)	mg/L	< 2.0	< 2.0	50.0	50.3	101%	-	-	-	50.0	48.6	97%	VA-ALK-L-MAN
		mg/L	< 2.5	< 2.5	50.0	50.3	101%	-	-	-	-	-	-	-
		mg/L	< 2.0	< 2.0	-	-	-	-	-	-	-	-	-	-
	Ammonia (as N)	mg/L	< 0.005	< 0.005	-	-	-	0.20	0.21	103%	0.12	0.12	103%	VA-NH3-F
		mg/L	< 0.005	< 0.005	-	-	-	0.21	0.21	99%	0.12	0.11	95%	VA-NH3-F
		mg/L	< 0.005	< 0.005	-	-	-	-	-	-	0.12	0.12	97%	VA-NH3-F
		mg/L	< 0.005	< 0.005	-	-	-	-	-	-	0.12	0.12	98%	VA-NH3-F
		mg/L	< 0.005	< 0.005	-	-	-	-	-	-	0.12	0.12	100%	VA-NH3-F
		mg/L	< 0.005	< 0.005	-	-	-	-	-	-	0.12	0.11	93%	VA-NH3-F
		mg/L	< 0.005	< 0.005	-	-	-	-	-	-	0.12	0.12	98%	VA-NH3-F
		mg/L	< 0.005	< 0.005	-	-	-	-	-	-	0.12	0.12	100%	VA-NH3-F
		mg/L	< 0.005	< 0.005	-	-	-	-	-	-	0.12	0.12	100%	VA-NH3-F
	Chloride (Cl)	mg/L	< 0.5	< 0.5	100	102	102%	64.7	65.2	101%	-	-	-	-
		mg/L	< 0.5	< 0.5	100	99	99%	100	101	101%	-	-	-	-
		mg/L	< 0.5	< 0.5	100	98	98%	-	-	-	-	-	-	-

Table A.3: Laboratory QAQC for water quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Spiked Blank			Matrix Spike			Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Material
Anions and nutrients	Fluoride (F)	mg/L	< 0.02	< 0.02	1.00	0.97	97%	0.56	0.54	95%	-	-	-	-
		mg/L	< 0.02	< 0.02	1.00	1.04	104%	1.23	1.30	106%	-	-	-	-
		mg/L	< 0.02	< 0.02	1.00	1.04	104%	-	-	-	-	-	-	-
	Nitrate (as N)	mg/L	< 0.005	< 0.005	2.50	2.59	104%	1.25	1.30	104%	-	-	-	-
		mg/L	< 0.005	< 0.005	2.50	2.59	104%	1.53	1.56	102%	-	-	-	-
		mg/L	-	-	-	-	-	1.25	1.30	104%	-	-	-	-
		mg/L	-	-	-	-	-	1.53	1.56	102%	-	-	-	-
	Nitrite (as N)	mg/L	< 0.001	< 0.001	0.50	0.52	104%	0.25	0.26	102%	-	-	-	-
		mg/L	< 0.001	< 0.001	0.50	0.52	104%	0.25	0.26	104%	-	-	-	-
		mg/L	-	-	-	-	-	0.25	0.26	102%	-	-	-	-
		mg/L	-	-	-	-	-	0.25	0.26	104%	-	-	-	-
	Phosphorus (P)-Total Dissolved	mg/L	< 0.002	< 0.002	-	-	-	0.06	0.06	98%	3.99	3.93	98%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	3.87	97%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	4.11	103%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	4.15	104%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	4.24	106%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	4.27	107%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	4.04	101%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	4.22	106%	VA-ERA-PO4
	Phosphorus (P)-Total	mg/L	< 0.002	< 0.002	-	-	-	0.05	0.05	101%	3.99	4.02	101%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	0.14	0.13	MS-B	3.99	3.98	100%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	0.05	0.05	99%	3.99	4.04	101%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	0.06	0.06	99%	3.99	4.13	104%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	0.08	0.08	99%	3.99	4.09	103%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	0.06	0.05	94%	3.99	4.19	105%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	0.06	0.06	100%	3.99	3.96	99%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	0.09	0.09	98%	3.99	3.98	100%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	0.05	0.05	98%	3.99	4.03	101%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	4.04	101%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	4.18	105%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	4.03	101%	VA-ERA-PO4
		mg/L	< 0.002	< 0.002	-	-	-	-	-	-	3.99	4.03	101%	VA-ERA-PO4
	Sulfate (SO_4)	mg/L	< 0.5	< 0.5	100	104	104%	75.0	75.2	100%	-	-	-	-
		mg/L	< 0.5	< 0.5	100	102	102%	107	110	103%	-	-	-	-
		mg/L	< 0.5	< 0.5	100	101	101%	-	-	-	-	-	-	-

Table A.3: Laboratory QAQC for water quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Spiked Blank			Matrix Spike			Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Material
Cyanides	Cyanide, Total	mg/L	< 0.005	< 0.005	0.25	0.24	94%	0.25	0.26	103%	-	-	-	-
		mg/L	< 0.005	< 0.005	0.25	0.23	94%	0.32	0.34	104%	-	-	-	-
		mg/L	< 0.005	< 0.005	0.25	0.24	96%	0.25	0.25	102%	-	-	-	-
		mg/L	< 0.005	< 0.005	0.25	0.24	96%	0.25	0.25	102%	-	-	-	-
		mg/L	< 0.005	< 0.005	0.25	0.23	94%	-	-	-	-	-	-	-
		mg/L	< 0.005	< 0.005	0.25	0.24	96%	-	-	-	-	-	-	-
		mg/L	< 0.005	< 0.005	0.25	0.24	96%	-	-	-	-	-	-	-
	Cyanide, Free	mg/L	< 0.001	< 0.001	0.25	0.26	104%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	104%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	104%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	104%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	103%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	104%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	106%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	104%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	104%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	104%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	104%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	103%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	104%	-	-	-	-	-	-	-
		mg/L	< 0.001	< 0.001	0.25	0.26	106%	-	-	-	-	-	-	-
Organic/ inorganic carbon	Dissolved Organic Carbon	mg/L	< 0.5	< 0.5	-	-	-	42.8	42.6	MS-B	8.57	9.34	109%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	6.70	6.56	98%	8.57	9.03	105%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	6.97	6.98	100%	8.57	8.69	101%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	9.35	109%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.42	98%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.59	100%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	9.34	109%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	9.03	105%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.69	101%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.39	98%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.25	96%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.22	96%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.19	96%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.27	96%	VA-DOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.85	103%	VA-DOC-C-CAFFEINE

Table A.3: Laboratory QAQC for water quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Spiked Blank			Matrix Spike			Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Material
Organic/ inorganic carbon	Total Organic Carbon	mg/L	< 0.5	< 0.5	-	-	-	5.00	5.57	111%	8.57	8.55	100%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	11.7	11.5	MS-B	8.57	8.63	101%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	5.00	5.21	104%	8.57	8.69	101%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	10.0	9.68	MS-B	8.57	8.60	100%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	6.22	6.32	102%	8.57	8.83	103%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	5.00	5.57	111%	8.57	8.75	102%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.66	101%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.72	102%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.55	100%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.63	101%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.69	101%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.60	100%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.29	97%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.53	100%	VA-TOC-C-CAFFEINE
		mg/L	< 0.5	< 0.5	-	-	-	-	-	-	8.57	8.45	99%	VA-TOC-C-CAFFEINE
		mg/L	-	-	-	-	-	-	-	-	8.57	8.31	97%	VA-TOC-C-CAFFEINE
		mg/L	-	-	-	-	-	-	-	-	8.57	8.40	98%	VA-TOC-C-CAFFEINE
		mg/L	-	-	-	-	-	-	-	-	8.57	8.41	98%	VA-TOC-C-CAFFEINE
		mg/L	-	-	-	-	-	-	-	-	8.57	8.51	99%	VA-TOC-C-CAFFEINE
Total metals	Aluminum (Al)-Total	mg/L	< 0.003	< 0.003	-	-	-	-	-	-	2.00	2.05	103%	VA-HIGH-WATRM
		mg/L	< 0.003	< 0.003	-	-	-	-	-	-	2.00	2.17	109%	VA-HIGH-WATRM
	Antimony (Sb)-Total	mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	1.00	1.07	107%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	1.00	1.06	106%	VA-HIGH-WATRM
	Arsenic (As)-Total	mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	1.00	0.99	99%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	1.00	1.04	104%	VA-HIGH-WATRM
	Barium (Ba)-Total	mg/L	< 0.00005	< 0.00005	-	-	-	-	-	-	0.25	0.26	103%	VA-HIGH-WATRM
		mg/L	< 0.00005	< 0.00005	-	-	-	-	-	-	0.25	0.26	105%	VA-HIGH-WATRM
	Beryllium (Be)-Total	mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	0.10	0.11	106%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	0.10	0.10	102%	VA-HIGH-WATRM
	Bismuth (Bi)-Total	mg/L	< 0.0005	< 0.0005	-	-	-	-	-	-	1.00	0.99	99%	VA-HIGH-WATRM
		mg/L	< 0.0005	< 0.0005	-	-	-	-	-	-	1.00	1.00	100%	VA-HIGH-WATRM
	Boron (B)-Total	mg/L	< 0.01	< 0.01	-	-	-	-	-	-	1.00	1.00	100%	VA-HIGH-WATRM
		mg/L	< 0.01	< 0.01	-	-	-	-	-	-	1.00	1.00	100%	VA-HIGH-WATRM
	Cadmium (Cd)-Total	mg/L	< 0.00001	< 0.00001	-	-	-	-	-	-	0.10	0.11	105%	VA-HIGH-WATRM
		mg/L	< 0.00001	< 0.00001	-	-	-	-	-	-	0.10	0.11	105%	VA-HIGH-WATRM
	Calcium (Ca)-Total	mg/L	< 0.05	< 0.05	-	-	-	-	-	-	50.0	49.6	99%	VA-HIGH-WATRM
		mg/L	< 0.05	< 0.05	-	-	-	-	-	-	50.0	51.7	103%	VA-HIGH-WATRM
	Chromium (Cr)-Total	mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	0.25	0.26	102%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	0.25	0.26	104%	VA-HIGH-WATRM
	Cobalt (Co)-Total	mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	0.25	0.25	99%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	0.25	0.26	104%	VA-HIGH-WATRM

Table A.3: Laboratory QAQC for water quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Spiked Blank			Matrix Spike			Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Material
Total metals	Copper (Cu)-Total	mg/L	< 0.0005	< 0.0005	-	-	-	-	-	-	0.25	0.24	97%	VA-HIGH-WATRM
		mg/L	< 0.0005	< 0.0005	-	-	-	-	-	-	0.25	0.26	103%	VA-HIGH-WATRM
	Iron (Fe)-Total	mg/L	< 0.01	< 0.01	-	-	-	-	-	-	1.00	0.99	99%	VA-HIGH-WATRM
		mg/L	< 0.01	< 0.01	-	-	-	-	-	-	1.00	1.00	100%	VA-HIGH-WATRM
	Lead (Pb)-Total	mg/L	< 0.00005	< 0.00005	-	-	-	-	-	-	0.50	0.50	99%	VA-HIGH-WATRM
		mg/L	< 0.00005	< 0.00005	-	-	-	-	-	-	0.50	0.51	103%	VA-HIGH-WATRM
	Lithium (Li)-Total	mg/L	< 0.0005	< 0.0005	-	-	-	-	-	-	0.25	0.28	113%	VA-HIGH-WATRM
		mg/L	< 0.0005	< 0.0005	-	-	-	-	-	-	0.25	0.26	104%	VA-HIGH-WATRM
	Magnesium (Mg)-Total	mg/L	< 0.05	< 0.05	-	-	-	-	-	-	50.0	51.0	102%	VA-HIGH-WATRM
		mg/L	< 0.05	< 0.05	-	-	-	-	-	-	50.0	52.5	105%	VA-HIGH-WATRM
	Manganese (Mn)-Total	mg/L	< 0.00005	< 0.00005	-	-	-	-	-	-	0.25	0.26	102%	VA-HIGH-WATRM
		mg/L	< 0.00005	< 0.00005	-	-	-	-	-	-	0.25	0.26	105%	VA-HIGH-WATRM
	Mercury (Hg) - Total	mg/L	< 0.00001	< 0.00001	0.0001	0.0001	97%	0.0001	0.0001	96%	-	-	-	-
		mg/L	< 0.00001	< 0.00001	0.0001	0.0001	96%	0.0001	0.0001	98%	-	-	-	-
		mg/L	< 0.00001	< 0.00001	0.0001	0.0001	93%	0.0001	0.0001	101%	-	-	-	-
		mg/L	< 0.00001	< 0.00001	0.0001	0.0001	90%	0.0001	0.0001	98%	-	-	-	-
		mg/L	< 0.00001	< 0.00001	0.0001	0.0001	91%	0.0001	0.0001	95%	-	-	-	-
		mg/L	-	-	0.0001	0.0001	90%	0.0002	0.0001	95%	-	-	-	-
		mg/L	-	-	0.0001	0.0001	100%	0.0001	0.0001	97%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	98%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	96%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	87%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	97%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	93%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	97%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	97%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	97%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	99%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	98%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	91%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	87%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	91%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	91%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	88%	-	-	-	-
	Molybdenum (Mo)-Total	mg/L	< 0.00005	< 0.00005	-	-	-	-	-	-	0.25	0.26	102%	VA-HIGH-WATRM
		mg/L	< 0.00005	< 0.00005	-	-	-	-	-	-	0.25	0.26	103%	VA-HIGH-WATRM
	Nickel (Ni)-Total	mg/L	< 0.0005	< 0.0005	-	-	-	-	-	-	0.50	0.50	101%	VA-HIGH-WATRM
		mg/L	< 0.0005	< 0.0005	-	-	-	-	-	-	0.50	0.52	104%	VA-HIGH-WATRM
	Phosphorus (P)-Total	mg/L	< 0.05	< 0.05	-	-	-	-	-	-	2.50	2.55	102%	VA-HIGH-WATRM
		mg/L	< 0.05	< 0.05	-	-	-	-	-	-	2.50	2.57	103%	VA-HIGH-WATRM
	Potassium (K)-Total	mg/L	< 0.1	< 0.1	-	-	-	-	-	-	50.0	51.9	104%	VA-HIGH-WATRM
		mg/L	< 0.1	< 0.1	-	-	-	-	-	-	50.0	51.3	103%	VA-HIGH-WATRM

Table A.3: Laboratory QAQC for water quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Spiked Blank			Matrix Spike			Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Material
Total metals	Selenium (Se)-Total	mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	1.00	1.00	100%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	1.00	1.02	102%	VA-HIGH-WATRM
	Silicon (Si)-Total	mg/L	< 0.05	< 0.05	-	-	-	-	-	-	1.00	1.07	107%	VA-HIGH-WATRM
		mg/L	< 0.05	< 0.05	-	-	-	-	-	-	1.00	1.08	108%	VA-HIGH-WATRM
	Silver (Ag)-Total	mg/L	< 0.00001	< 0.00001	-	-	-	-	-	-	0.100	0.102	102%	VA-HIGH-WATRM
		mg/L	< 0.00001	< 0.00001	-	-	-	-	-	-	0.100	0.106	106%	VA-HIGH-WATRM
	Sodium (Na)-Total	mg/L	< 0.05	< 0.05	-	-	-	-	-	-	50.0	52.3	105%	VA-HIGH-WATRM
		mg/L	< 0.05	< 0.05	-	-	-	-	-	-	50.0	53.7	107%	VA-HIGH-WATRM
	Strontium (Sr)-Total	mg/L	< 0.0002	< 0.0002	-	-	-	-	-	-	0.250	0.256	102%	VA-HIGH-WATRM
		mg/L	< 0.0002	< 0.0002	-	-	-	-	-	-	0.250	0.253	101%	VA-HIGH-WATRM
	Thallium (Tl)-Total	mg/L	< 0.00001	< 0.00001	-	-	-	-	-	-	1.00	0.98	98%	VA-HIGH-WATRM
		mg/L	< 0.00001	< 0.00001	-	-	-	-	-	-	1.00	1.02	102%	VA-HIGH-WATRM
	Tin (Sn)-Total	mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	0.500	0.511	102%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	-	-	-	0.500	0.520	104%	VA-HIGH-WATRM
	Titanium (Ti)-Total	mg/L	< 0.01	< 0.01	-	-	-	-	-	-	0.25	0.25	100%	VA-HIGH-WATRM
		mg/L	< 0.01	< 0.01	-	-	-	-	-	-	0.25	0.27	108%	VA-HIGH-WATRM
	Uranium (U)-Total	mg/L	< 0.00001	< 0.00001	-	-	-	-	-	-	0.005	0.005	100%	VA-HIGH-WATRM
		mg/L	< 0.00001	< 0.00001	-	-	-	-	-	-	0.005	0.005	103%	VA-HIGH-WATRM
	Vanadium (V)-Total	mg/L	< 0.001	< 0.001	-	-	-	-	-	-	0.50	0.51	102%	VA-HIGH-WATRM
		mg/L	< 0.001	< 0.001	-	-	-	-	-	-	0.50	0.52	105%	VA-HIGH-WATRM
	Zinc (Zn)-Total	mg/L	< 0.003	< 0.003	-	-	-	-	-	-	0.50	0.48	96%	VA-HIGH-WATRM
		mg/L	< 0.003	< 0.003	-	-	-	-	-	-	0.50	0.47	94%	VA-HIGH-WATRM
Dissovled metals	Aluminum (Al)-Dissolved	mg/L	< 0.001	< 0.001	-	-	-	0.20	0.19	95%	2.00	2.35	118%	VA-HIGH-WATRM
		mg/L	< 0.001	< 0.001	-	-	-	0.20	0.20	99%	2.00	2.35	118%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.23	0.23	103%	-	-	-	-
		mg/L	-	-	-	-	-	0.20	0.19	95%	-	-	-	-
		mg/L	-	-	-	-	-	0.20	0.20	99%	-	-	-	-
		mg/L	-	-	-	-	-	0.23	0.23	103%	-	-	-	-
	Antimony (Sb)-Dissolved	mg/L	< 0.0001	< 0.0001	-	-	-	0.02	0.02	103%	1.00	1.19	119%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	0.02	0.02	104%	1.00	1.19	119%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.02	0.02	104%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	103%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	104%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	104%	-	-	-	-
	Arsenic (As)-Dissolved	mg/L	< 0.0001	< 0.0001	-	-	-	0.02	0.02	108%	1.00	1.13	113%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	0.02	0.02	108%	1.00	1.13	113%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.02	0.02	113%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	108%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	108%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	113%	-	-	-	-

Table A.3: Laboratory QAQC for water quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Spiked Blank			Matrix Spike			Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Material
Dissovled metals	Barium (Ba)-Dissolved	mg/L	< 0.00005	< 0.00005	-	-	-	0.28	0.27	MS-B	0.25	0.29	118%	VA-HIGH-WATRM
		mg/L	< 0.00005	< 0.00005	-	-	-	0.02	0.02	104%	0.25	0.29	118%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.03	0.04	103%	-	-	-	-
		mg/L	-	-	-	-	-	0.28	0.27	MS-B	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	104%	-	-	-	-
		mg/L	-	-	-	-	-	0.03	0.04	103%	-	-	-	-
	Beryllium (Be)-Dissolved	mg/L	< 0.0001	< 0.0001	-	-	-	0.04	0.04	100%	0.10	0.12	116%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	0.04	0.04	105%	0.10	0.12	116%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.04	0.04	105%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	105%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	105%	-	-	-	-
	Bismuth (Bi)-Dissolved	mg/L	< 0.0005	< 0.0005	-	-	-	0.01	0.01	88%	1.00	1.13	113%	VA-HIGH-WATRM
		mg/L	< 0.0005	< 0.0005	-	-	-	0.01	0.01	99%	1.00	1.13	113%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.01	0.01	87%	-	-	-	-
		mg/L	-	-	-	-	-	0.01	0.01	88%	-	-	-	-
		mg/L	-	-	-	-	-	0.01	0.01	99%	-	-	-	-
		mg/L	-	-	-	-	-	0.01	0.01	87%	-	-	-	-
	Boron (B)-Dissolved	mg/L	< 0.01	< 0.01	-	-	-	0.10	0.10	103%	1.0	1.1	110%	VA-HIGH-WATRM
		mg/L	< 0.01	< 0.01	-	-	-	0.10	0.10	100%	1.0	1.1	110%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.11	0.11	98%	-	-	-	-
		mg/L	-	-	-	-	-	0.10	0.10	103%	-	-	-	-
		mg/L	-	-	-	-	-	0.10	0.10	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.11	0.11	98%	-	-	-	-
	Cadmium (Cd)-Dissolved	mg/L	< 0.00001	< 0.00001	-	-	-	0.004	0.004	103%	0.10	0.12	120%	VA-HIGH-WATRM
		mg/L	< 0.00001	< 0.00001	-	-	-	0.004	0.004	105%	0.10	0.12	120%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.004	0.004	103%	-	-	-	-
		mg/L	-	-	-	-	-	0.004	0.004	103%	-	-	-	-
		mg/L	-	-	-	-	-	0.004	0.004	105%	-	-	-	-
		mg/L	-	-	-	-	-	0.004	0.004	103%	-	-	-	-
	Calcium (Ca)-Dissolved	mg/L	< 0.05	< 0.05	-	-	-	-	-	-	50.0	51.2	102%	VA-HIGH-WATRM
		mg/L	< 0.05	< 0.05	-	-	-	-	-	-	50.0	51.2	102%	VA-HIGH-WATRM
	Chromium (Cr)-Dissolved	mg/L	< 0.0001	< 0.0001	-	-	-	0.04	0.04	98%	0.25	0.29	117%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	0.04	0.04	98%	0.25	0.29	117%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.04	0.04	98%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	98%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	98%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	98%	-	-	-	-

Table A.3: Laboratory QAQC for water quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Spiked Blank			Matrix Spike			Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Material
Dissolved metals	Cobalt (Co)-Dissolved	mg/L	< 0.0001	< 0.0001	-	-	-	0.02	0.02	97%	0.25	0.29	114%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	0.02	0.02	100%	0.25	0.29	114%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.02	0.02	98%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	97%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	98%	-	-	-	-
	Copper (Cu)-Dissolved	mg/L	< 0.0002	< 0.0002	-	-	-	0.02	0.02	95%	0.25	0.28	112%	VA-HIGH-WATRM
		mg/L	< 0.0002	< 0.0002	-	-	-	0.02	0.02	100%	0.25	0.28	112%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.02	0.02	95%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	95%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	95%	-	-	-	-
	Iron (Fe)-Dissolved	mg/L	< 0.01	< 0.01	-	-	-	-	-	-	1.00	1.00	100%	VA-HIGH-WATRM
		mg/L	< 0.01	< 0.01	-	-	-	-	-	-	1.00	1.00	100%	VA-HIGH-WATRM
	Lead (Pb)-Dissolved	mg/L	< 0.00005	< 0.00005	-	-	-	0.02	0.02	96%	0.50	0.57	113%	VA-HIGH-WATRM
		mg/L	< 0.00005	< 0.00005	-	-	-	0.02	0.02	102%	0.50	0.57	113%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.02	0.02	94%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	96%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	102%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	94%	-	-	-	-
	Lithium (Li)-Dissolved	mg/L	< 0.0005	< 0.0005	-	-	-	0.11	0.11	100%	0.25	0.30	118%	VA-HIGH-WATRM
		mg/L	< 0.0005	< 0.0005	-	-	-	0.10	0.10	101%	0.25	0.30	118%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.13	0.13	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.11	0.11	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.10	0.10	101%	-	-	-	-
		mg/L	-	-	-	-	-	0.13	0.13	100%	-	-	-	-
	Magnesium (Mg)-Dissolved	mg/L	< 0.05	< 0.05	-	-	-	-	-	-	50.0	51.1	102%	VA-HIGH-WATRM
		mg/L	< 0.05	< 0.05	-	-	-	-	-	-	50.0	51.1	102%	VA-HIGH-WATRM
	Manganese (Mn)-Dissolved	mg/L	< 0.00005	< 0.00005	-	-	-	0.03	0.03	95%	0.25	0.30	118%	VA-HIGH-WATRM
		mg/L	< 0.00005	< 0.00005	-	-	-	0.02	0.02	100%	0.25	0.30	118%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.10	0.10	MS-B	-	-	-	-
		mg/L	-	-	-	-	-	0.03	0.03	95%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.10	0.10	MS-B	-	-	-	-
	Mercury (Hg) - Dissolved	mg/L	-	-	0.0001	0.0001	96%	0.0001	0.0001	95%	-	-	-	-
		mg/L	-	-	0.0001	0.0001	96%	0.0001	0.0001	92%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	97%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	86%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	92%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	95%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	95%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	92%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	97%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	86%	-	-	-	-
		mg/L	-	-	-	-	-	0.0001	0.0001	92%	-	-	-	-

Table A.3: Laboratory QAQC for water quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Spiked Blank			Matrix Spike			Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Material
Dissovled metals	Molybdenum (Mo)-Dissolved	mg/L	< 0.00005	< 0.00005	-	-	-	0.02	0.02	101%	0.25	0.29	114%	VA-HIGH-WATRM
		mg/L	< 0.00005	< 0.00005	-	-	-	0.02	0.02	100%	0.25	0.29	114%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.02	0.02	99%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	101%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	99%	-	-	-	-
	Nickel (Ni)-Dissolved	mg/L	< 0.0005	< 0.0005	-	-	-	0.04	0.04	94%	0.50	0.58	116%	VA-HIGH-WATRM
		mg/L	< 0.0005	< 0.0005	-	-	-	0.04	0.04	101%	0.50	0.58	116%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.04	0.04	95%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	94%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	101%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	95%	-	-	-	-
	Phosphorus (P)-Dissolved	mg/L	< 0.05	< 0.05	-	-	-	-	-	-	2.50	2.55	102%	VA-HIGH-WATRM
		mg/L	< 0.05	< 0.05	-	-	-	-	-	-	2.50	2.55	102%	VA-HIGH-WATRM
	Potassium (K)-Dissolved	mg/L	< 0.1	< 0.1	-	-	-	-	-	-	50.0	50.8	102%	VA-HIGH-WATRM
		mg/L	< 0.1	< 0.1	-	-	-	-	-	-	50.0	50.8	102%	VA-HIGH-WATRM
	Selenium (Se)-Dissolved	mg/L	< 0.0001	< 0.0001	-	-	-	0.04	0.04	101%	1.00	1.13	113%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	0.04	0.04	108%	1.00	1.13	113%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.04	0.04	105%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	101%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	108%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	105%	-	-	-	-
	Silicon (Si)-Dissolved	mg/L	< 0.05	< 0.05	-	-	-	-	-	-	1.00	1.05	105%	VA-HIGH-WATRM
		mg/L	< 0.05	< 0.05	-	-	-	-	-	-	1.00	1.05	105%	VA-HIGH-WATRM
	Silver (Ag)-Dissolved	mg/L	< 0.00001	< 0.00001	-	-	-	0.004	0.004	101%	0.10	0.12	115%	VA-HIGH-WATRM
		mg/L	< 0.00001	< 0.00001	-	-	-	0.004	0.004	105%	0.10	0.12	115%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.004	0.004	101%	-	-	-	-
		mg/L	-	-	-	-	-	0.004	0.004	105%	-	-	-	-
	Sodium (Na)-Dissolved	mg/L	< 0.05	< 0.05	-	-	-	6.69	6.46	MS-B	50.0	59.7	119%	VA-HIGH-WATRM
		mg/L	< 0.05	< 0.05	-	-	-	2.00	2.03	102%	50.0	59.7	119%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	161	157	MS-B	-	-	-	-
		mg/L	-	-	-	-	-	6.69	6.46	MS-B	-	-	-	-
		mg/L	-	-	-	-	-	2.00	2.03	102%	-	-	-	-
		mg/L	-	-	-	-	-	161	157	MS-B	-	-	-	-
	Strontium (Sr)-Dissolved	mg/L	< 0.0002	< 0.0002	-	-	-	0.16	0.15	MS-B	0.25	0.29	116%	VA-HIGH-WATRM
		mg/L	< 0.0002	< 0.0002	-	-	-	0.02	0.02	100%	0.25	0.29	116%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.14	0.14	MS-B	-	-	-	-
		mg/L	-	-	-	-	-	0.16	0.15	MS-B	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.14	0.14	MS-B	-	-	-	-
	Thallium (Tl)-Dissolved	mg/L	< 0.00001	< 0.00001	-	-	-	0.004	0.004	98%	1.00	1.11	111%	VA-HIGH-WATRM
		mg/L	< 0.00001	< 0.00001	-	-	-	0.004	0.004	101%	1.00	1.11	111%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.004	0.004	94%	-	-	-	-
		mg/L	-	-	-	-	-	0.004	0.004	98%	-	-	-	-
		mg/L	-	-	-	-	-	0.004	0.004	101%	-	-	-	-
		mg/L	-	-	-	-	-	0.004	0.004	94%	-	-	-	-

Table A.3: Laboratory QAQC for water quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Spiked Blank			Matrix Spike			Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Target	Achieved	% Recovery	Material
Dissovled metals	Tin (Sn)-Dissolved	mg/L	< 0.0001	< 0.0001	-	-	-	0.02	0.02	102%	0.50	0.59	117%	VA-HIGH-WATRM
		mg/L	< 0.0001	< 0.0001	-	-	-	0.02	0.02	100%	0.50	0.59	117%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.02	0.02	101%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	102%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	101%	-	-	-	-
	Titanium (Ti)-Dissolved	mg/L	< 0.01	< 0.01	-	-	-	0.04	0.04	97%	0.25	0.30	120%	VA-HIGH-WATRM
		mg/L	< 0.01	< 0.01	-	-	-	0.04	0.04	105%	0.25	0.30	120%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.04	0.04	106%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	97%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	105%	-	-	-	-
		mg/L	-	-	-	-	-	0.04	0.04	106%	-	-	-	-
	Uranium (U)-Dissolved	mg/L	< 0.00001	< 0.00001	-	-	-	0.004	0.004	100%	0.01	0.01	114%	VA-HIGH-WATRM
		mg/L	< 0.00001	< 0.00001	-	-	-	0.004	0.004	102%	0.01	0.01	114%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.02	0.02	MS-B	-	-	-	-
		mg/L	-	-	-	-	-	0.004	0.004	100%	-	-	-	-
		mg/L	-	-	-	-	-	0.004	0.004	102%	-	-	-	-
		mg/L	-	-	-	-	-	0.02	0.02	MS-B	-	-	-	-
	Vanadium (V)-Dissolved	mg/L	< 0.001	< 0.001	-	-	-	0.10	0.10	101%	0.50	0.59	118%	VA-HIGH-WATRM
		mg/L	< 0.001	< 0.001	-	-	-	0.10	0.10	99%	0.50	0.59	118%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.10	0.10	103%	-	-	-	-
		mg/L	-	-	-	-	-	0.10	0.10	101%	-	-	-	-
		mg/L	-	-	-	-	-	0.10	0.10	99%	-	-	-	-
		mg/L	-	-	-	-	-	0.10	0.10	103%	-	-	-	-
	Zinc (Zn)-Dissolved	mg/L	< 0.001	< 0.001	-	-	-	0.40	0.37	93%	0.50	0.54	109%	VA-HIGH-WATRM
		mg/L	< 0.001	< 0.001	-	-	-	0.40	0.38	95%	0.50	0.54	109%	VA-HIGH-WATRM
		mg/L	-	-	-	-	-	0.41	0.37	90%	-	-	-	-
		mg/L	-	-	-	-	-	0.40	0.37	93%	-	-	-	-
		mg/L	-	-	-	-	-	0.40	0.38	95%	-	-	-	-
		mg/L	-	-	-	-	-	0.41	0.37	90%	-	-	-	-

(grey box) value greater than DQO

Table A.4: Laboratory duplicate results for water quality, Minto Mine, 2012.

Analyte		Units	Lab Dup		
			Replicate 1	Replicate 2	RPD (%)
Physical Tests	pH	pH units	8.1	8.1	0%
	Total Suspended Solids	mg/L	4.7	5.3	12%
		mg/L	< 3.0	< 3.0	0%
Anions and nutrients	Alkalinity, Total	mg/L	90.5	90.5	0%
	Chloride (Cl)	mg/L	< 0.50	< 0.50	0%
	Fluoride (F)	mg/L	0.23	0.23	0%
	Nitrate (as N)	mg/L	< 0.005	< 0.005	0%
	Nitrite (as N)	mg/L	< 0.001	< 0.001	0%
	Phosphorus (P)-Total	mg/L	0.03	0.03	10%
	Sulfate (SO_4)	mg/L	7.1	7.1	0%
Organic / inorganic carbon	Dissolved Organic Carbon	mg/L	13.1	14.0	7%
	Total Organic Carbon	mg/L	13.8	14.2	3%

value greater than DQO

antimony, barium, beryllium, cadmium, chromium, lithium, manganese, nickel, sodium, strontium, tin, titanium and vanadium. These analytes were over-recovered (they had recoveries greater than 115%). The recovery of reference material indicates good analytical accuracy.

A3.0 SEDIMENT SAMPLES

A3.1 Method Detection Limits

All analytes, except silver, had reported MDLs that were at or below the target MDLs (Table A.5). The MDL achieved for silver was still below guideline levels. Therefore, all data can be reliably interpreted relative to the guidelines.

A3.2 Laboratory Blank Sample Analysis

All blank samples contained non-detectable analyte concentrations indicating no inadvertent contamination of samples within the laboratory during analysis (Table A.6).

A3.3 Data Precision

The laboratory duplicate sediment samples showed very good agreement in analyte concentrations (Tables A.7) indicating very good precision.

A3.4 Data Accuracy

Recoveries of all analytes in certified reference materials met the data quality objective (Table A.6). These data indicated excellent analytical accuracy associated with the analysis of sediment samples.

Table A.5: Laboratory method detection limits (MDLs) relative to targets and to sediment quality guidelines, Minto Mine, 2012.

Analyte		Units	CCME Water Quality Guidelines[a]		Method Detection Limit	
			ISQG[b]	PEL[c]	Target	Achieved
Physical Tests	Loss on Ignition @ 550 C	%	-	-	-	1.0
	pH (1:2 soil:water)	pH units	-	-	-	0.1
Partical Size	% Gravel (> 2 mm)	%	-	-	-	0.1
	% Sand (2.0 mm - 0.063 mm)	%	-	-	-	0.1
	% Silt (0.063 mm - 4 µm)	%	-	-	-	0.1
	% Clay (< 4 µm)	%	-	-	-	0.1
Anions and nutrients	Total Kjeldahl Nitrogen (TKN)	%	-	-	-	0.02
Organic / inorganic carbon	Total Organic Carbon	%	-	-	-	0.1
Metals	Total Aluminum (Al)	mg/kg	-	-	-	50
	Total Antimony (Sb)	mg/kg	-	-	-	0.1
	Total Arsenic (As)	mg/kg	5.9	17	0.59	0.05
	Total Barium (Ba)	mg/kg	-	-	-	0.5
	Total Beryllium (Be)	mg/kg	-	-	-	0.2
	Total Bismuth (Bi)	mg/kg	-	-	-	0.2
	Total Cadmium (Cd)	mg/kg	0.6	3.5	0.06	0.05
	Total Calcium (Ca)	mg/kg	-	-	-	50
	Total Chromium (Cr)	mg/kg	37.3	90	3.73	0.5
	Total Cobalt (Co)	mg/kg	-	-	-	0.1
	Total Copper (Cu)	mg/kg	35.7	197	3.57	0.5
	Total Iron (Fe)	mg/kg	-	-	-	50
	Total Lead (Pb)	mg/kg	35	91.3	3.5	0.5
	Total Lithium (Li)	mg/kg	-	-	-	5
	Total Magnesium (Mg)	mg/kg	-	-	-	20
	Total Manganese (Mn)	mg/kg	-	-	-	1.0
	Total Mercury (Hg)	mg/kg	0.17	0.486	0.017	0.005
	Total Molybdenum (Mo)	mg/kg	-	-	-	0.5
	Total Nickel (Ni)	mg/kg	-	-	-	0.5
	Total Phosphorus (P)	mg/kg	-	-	-	50
	Total Potassium (K)	mg/kg	-	-	-	100
	Total Selenium (Se)	mg/kg	-	-	-	0.2
	Total Silver (Ag)	mg/kg	-	-	-	0.1
	Total Sodium (Na)	mg/kg	-	-	-	100
	Total Strontium (Sr)	mg/kg	-	-	-	0.5
	Total Thallium (Tl)	mg/kg	-	-	-	0.05
	Total Tin (Sn)	mg/kg	-	-	-	2
	Total Titanium (Ti)	mg/kg	-	-	-	1
	Total Uranium (U)	mg/kg	-	-	-	0.05
	Total Vanadium (V)	mg/kg	-	-	-	0.2
	Total Zinc (Zn)	mg/kg	123	315	12.3	1

[a] CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. 1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg.

[b] Interim sediment quality guideline (ISQG)/probable effect level (PEL)

[c] Probable effect level (PEL)

value greater than DQO

Table A.6: Laboratory QAQC for sediment quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Material
Physical tests [a]	Loss of Ignition @ 550 C	%	< 1	< 1	7	7	100%	FARM2009
Partical Size [a]	% Sand (2.0 mm - 0.063 mm)	%	-	-	45.0	45.5	101%	FARM2009
	% Silt (0.063 mm - 4 μm)	%	-	-	35.0	36.9	105%	FARM2009
	% Clay (< 4 μm)	%	-	-	18.0	17.7	98%	FARM2009
Anions and nutrients [a]	Total Kjeldahl Nitrogen (TKN)	mg/L	< 0.02	< 0.02	0.08	0.07	84%	07-114_SOIL
		mg/L	< 0.02	< 0.02	0.08	0.06	76%	07-114_SOIL
Organic/ inorganic carbon [a]	Total Organic Carbon	mg/L	< 0.1	< 0.1	1.10	1.04	95%	08-109_SOIL
Total metals	Aluminum (Al)-Total	mg/L	< 50	< 50	18,200	16,600	91%	VA-CANMET-TILL1
		mg/L	< 50	< 50	18,200	15,800	87%	VA-CANMET-TILL1
		mg/L	< 50	< 50	17,500	15,900	91%	VA-NRC-PACS2
		mg/L	-	-	17,500	15,700	90%	VA-NRC-PACS2
	Antimony (Sb)-Total	mg/L	< 0.1	< 0.1	6.27	6.20	99%	VA-CANMET-TILL1
		mg/L	< 0.1	< 0.1	6.27	6.47	103%	VA-CANMET-TILL1
		mg/L	< 0.1	< 0.1	9.79	9.01	92%	VA-NRC-PACS2
		mg/L	-	-	9.79	9.67	99%	VA-NRC-PACS2
	Arsenic (As)-Total	mg/L	< 0.05	< 0.05	15.4	15.3	99%	VA-CANMET-TILL1
		mg/L	< 0.05	< 0.05	15.4	15.3	99%	VA-CANMET-TILL1
		mg/L	< 0.05	< 0.05	23.3	23.6	101%	VA-NRC-PACS2
		mg/L	-	-	23.3	24.1	103%	VA-NRC-PACS2
	Barium (Ba)-Total	mg/L	< 0.5	< 0.5	80.6	76.2	95%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	80.6	77.6	96%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	294	287	98%	VA-NRC-PACS2
		mg/L	-	-	294	302	103%	VA-NRC-PACS2
	Beryllium (Be)-Total	mg/L	< 0.2	< 0.2	0.54	0.48	89%	VA-CANMET-TILL1
		mg/L	< 0.2	< 0.2	0.54	0.47	87%	VA-CANMET-TILL1
		mg/L	< 0.2	< 0.2	0.41	0.36	88%	VA-NRC-PACS2
		mg/L	-	-	0.41	0.35	85%	VA-NRC-PACS2
	Bismuth (Bi)-Total	mg/L	< 0.2	< 0.2	0.35	0.33	94%	VA-NRC-PACS2
		mg/L	< 0.2	< 0.2	0.35	0.31	89%	VA-NRC-PACS2
		mg/L	< 0.2	< 0.2	-	-	-	-
	Cadmium (Cd)-Total	mg/L	< 0.05	< 0.05	0.23	0.22	94%	VA-CANMET-TILL1
		mg/L	< 0.05	< 0.05	0.23	0.22	94%	VA-CANMET-TILL1
		mg/L	< 0.05	< 0.05	1.98	2.11	107%	VA-NRC-PACS2
		mg/L	-	-	1.98	2.17	110%	VA-NRC-PACS2
	Calcium (Ca)-Total	mg/L	< 50	< 50	3,320	3,180	96%	VA-CANMET-TILL1
		mg/L	< 50	< 50	3,320	3,070	92%	VA-CANMET-TILL1
		mg/L	< 50	< 50	7,790	7,410	95%	VA-NRC-PACS2
		mg/L	-	-	7,790	7,460	96%	VA-NRC-PACS2
	Chromium (Cr)-Total	mg/L	< 0.5	< 0.5	27.2	26.7	98%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	27.2	26.0	96%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	48.1	46.2	96%	VA-NRC-PACS2
		mg/L	-	-	48.1	47.7	99%	VA-NRC-PACS2
	Cobalt (Co)-Total	mg/L	< 0.1	< 0.1	12.5	11.9	95%	VA-CANMET-TILL1
		mg/L	< 0.1	< 0.1	12.5	11.8	94%	VA-CANMET-TILL1
		mg/L	< 0.1	< 0.1	8.75	8.06	92%	VA-NRC-PACS2
		mg/L	-	-	8.75	8.43	96%	VA-NRC-PACS2
	Copper (Cu)-Total	mg/L	< 0.5	< 0.5	44.9	42.2	94%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	44.9	41.6	93%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	297	275	93%	VA-NRC-PACS2
		mg/L	-	-	297	285	96%	VA-NRC-PACS2
	Iron (Fe)-Total	mg/L	< 50	< 50	33,300	30,700	92%	VA-CANMET-TILL1
		mg/L	< 50	< 50	33,300	30,000	90%	VA-CANMET-TILL1
		mg/L	< 50	< 50	31,200	29,000	93%	VA-NRC-PACS2
		mg/L	-	-	31,200	29,800	96%	VA-NRC-PACS2
	Lead (Pb)-Total	mg/L	< 0.5	< 0.5	14.4	12.3	85%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	14.4	13.5	94%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	167	163	98%	VA-NRC-PACS2
		mg/L	-	-	167	166	99%	VA-NRC-PACS2
	Lithium (Li)-Total	mg/L	< 5.0	< 5.0	9.8	9.5	97%	VA-CANMET-TILL1
		mg/L	< 5.0	< 5.0	9.8	9.6	98%	VA-CANMET-TILL1
		mg/L	< 5.0	< 5.0	25.8	21.3	83%	VA-NRC-PACS2
		mg/L	-	-	25.8	22.5	87%	VA-NRC-PACS2
	Magnesium (Mg)-Total	mg/L	< 20	< 20	5,830	5,440	93%	VA-CANMET-TILL1
		mg/L	< 20	< 20	5,830	5,370	92%	VA-CANMET-TILL1
		mg/L	< 20	< 20	9,900	9,380	95%	VA-NRC-PACS2
		mg/L	-	-	9,900	9,490	96%	VA-NRC-PACS2

Table A.6: Laboratory QAQC for sediment quality, Minto Mine, 2012.

Analyte		Units	Method Blank		Reference Material			
			Target	Achieved	Target	Achieved	% Recovery	Material
Total metals	Manganese (Mn)-Total	mg/L	< 1.0	< 1.0	1,100	1,080	98%	VA-CANMET-TILL1
		mg/L	< 1.0	< 1.0	1,100	1,040	95%	VA-CANMET-TILL1
		mg/L	< 1.0	< 1.0	253	238	94%	VA-NRC-PACS2
		mg/L	-	-	253	247	98%	VA-NRC-PACS2
	Mercury (Hg) - Total	mg/L	< 0.005	< 0.005	0.10	0.09	94%	VA-CANMET-TILL1
		mg/L	< 0.005	< 0.005	0.10	0.09	92%	VA-CANMET-TILL1
		mg/L	< 0.005	< 0.005	2.88	2.89	100%	VA-NRC-PACS2
		mg/L	-	-	2.88	3.13	109%	VA-NRC-PACS2
	Molybdenum (Mo)-Total	mg/L	< 0.5	< 0.5	0.74	0.65	88%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	0.74	0.62	84%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	4.57	4.56	100%	VA-NRC-PACS2
		mg/L	-	-	4.57	4.63	101%	VA-NRC-PACS2
	Nickel (Ni)-Total	mg/L	< 0.5	< 0.5	17.4	16.7	96%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	17.4	16.5	95%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	31.6	29.6	94%	VA-NRC-PACS2
		mg/L	-	-	31.6	30.2	96%	VA-NRC-PACS2
	Phosphorus (P)-Total	mg/L	< 50	< 50	796	856	108%	VA-CANMET-TILL1
		mg/L	< 50	< 50	796	733	92%	VA-CANMET-TILL1
		mg/L	< 50	< 50	838	804	96%	VA-NRC-PACS2
		mg/L	-	-	838	801	96%	VA-NRC-PACS2
	Potassium (K)-Total	mg/L	< 100	< 100	620	650	105%	VA-CANMET-TILL1
		mg/L	< 100	< 100	620	530	85%	VA-CANMET-TILL1
		mg/L	< 100	< 100	3,230	2,810	87%	VA-NRC-PACS2
		mg/L	-	-	3,230	2,890	89%	VA-NRC-PACS2
	Selenium (Se)-Total	mg/L	< 0.2	< 0.2	0.32	0.32	100%	VA-CANMET-TILL1
		mg/L	< 0.2	< 0.2	0.32	0.30	94%	VA-CANMET-TILL1
		mg/L	< 0.2	< 0.2	0.92	0.91	99%	VA-NRC-PACS2
		mg/L	-	-	0.92	0.93	101%	VA-NRC-PACS2
	Silver (Ag)-Total	mg/L	< 0.1	< 0.1	0.22	0.21	95%	VA-CANMET-TILL1
		mg/L	< 0.1	< 0.1	0.22	0.21	95%	VA-CANMET-TILL1
		mg/L	< 0.1	< 0.1	1.12	1.09	97%	VA-NRC-PACS2
		mg/L	-	-	1.12	1.08	96%	VA-NRC-PACS2
	Sodium (Na)-Total	mg/L	< 100	< 100	340	320	94%	VA-CANMET-TILL1
		mg/L	< 100	< 100	340	300	88%	VA-CANMET-TILL1
		mg/L	< 100	< 100	18,600	16,600	89%	VA-NRC-PACS2
		mg/L	-	-	18,600	16,800	90%	VA-NRC-PACS2
	Strontium (Sr)-Total	mg/L	< 0.5	< 0.5	11.6	10.7	92%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	11.6	10.4	90%	VA-CANMET-TILL1
		mg/L	< 0.5	< 0.5	68.0	62.5	92%	VA-NRC-PACS2
		mg/L	-	-	68.0	67.6	99%	VA-NRC-PACS2
	Thallium (Tl)-Total	mg/L	< 0.05	< 0.05	0.13	0.11	90%	VA-CANMET-TILL1
		mg/L	< 0.05	< 0.05	0.13	0.11	85%	VA-CANMET-TILL1
		mg/L	< 0.05	< 0.05	0.41	0.38	93%	VA-NRC-PACS2
		mg/L	-	-	0.41	0.38	92%	VA-NRC-PACS2
	Tin (Sn)-Total	mg/L	< 2.0	< 2.0	19.1	19.1	100%	VA-NRC-PACS2
		mg/L	< 2.0	< 2.0	19.1	18.4	96%	VA-NRC-PACS2
		mg/L	< 2.0	< 2.0	-	-	-	-
	Titanium (Ti)-Total	mg/L	< 1.0	< 1.0	764	847	111%	VA-CANMET-TILL1
		mg/L	< 1.0	< 1.0	764	743	97%	VA-CANMET-TILL1
		mg/L	< 1.0	< 1.0	900	1,010	112%	VA-NRC-PACS2
		mg/L	-	-	900	939	104%	VA-NRC-PACS2
	Uranium (U)-Total	mg/L	< 0.05	< 0.05	0.80	0.75	94%	VA-CANMET-TILL1
		mg/L	< 0.05	< 0.05	0.80	0.79	99%	VA-CANMET-TILL1
		mg/L	< 0.05	< 0.05	1.64	1.43	87%	VA-NRC-PACS2
		mg/L	-	-	1.64	1.47	90%	VA-NRC-PACS2
	Vanadium (V)-Total	mg/L	< 0.2	< 0.2	54.9	54.0	98%	VA-CANMET-TILL1
		mg/L	< 0.2	< 0.2	54.9	52.3	95%	VA-CANMET-TILL1
		mg/L	< 0.2	< 0.2	74.4	72.2	97%	VA-NRC-PACS2
		mg/L	-	-	74.4	74.0	99%	VA-NRC-PACS2
	Zinc (Zn)-Total	mg/L	< 1.0	< 1.0	67.5	61.6	91%	VA-CANMET-TILL1
		mg/L	< 1.0	< 1.0	67.5	59.8	89%	VA-CANMET-TILL1
		mg/L	< 1.0	< 1.0	337	320	95%	VA-NRC-PACS2
		mg/L	-	-	337	326	97%	VA-NRC-PACS2

[a] Results reported by the lab as IRM (Internal Reference Material) which is a reference material developed by the lab and is similar to commercially available CRMs.

(grey box) value greater than DQO

Table A.7: Laboratory duplicate results for sediment quality, Minto Mine, 2012.

Analyte		Units	Lab Dup		
			Replicate 1	Replicate 2	RPD (%)
Physical tests	Loss of Ignition @ 550 C	%	6	6	0%
	pH	pH units	8.19	8.24	1%
		pH units	8.08	8.04	0%
Partical Size	% Gravel (> 2 mm)	%	< 0.10	< 0.10	0%
	% Sand (2.0 mm - 0.063 mm)	%	0.97	1.00	3%
	% Silt (0.063 mm - 4 µm)	%	85.7	85.9	0%
	% Clay (< 4 µm)	%	13.4	13.1	2%
Metals	Total Aluminum (Al)	mg/L	10,800	10,300	5%
		mg/L	9,290	9,060	3%
	Total Antimony (Sb)	mg/L	0.41	0.41	0%
		mg/L	0.40	0.42	5%
	Total Arsenic (As)	mg/L	5.16	4.48	14%
		mg/L	4.85	5.45	12%
	Total Barium (Ba)	mg/L	167	150	11%
		mg/L	151	172	13%
	Total Beryllium (Be)	mg/L	0.35	0.31	12%
		mg/L	0.32	0.37	14%
	Total Bismuth (Bi)	mg/L	< 0.20	< 0.20	0%
		mg/L	< 0.20	< 0.20	0%
	Total Cadmium (Cd)	mg/L	0.10	0.10	2%
		mg/L	0.11	0.13	17%
	Total Calcium (Ca)	mg/L	7,860	7,400	6%
		mg/L	7,810	9,090	15%
	Total Chromium (Cr)	mg/L	21.4	20.4	5%
		mg/L	18.2	18.8	3%
	Total Cobalt (Co)	mg/L	6.90	6.35	8%
		mg/L	6.52	7.11	9%
	Total Copper (Cu)	mg/L	16.6	15.1	9%
		mg/L	15.8	18.8	17%
	Total Iron (Fe)	mg/L	17,200	16,300	5%
		mg/L	16,100	17,300	7%
	Total Lead (Pb)	mg/L	5.02	4.77	5%
		mg/L	4.42	4.75	7%
	Total Lithium (Li)	mg/L	7.6	7.5	1%
		mg/L	6.8	7.4	8%
	Total Magnesium (Mg)	mg/L	4,620	4,360	6%
		mg/L	4,220	4,380	4%
	Total Manganese (Mn)	mg/L	320	281	13%
		mg/L	345	408	17%
	Total Mercury (Hg)	mg/L	0.02	0.02	5%
		mg/L	0.03	0.03	13%
	Total Molybdenum (Mo)	mg/L	< 0.5	< 0.5	0%
		mg/L	< 0.5	< 0.5	0%
	Total Nickel (Ni)	mg/L	16.5	15.6	6%
		mg/L	15.8	16.9	7%

Table A.7: Laboratory duplicate results for sediment quality, Minto Mine, 2012.

Analyte		Units	Lab Dup		
			Replicate 1	Replicate 2	RPD (%)
Metals	Total Phosphorus (P)	mg/L	796	713	11%
		mg/L	758	838	10%
	Total Potassium (K)	mg/L	760	710	7%
		mg/L	620	610	2%
	Total Selenium (Se)	mg/L	< 0.2	< 0.2	0%
		mg/L	< 0.2	0.2	18%
	Total Silver (Ag)	mg/L	< 0.1	< 0.1	0%
		mg/L	< 0.1	< 0.1	0%
	Total Sodium (Na)	mg/L	260	260	0%
		mg/L	210	190	10%
	Total Strontium (Sr)	mg/L	59.5	54.7	8%
		mg/L	58.8	68.2	15%
	Total Thallium (Tl)	mg/L	0.07	0.07	0%
		mg/L	0.06	0.06	4%
	Total Tin (Sn)	mg/L	< 2.0	< 2.0	0%
		mg/L	< 2.0	< 2.0	0%
	Total Titanium (Ti)	mg/L	594	585	2%
		mg/L	476	423	12%
	Total Uranium (U)	mg/L	0.65	0.59	9%
		mg/L	0.66	0.75	12%
	Total Vanadium (V)	mg/L	38.7	37.0	4%
		mg/L	35.5	36.0	1%
	Total Zinc (Zn)	mg/L	41.4	39.2	5%
		mg/L	37.7	39.5	5%

value greater than DQO

A4.0 BENTHIC MACROINVERTEBRATE SAMPLES

The objective for percent organism recovery was met for each of the four re-sorted samples, with an average percent recovery of approximately 95% at 250 µm and 99% at 500 µm (Table A.8). Records of sub-sampling were maintained (Table A.9). There was no evaluation of sub-sampling error.

Table A.8: Percent recovery of benthic invertebrates, Minto Mine, 2012.

Site	Initial Sort	Re-sort	Percent sorting efficiency[a]
LMC-1, 250 µm	306	15	95%
LWC-4, 250 µm	240	12	95%
LWC-4, 500 µm	213	2	99%
LWC-3, 500 µm	231	3	99%

[a] percent sorting efficiency = [1-((# in QA/AC re-sort / (# sorted originally + # in QA/QC resort))]* 100

(shaded box) value less than 90%

Table A.9: Percent of benthic sample analyzed for each station.

Area	Station				
	1	2	3	4	5
LMC, 250 µm	38%	100%	100%	100%	100%
LWC, 250 µm	38%	63%	100%	44%	50%
LMC, 500 µm	100%	100%	100%	100%	53%
LWC, 500 µm	10%	14%	13%	11%	6%

A5.0 TISSUE SAMPLES

A5.1 Method Detection Limits

All analytes had reported MDLs that were at or below the target concentrations (Table A.10). Therefore, data are reported reliably.

A5.2 Laboratory Blank Sample Analysis

All blank samples contained non-detectable analyte concentrations indicating no inadvertent contamination of samples within the laboratory during analysis (Table A.10).

A5.3 Data Precision

The laboratory duplicate sediment samples showed very good agreement in analyte concentrations (Tables A.10) indicating very good precision. High variability was reported for concentrations of cadmium, mercury and tin; only for mercury was it excessively high, indicating a potential issue with precision associated with tissue mercury concentrations.

A5.4 Data Accuracy

Recoveries of all analytes in certified reference materials, except for selenium, met the data quality objective (Table A.11). Selenium was slightly over-recovered and reported concentrations could be slightly high. Overall, these data indicated excellent analytical accuracy associated with the analysis of tissue samples.

Table A.10: Laboratory method detection limits and precision for tissue analyses, Minto Mine, 2012.

Analyte	dry or wet weight	Method Detection Limits		Method Blank Results	Laboratory Duplicate Results		
		Target	Achieved		Duplicate 1	Duplicate 2	RPD%
Physical Tests							
% Moisture		0.10	0.10		75.8	73.9	2.6
Metals							
Aluminum (Al)-Total	dw	2.0	2.0	<2	28100	28300	0.9
Aluminum (Al)-Total	ww	0.40	0.40	<0.4	6790	6850	0.9
Antimony (Sb)-Total	dw	0.010	0.010	<0.01	0.038	0.043	14
Antimony (Sb)-Total	ww	0.0020	0.0020	<0.002	0.0091	0.0105	14
Arsenic (As)-Total	dw	0.020	0.020	<0.02	6.18	7.06	13
Arsenic (As)-Total	ww	0.0040	0.0040	<0.004	1.49	1.70	13
Barium (Ba)-Total	dw	0.050	0.050	<0.05	315	339	7.3
Barium (Ba)-Total	ww	0.010	0.010	<0.01	76.2	82.0	7.3
Beryllium (Be)-Total	dw	0.010	0.010	<0.01	1.10	1.20	9.1
Beryllium (Be)-Total	ww	0.0020	0.0020	<0.002	0.265	0.290	9.1
Bismuth (Bi)-Total	dw	0.010	0.010	<0.01	0.132	0.137	3.3
Bismuth (Bi)-Total	ww	0.0020	0.0020	<0.002	0.0320	0.0331	3.3
Boron (B)-Total	dw	1.0	1.0	<1	5.6	6.2	10
Boron (B)-Total	ww	0.20	0.20	<0.2	1.36	1.51	10
Cadmium (Cd)-Total	dw	0.010	0.010	<0.01	0.300	0.439	38
Cadmium (Cd)-Total	ww	0.0020	0.0020	<0.002	0.0725	0.106	38
Calcium (Ca)-Total	dw	30	30	<30	13900	15900	14
Calcium (Ca)-Total	ww	5.0	5.0	<5	3360	3850	14
Cesium (Cs)-Total	dw	0.0050	0.0050	<0.005	3.36	3.45	2.8
Cesium (Cs)-Total	ww	0.0010	0.0010	<0.001	0.811	0.833	2.8
Chromium (Cr)-Total	dw	0.050	0.050	<0.05	73.8	74.6	1.1
Chromium (Cr)-Total	ww	0.010	0.010	<0.01	17.8	18.0	1.1
Cobalt (Co)-Total	dw	0.020	0.020	<0.02	16.8	17.6	4.6
Cobalt (Co)-Total	ww	0.0040	0.0040	<0.004	4.05	4.24	4.6
Copper (Cu)-Total	dw	0.050	0.050	<0.05	38.2	44.0	14
Copper (Cu)-Total	ww	0.010	0.010	<0.01	9.22	10.6	14
Gallium (Ga)-Total	dw	0.020	0.020	<0.02	8.13	8.26	1.6
Gallium (Ga)-Total	ww	0.0040	0.0040	<0.004	1.96	1.99	1.6
Iron (Fe)-Total	dw	1.0	1.0	<1	32200	33700	4.5
Iron (Fe)-Total	ww	0.20	0.20	<0.2	7790	8150	4.5
Lead (Pb)-Total	dw	0.020	0.020	<0.02	7.69	7.81	1.6
Lead (Pb)-Total	ww	0.0040	0.0040	<0.004	1.86	1.89	1.6
Lithium (Li)-Total	dw	0.10	0.10	<0.1	17.6	18.0	2.2
Lithium (Li)-Total	ww	0.020	0.020	<0.02	4.24	4.34	2.2
Magnesium (Mg)-Total	dw	50	50	<50	11900	12700	5.9
Magnesium (Mg)-Total	ww	10	10	<10	2880	3060	5.9
Manganese (Mn)-Total	dw	0.020	0.020	<0.02	900	1070	17
Manganese (Mn)-Total	ww	0.0040	0.0040	<0.004	217	259	17
Mercury (Hg)-Total	dw	0.0050	0.0050	<0.005	0.0101	0.0844	157
Mercury (Hg)-Total	ww	0.0010	0.0010	<0.001	0.0024	0.0204	157
Molybdenum (Mo)-Total	dw	0.020	0.020	<0.02	0.420	0.452	7.4
Molybdenum (Mo)-Total	ww	0.0040	0.0040	<0.004	0.101	0.109	7.4
Nickel (Ni)-Total	dw	0.050	0.050	<0.05	44.1	45.2	2.4
Nickel (Ni)-Total	ww	0.010	0.010	<0.01	10.7	10.9	2.4
Phosphorus (P)-Total	dw	200	200	<200	1090	1240	14
Phosphorus (P)-Total	ww	50	50	<50	262	300	13
Potassium (K)-Total	dw	1000	1000	<1000	2500	2800	8.3
Potassium (K)-Total	ww	200	200	<200	610	670	8.3
Rhenium (Re)-Total	dw	0.010	0.010	<0.01	<0.010	<0.010	N/A
Rhenium (Re)-Total	ww	0.0020	0.0020	<0.002	<0.0020	<0.0020	N/A
Rubidium (Rb)-Total	dw	0.050	0.050	<0.05	26.3	27.2	3.1
Rubidium (Rb)-Total	ww	0.010	0.010	<0.01	6.36	6.56	3.1
Selenium (Se)-Total	dw	0.10	0.10	<0.1	0.67	0.80	18
Selenium (Se)-Total	ww	0.020	0.020	<0.02	0.161	0.193	18
Sodium (Na)-Total	dw	1000	1000	<1000	<1000	<1000	N/A
Sodium (Na)-Total	ww	200	200	<200	<200	<200	N/A
Strontium (Sr)-Total	dw	0.050	0.050	<0.05	122	132	8.4
Strontium (Sr)-Total	ww	0.010	0.010	<0.01	29.4	32.0	8.4
Tellurium (Te)-Total	dw	0.020	0.020	<0.02	0.022	0.027	18
Tellurium (Te)-Total	ww	0.0040	0.0040	<0.004	0.0054	0.0065	18
Thallium (Tl)-Total	dw	0.0020	0.0020	<0.002	0.185	0.193	4.0
Thallium (Tl)-Total	ww	0.00040	0.00040	<0.0004	0.0447	0.0465	4.0
Thorium (Th)-Total	dw	0.010	0.010	<0.01	5.21	5.39	3.4
Thorium (Th)-Total	ww	0.0020	0.0020	<0.002	1.26	1.30	3.4
Tin (Sn)-Total	dw	0.020	0.020	<0.02	0.181	0.270	40
Tin (Sn)-Total	ww	0.0040	0.0040	<0.004	0.0437	0.0653	40
Titanium (Ti)-Total	dw	0.050	0.050	<0.05	1420	1370	4.0
Titanium (Ti)-Total	ww	0.010	0.010	<0.01	344	330	4.0
Uranium (U)-Total	dw	0.0020	0.0020	<0.002	2.21	2.67	19
Uranium (U)-Total	ww	0.00040	0.00040	<0.0004	0.533	0.645	19
Vanadium (V)-Total	dw	0.020	0.020	<0.02	92.1	100	8.6
Vanadium (V)-Total	ww	0.0040	0.0040	<0.004	22.3	24.3	8.6
Yttrium (Y)-Total	dw	0.010	0.010	<0.01	14.6	15.7	7.5
Yttrium (Y)-Total	ww	0.0020	0.0020	<0.002	3.52	3.79	7.5
Zinc (Zn)-Total	dw	0.50	0.50	<0.5	85.8	88.0	2.5
Zinc (Zn)-Total	ww	0.10	0.10	<0.1	20.7	21.3	2.5
Zirconium (Zr)-Total	dw	0.20	0.20	<0.2	19.7	20.6	4.6
Zirconium (Zr)-Total	ww	0.040	0.040	<0.04	4.76	4.98	4.6

[grey box] indicates an instance when the DQO was not achieved

Table A.11: Laboratory accuracy for tissue analyses, Minto Mine, 2012.

	Certified Reference Material	dry weight concentrations (mg/kg dw)		
		Achieved Value	Certified Value	% Recovery
Aluminum (Al)-Total	VA-NIST-1547	248	199	124.5
Antimony (Sb)-Total	VA-NIST-1547	0.018	0.020	90.0
Arsenic (As)-Total	VA-NRC-DOLT4	10.0	9.66	104.0
Barium (Ba)-Total	VA-NIST-1547	119	124	95.8
Cadmium (Cd)-Total	VA-NIST-1547	0.024	0.026	92.3
Cadmium (Cd)-Total	VA-NRC-DOLT4	26.9	24.3	110.6
Calcium (Ca)-Total	VA-NIST-1547	17500	15600	112.4
Calcium (Ca)-Total	VA-NRC-DOLT4	665	680	97.8
Chromium (Cr)-Total	VA-NIST-1547	0.845	1.00	84.5
Chromium (Cr)-Total	VA-NRC-DOLT4	1.28	1.40	91.2
Cobalt (Co)-Total	VA-NIST-1547	0.062	0.060	103.3
Cobalt (Co)-Total	VA-NRC-DOLT4	0.227	0.250	90.9
Copper (Cu)-Total	VA-NIST-1547	4.02	3.70	108.7
Copper (Cu)-Total	VA-NRC-DOLT4	34.5	31.2	110.4
Iron (Fe)-Total	VA-NIST-1547	196	218	90.1
Iron (Fe)-Total	VA-NRC-DOLT4	1740	1830	95.1
Lead (Pb)-Total	VA-NIST-1547	0.752	0.870	86.5
Lead (Pb)-Total	VA-NRC-DOLT4	0.114	0.160	71.5
Magnesium (Mg)-Total	VA-NIST-1547	4720	4320	109.2
Magnesium (Mg)-Total	VA-NRC-DOLT4	1460	1500	97.1
Manganese (Mn)-Total	VA-NIST-1547	103	98.0	104.8
Mercury (Hg)-Total	VA-NIST-1547	0.0342	0.0310	110.4
Mercury (Hg)-Total	VA-NRC-DOLT4	2.40	2.58	93.2
Molybdenum (Mo)-Total	VA-NRC-DOLT4	1.06	1.00	105.6
Nickel (Ni)-Total	VA-NRC-DOLT4	0.883	0.970	91.0
Phosphorus (P)-Total	VA-NIST-1547	1490	1370	109.0
Potassium (K)-Total	VA-NIST-1547	27800	24300	114.3
Potassium (K)-Total	VA-NRC-DOLT4	10100	9800	103.5
Rubidium (Rb)-Total	VA-NIST-1547	19.3	19.7	97.8
Selenium (Se)-Total	VA-NIST-1547	0.16	0.12	133.3
Selenium (Se)-Total	VA-NRC-DOLT4	9.33	8.30	112.4
Sodium (Na)-Total	VA-NRC-DOLT4	7200	6800	105.9
Strontium (Sr)-Total	VA-NIST-1547	52.4	53.0	98.9
Strontium (Sr)-Total	VA-NRC-DOLT4	4.95	5.50	90.0
Thorium (Th)-Total	VA-NIST-1547	0.032	0.045	72.2
Tin (Sn)-Total	VA-NRC-DOLT4	0.127	0.170	74.9
Vanadium (V)-Total	VA-NIST-1547	0.307	0.370	83.1
Vanadium (V)-Total	VA-NRC-DOLT4	0.536	0.600	89.3
Zinc (Zn)-Total	VA-NIST-1547	20.4	17.9	113.8
Zinc (Zn)-Total	VA-NRC-DOLT4	137	116	118.4

(shaded) indicates an instance when the DQO (70% - 130% recovery) was not achieved

A6.0 DATA QUALITY STATEMENT

The overall quality of data for this project was adequate to serve the project objectives.

APPENDIX B

SUPPORTING INFORMATION AND DATA

Table B.1: Habitat characteristics for benthic invertebrate areas, Minto Mine, September 2012.

Characteristics		Lower Wolverine Creek (Reference)	Lower Minto Creek (Exposure)
Latitude (dd mm ss.s)		62° 42' 27.2"	62° 38' 49.9"
Longitude (ddd mm ss.s)		137° 17' 46.5"	137° 06' 08.1"
Approximate Length of Reach Assessed (m)		-	40
Gradient (%)		1.5	1 (low gradient but plunge below)
Depth (m)	Mean	0.18	0.18
	Maximum	-	0.26
Width (m)	Wetted	6	1.8
	Bankfull	13	2.8
General Morphology	% pool	0	0
	% riffle	80	0
	% run	20	100
Bank Condition		Moderate	Stable - no Bank Erosion
Substrate Coverage	% bedrock	0	0
	% boulder	0	0
	% cobble	60	70
	% gravel	35	30
	% sand and finer	5	0
Instream Cover (% total Surface)	undercut banks	0	2
	boulder	0	0
	woody debris	2 - 5	5
	deep pool	0	0
	macrophytes	0	0
	other	0	0
Overhead Canopy (%Surface)	Dense	-	0
	Partially Open	20	100
	Open	80	0
Aquatic Vegetation (% areal coverage)	Emergent	0	0
	Submergent	0	0
	Floating	0	0
	Attached Algae	22 (green)	0
Riparian vegetation		willow, alder, spruce	willow, alder, spruce
Surrounding Land Use		forested	forested
Evidence of Anthropogenic Disturbance		-	Mine upstream
General Comments/Notes		overcast, log jam	overcast, calm, small log jams

Table B.2: Erosional benthic invertebrate grab sample collections, Minto Mine, September 2012.

Characteristics		Lower Wolverine Creek (Reference)				
		LWC-1	LWC-2	LWC-3	LWC-4	LWC-5
Latitude (dd mm ss.s)		62° 42' 30.5"	62° 42' 15.4"	62° 42' 17.9"	62° 42' 25.2"	62° 42' 27.2"
Longitude (ddd mm ss.s)		137° 17' 45.1"	137° 17' 54.1"	137° 17' 51.4"	137° 17' 14.6"	137° 17' 46.5"
Sampling Device		Hess	Hess	Hess	Hess	Hess
Sampler Size (m^2)		0.1	0.1	0.1	0.1	0.1
Mesh Size (μm)		250	250	250	250	250
Grabs in Comosite		3	3	3	3	3
Water Velocity (m/s)		0.58	0.48	0.55	0.54	0.51
Depth (m)		0.16	0.19	-	0.16	0.18
Number of Jars		1	1	1	1	1
Average Depth (Sampler pushed into substrate)		10	10	10	10	10
Average Depth (substrate is sampled/cleaned)		10	10	10	10	10
Average Sampling Time per Grab (min)		8	8	8	6 - 8	7
Macrophytes (in sample)		none	none	none	none	none
Algae (in sample)		sparse (skim of green algae)	none	sparse (green)	sparse (green)	sparse (some green)
Sample Texture	% cobble	60	80	75	70	60
	% gravel	35	15	50	25	35
	% sand and finer	5	5	5	5	5
	% organic	0	0	0	0	0

Table B.2: Erosional benthic invertebrate grab sample collections, Minto Mine, September 2012.

Characteristics		Lower Minto Creek (Exposure)				
		LMC-1	LMC-2	LMC-3	LMC-4	LMC-5
Latitude (dd mm ss.s)		62° 38' 50.1"	62° 38' 49.9"	62° 38' 48.9"	62° 38' 49.3"	62° 38' 49.9" (08V 0392246)
Longitude (ddd mm ss.s)		137° 06' 18.1"	137° 06' 16.4"	137° 06' 10.1"	137° 06' 09.1"	137° 06' 08.1" (6948037)
Sampling Device		Hess	Hess	Hess	Hess	Hess
Sampler Size (m^2)		0.1	0.1	0.1	0.1	0.1
Mesh Size (µm)		250	250	250	250	250
Grabs in Comosite		3	3	3	3	3
Water Velocity (m/s)		0.45	0.39	0.59	0.51	0.58
Depth (m)		0.16	0.18	0.18	0.20	0.18
Number of Jars		1	1	1	1	1
Average Depth (Sampler pushed into substrate)		10	10	10	10	10
Average Depth (substrate is sampled/cleaned)		10	10	10	10	10
Average Sampling Time per Grab (min)		8	8	8	7	7
Macrophytes (in sample)		none	none	none	none	none
Algae (in sample)		none	none	none	none	none
Sample Texture	% cobble	70	75	60	60	70
	% gravel	25	50	35	35	30
	% sand and finer	5	5	5	5	trace
	% organic	0	0	0	0	0

Table B.3: *In situ* measures at benthic invertebrate stations, Minto Mine WUL, September 2012. Shade indicates value does not meet WUL standard or water quality guideline.

Area	Variable	Temperature	Specific Conductance	Dissolved Oxygen	Dissolved Oxygen	pH	Mean Depth	Mean Velocity
	Unit	°C	µS/cm	mg/L	%	pH units	m	m/s
	Water Quality Guidelines	-	-	7	54	6.5-9.0[a]	-	-
Upper McGinty Creek (Reference)	URC	2.12	140	11.68	84.4	7.38	-	-
Upper Minto Creek (Exposure)	UMC	3.46	505	13	95	7.76	-	-
Lower Wolverine Creek (Reference)	LWC-1	4.56	208	10.39	81.1	7.26	0.16	0.58
	LWC-2	3.80	202	12.75	96.8	7.78	0.19	0.48
	LWC-3	3.80	205	12.56	95.5	7.91	-	0.55
	LWC-4	4.28	210	10.92	83.8	7.46	0.16	0.54
	LWC-5	4.06	208	11.28	86.2	7.39	0.18	0.51
	Mean	4.10	207	11.58	88.7	7.56	0.17	0.53
	Standard Deviation	0.33	3	1.03	7.1	0.27	0.015	0.038
Lower Minto Creek (Exposure)	LMC-1	6.31	293	12.37	99.0	8.56	0.16	0.45
	LMC-2	5.99	289	12.35	99.3	8.32	0.18	0.39
	LMC-3	5.83	290	12.38	99.1	8.28	0.18	0.59
	LMC-4	5.45	273	12.47	99.0	8.08	0.20	0.51
	LMC-5	5.11	282	12.37	97.2	8.06	0.18	0.58
	Mean	5.74	285	12.39	98.7	8.26	0.18	0.50
	Standard Deviation	0.47	8	0.05	0.9	0.204	0.014	0.085

[a] Range for the Water Use Licence is 6.0 - 9.0

[c] see Appendix Table B.4 for explanatory notes on selected water quality guidelines.

Note: data for dissolved oxygen at upper Minto Creek was accidentally lost; however, observed percent saturation at the time of the survey was >80% at each station.

Table B.4: Water quality results at reference and exposure areas, Minto Mine WUL, September 5th to 8th, 2012.

Analyte		Units	LWC (reference)	URC (reference)	LBC (reference)	LMC (exposure)	UMC (exposure)
Sampling Dates:			7-Sep-12	8-Sep-12	6-Sep-12	5-Sep-12	6-Sep-12
Physical Tests	Conductivity	µS/cm	197	139	191	275	482
	Hardness (as $CaCO_3$)	mg/L	104	77.5	92.1	146	239
	pH	ph Units	8.00	7.93	8.14	8.25	7.97
	Total Suspended Solids	mg/L	22.0	4.7	12.7	425	< 3.0
	Total Dissolved Solids	mg/L	123	91.6	116	158	253
	Turbidity	NTU	6.11	3.58	-	-	-
Leachable Anions & Nutrients	Anion Sum	meq/L	2.06	1.44	2.06	2.82	4.72
	Cation Sum	meq/L	2.40	1.80	2.21	3.29	5.65
	Cation - Anion Balance	%	7.6	11.2	3.5	7.8	9.0
Anions and Nutrients	Alkalinity, Total	mg/L	86.7	63.9	90.5	140	223
	Ammonia, Total (as N)	mg/L	0.010	0.007	< 0.005	0.036	< 0.005
	Chloride (Cl)	mg/L	< 0.5	< 0.5	0.8	< 0.5	< 0.5
	Fluoride (F)	mg/L	0.13	0.23	0.15	< 0.02	0.06
	Nitrate (as N)	mg/L	< 0.005	< 0.005	0.079	< 0.005	0.097
	Nitrite (as N)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	Phosphorus (P)-Total dissolved	mg/L	0.02	0.03	-	-	-
	Phosphorus (P)-Total	mg/L	0.032	0.031	0.014	0.298	0.005
	Sulfate (SO4)	mg/L	15.6	7.06	10.4	0.74	12.2
Cyanides	Cyanide, Total	mg/L	< 0.005	< 0.005	-	-	-
	Cyanide, Free	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Organic/ inorganic carbon	Dissolved Organic Carbon	mg/L	13.1	11.6	9.3	11.3	6.2
	Total Organic Carbon	mg/L	13.8	13.3	9.8	13.2	5.9
Total Metals	Total Aluminum (Al)	mg/L	0.56	0.11	0.30	6.76	0.01
	Total Antimony (Sb)	mg/L	0.0002	0.0002	0.0002	0.0003	< 0.0001
	Total Arsenic (As)	mg/L	0.0009	0.0012	0.0014	0.0045	0.0003
	Total Barium (Ba)	mg/L	0.05	0.05	0.07	0.24	0.08
	Total Beryllium (Be)	mg/L	< 0.0001	< 0.0001	< 0.0001	0.0003	< 0.0001
	Total Bismuth (Bi)	mg/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
	Total Boron (B)	mg/L	0.01	< 0.01	0.01	0.01	0.03
	Total Cadmium (Cd)	mg/L	0.00002	< 0.00001	0.00001	0.00012	< 0.00001
	Total Calcium (Ca)	mg/L	22.2	20.3	23.6	45.3	55.7
	Total Chromium (Cr)	mg/L	0.0020	0.0013	0.0008	0.0126	0.0002
	Total Cobalt (Co)	mg/L	0.0005	0.0005	0.0002	0.0050	< 0.0001
	Total Copper (Cu)	mg/L	0.003	0.002	0.003	0.017	0.002
	Total Iron (Fe)	mg/L	0.97	1.46	0.49	11.80	0.02
	Total Lead (Pb)	mg/L	0.00021	0.00006	0.00018	0.00314	< 0.00005
	Total Lithium (Li)	mg/L	0.0019	< 0.0005	0.0013	0.0051	0.0025
	Total Magnesium (Mg)	mg/L	11.5	5.9	9.5	14.4	25.1
	Total Manganese (Mn)	mg/L	0.05	0.14	0.03	0.42	0.05
	Total Mercury (Hg)	mg/L	< 0.00001	< 0.00001	< 0.00001	0.00002	< 0.00001
	Total Molybdenum (Mo)	mg/L	0.0007	0.0011	0.0011	0.0013	0.0049
	Total Nickel (Ni)	mg/L	0.003	0.002	0.002	0.014	0.001
	Total Phosphorus (P)	mg/L	< 0.05	< 0.05	< 0.05	0.408	< 0.05
	Total Potassium (K)	mg/L	0.90	0.48	0.84	1.67	2.19
	Total Selenium (Se)	mg/L	0.0002	0.00029	< 0.0001	0.00027	0.00044
	Total Silicon (Si)	mg/L	6.77	6.93	7.49	19.20	5.71
	Total Silver (Ag)	mg/L	0.00017	0.00001	< 0.00001	0.00006	< 0.00001
	Total Sodium (Na)	mg/L	6.98	3.94	7.48	7.59	18.7

Table B.4: Water quality results at reference and exposure areas, Minto Mine WUL, September 5th to 8th, 2012.

	Analyte	Units	LWC (reference)	URC (reference)	LBC (reference)	LMC (exposure)	UMC (exposure)
Sampling Dates:			7-Sep-12	8-Sep-12	6-Sep-12	5-Sep-12	6-Sep-12
Total Metals	Total Strontium (Sr)	mg/L	0.19	0.12	0.25	0.35	0.61
	Total Thallium (Tl)	mg/L	< 0.00001	< 0.00001	< 0.00001	0.000057	< 0.00001
	Total Tin (Sn)	mg/L	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001
	Total Titanium (Ti)	mg/L	0.02	< 0.01	0.01	0.22	< 0.01
	Total Uranium (U)	mg/L	0.0007	0.0003	0.0019	0.0015	0.0028
	Total Vanadium (V)	mg/L	0.0032	0.0015	0.0019	0.0226	< 0.001
	Total Zinc (Zn)	mg/L	0.003	< 0.003	< 0.003	0.0264	< 0.003
Dissolved Metals	Dissolved Aluminum (Al)	mg/L	0.0293	0.0491	0.0347	0.0384	0.0027
	Dissolved Antimony (Sb)	mg/L	< 0.0001	< 0.0001	0.0001	0.0001	< 0.0001
	Dissolved Arsenic (As)	mg/L	0.0006	0.0010	0.0009	0.0010	0.0003
	Dissolved Barium (Ba)	mg/L	0.04	0.04	0.07	0.07	0.08
	Dissolved Beryllium (Be)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Dissolved Bismuth (Bi)	mg/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
	Dissolved Boron (B)	mg/L	< 0.01	< 0.01	< 0.01	< 0.01	0.021
	Dissolved Cadmium (Cd)	mg/L	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001
	Dissolved Calcium (Ca)	mg/L	22.5	21.1	22.2	39.4	55.0
	Dissolved Chromium (Cr)	mg/L	0.0005	0.0005	0.0004	0.0005	< 0.0001
	Dissolved Cobalt (Co)	mg/L	0.0002	0.0005	< 0.0001	0.0003	< 0.0001
	Dissolved Copper (Cu)	mg/L	0.002	0.002	0.002	0.002	0.002
	Dissolved Iron (Fe)	mg/L	0.23	1.19	0.11	0.56	0.02
	Dissolved Lead (Pb)	mg/L	< 0.00005	< 0.00005	< 0.00005	0.00014	< 0.00005
	Dissolved Lithium (Li)	mg/L	0.0014	< 0.0005	0.0013	0.0010	0.0027
	Dissolved Magnesium (Mg)	mg/L	11.6	6.1	8.9	11.5	24.8
	Dissolved Manganese (Mn)	mg/L	0.03	0.13	0.02	0.08	0.05
	Dissolved Mercury (Hg)	mg/L	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001
	Dissolved Molybdenum (Mo)	mg/L	0.0005	0.0009	0.0010	0.0011	0.0047
	Dissolved Nickel (Ni)	mg/L	0.002	0.002	0.001	0.002	0.001
	Dissolved Phosphorus (P)	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
	Dissolved Potassium (K)	mg/L	0.82	0.51	0.76	0.92	2.19
	Dissolved Selenium (Se)	mg/L	0.0001	0.0003	< 0.0001	0.0001	0.0004
	Dissolved Silicon (Si)	mg/L	5.70	6.96	6.70	6.86	5.73
	Dissolved Silver (Ag)	mg/L	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001
	Dissolved Sodium (Na)	mg/L	6.7	3.7	7.8	7.4	18.6
	Dissolved Strontium (Sr)	mg/L	0.17	0.12	0.24	0.28	0.61
	Dissolved Thallium (Tl)	mg/L	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001
	Dissolved Tin (Sn)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Dissolved Titanium (Ti)	mg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	Dissolved Uranium (U)	mg/L	0.0006	0.0003	0.0017	0.0010	0.0027
	Dissolved Vanadium (V)	mg/L	0.001	0.001	0.001	0.002	< 0.001
	Dissolved Zinc (Zn)	mg/L	< 0.001	0.002	0.001	0.002	< 0.001

Table B.5: Explanatory notes for selected water quality guidelines, Minto Mine WUL, 2012.

Analyte		Water Quality Guidelines	Unit	CCME[a]
Physical, anion and nutrient analytes	**Ammonia (Total)**	**0.502**	mg/L	Ammonia guideline is based on highest field pH of 8.56 and highest temperature of 6.6°C
	Fluoride	**0.12**	mg/L	Guideline is an interm level
	Total Suspended Solids	**17.7**	mg/L	Guideline is based on the median of background of 12.7 mg/L plus 5 mg/L
	Turbidity	**6.85**	NTU	Guideline is based on the median of background of 4.85 NTU plus 2 NTU
Total Metals	**Aluminum**	**0.1**	mg/L	Guideline is baded on pH of > 6.5
	Cadmium	**0.000044**	mg/L	Guideline is based on lowest hardness of 139 mg/L.
	Chromium	**0.001**	mg/L	Guideline is based hexavalent chromium (Cr VI).
	Copper	**0.00313**	mg/L	Guideline is based on lowest hardness of 139 mg/L.
	Lead	**0.00484**	mg/L	Guideline is based on lowest hardness of 139 mg/L.
	Nickel	**0.12276**	mg/L	Guideline is based on lowest hardness of 139 mg/L.

[a] CCME (Canadian Council of Ministers of the Environment). 1999 (plus updates). Canadian Environmental Quality Guidelines. CCME, Winnipeg.

Table B.6: Comparing water quality results at reference and exposure areas in 2011 and 2012, Minto Mine WUL.

	Analyte	Units	CCME Water Quality[a]		WUL Limits at W2	2011				2012				
			30	Max		Upper McGinty Creek (reference)	Upper Minto Creek (exposure)	Lower Wolverine Creek (reference)	Lower Minto Creek (exposure)	Upper McGinty Creek (reference)	Upper Minto Creek (exposure)	Lower Wolverine Creek (reference)	Lower Minto Creek (exposure)	Little Big Creek (reference)
Physical Tests	Total Suspended Solids	mg/L	12.7	-	-	7.7	<3.0	24.5	24.5	4.7	< 3.0	22.0	425.0	12.7
Total Metals	Total Aluminum (Al)	mg/L	0.1[c]	-	0.62	0.284	0.0103	0.818	0.717	0.11	0.01	0.56	6.76	0.30
	Total Antimony (Sb)	mg/L	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	0.0002	< 0.0001	0.0002	0.0003	0.0002
	Total Arsenic (As)	mg/L	0.005	-	0.005	0.00076	0.00028	0.00077	0.00128	0.0012	0.0003	0.0009	0.0045	0.0014
	Total Barium (Ba)	mg/L	-	-	-	0.0467	0.0833	0.0520	0.0747	0.048	0.083	0.053	0.242	0.071
	Total Beryllium (Be)	mg/L	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	< 0.0001	< 0.0001	< 0.0001	0.0003	< 0.0001
	Total Bismuth (Bi)	mg/L	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
	Total Boron (B)	mg/L	1.5	2.9	-	<0.010	0.022	0.010	<0.010	< 0.01	0.03	0.01	0.01	0.01
	Total Cadmium (Cd)	mg/L	0.00004d	-	0.00004	<0.000010	<0.000010	0.000017	0.000014	< 0.00001	< 0.00001	0.00002	0.00012	0.00001
	Total Calcium (Ca)	mg/L	-	-	-	17.5	59.6	21.3	37.0	20.3	55.7	22.2	45.3	23.6
	Total Chromium (Cr)	mg/L	0.001 Cr(VI)	-	0.002	0.00109	0.00048	0.00236	0.00167	0.0013	0.0002	0.0020	0.0126	0.0008
	Total Cobalt (Co)	mg/L	-	-	-	0.00052	<0.00010	0.00067	0.00073	0.0005	< 0.0001	0.0005	0.0050	0.0002
	Total Copper (Cu)	mg/L	0.003[d]	-	0.013	0.00254	0.00192	0.00363	0.00278	0.002	0.002	0.003	0.017	0.003
	Total Iron (Fe)	mg/L	0.3	-	1.1	1.16	<0.030	1.39	1.95	1.46	0.02	0.97	11.80	0.49
	Total Lead (Pb)	mg/L	0.005[d]	-	0.004	0.000110	<0.000050	0.000330	0.000303	0.00006	< 0.00005	0.00021	0.00314	0.00018
	Total Lithium (Li)	mg/L	-	-	-	0.00073	0.00224	0.00158	0.00128	< 0.0005	0.0025	0.0019	0.0051	0.0013
	Total Magnesium (Mg)	mg/L	-	-	-	5.20	23.8	11.1	10.7	5.9	25.1	11.5	14.4	9.5
	Total Manganese (Mn)	mg/L	-	-	-	0.0910	0.0174	0.0591	0.163	0.14	0.05	0.05	0.42	0.03
	Total Mercury (Hg)	mg/L	-	-	-	<0.000010	<0.000010	-	-	< 0.00001	< 0.00001	< 0.00001	0.00002	< 0.00001
	Total Molybdenum (Mo)	mg/L	0.073	-	0.073	0.000789	0.00340	0.000558	0.00113	0.0011	0.0049	0.0007	0.0013	0.0011
	Total Nickel (Ni)	mg/L	0.12[d]	-	0.11	0.00188	0.00075	0.00353	0.00276	0.002	0.001	0.003	0.014	0.002
	Total Phosphorus (P)	mg/L	-	-	-	-	-	-	-	< 0.05	< 0.05	< 0.05	0.41	< 0.05
	Total Potassium (K)	mg/L	-	-	-	0.404	2.13	0.637	0.936	0.48	2.19	0.90	1.67	0.84
	Total Selenium (Se)	mg/L	0.001	-	0.001	0.00021	0.00034	0.00020	0.00013	0.0003	0.0004	0.0002	0.0003	< 0.0001
	Total Silicon (Si)	mg/L	-	-	-	7.61	5.58	7.82	8.66	6.93	5.71	6.77	19.20	7.49
	Total Silver (Ag)	mg/L	0.0001	-	-	<0.000010	<0.000010	<0.000010	<0.000010	0.00001	< 0.00001	0.00017	0.00006	< 0.00001
	Total Sodium (Na)	mg/L	-	-	-	3.57	16.5	6.48	6.25	3.94	18.70	6.98	7.59	7.48
	Total Strontium (Sr)	mg/L	-	-	-	0.109	0.636	0.199	0.269	0.120	0.611	0.187	0.351	0.250
	Total Thallium (Tl)	mg/L	0.0008	-	-	<0.000010	<0.000010	<0.000010	<0.000010	< 0.00001	< 0.00001	< 0.00001	0.00006	< 0.00001
	Total Tin (Sn)	mg/L	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001
	Total Titanium (Ti)	mg/L	-	-	-	0.017	0.011	0.040	0.032	< 0.01	< 0.01	0.02	0.22	0.01
	Total Uranium (U)	mg/L	0.015	0.033	-	0.000258	0.00292	0.000912	0.000785	0.0003	0.0028	0.0007	0.0015	0.0019
	Total Vanadium (V)	mg/L	-	-	-	0.0020	<0.0010	0.0042	0.0032	0.002	< 0.001	0.003	0.023	0.002
	Total Zinc (Zn)	mg/L	0.03	-	0.03	<0.0030	<0.0030	0.0035	0.0035	< 0.003	< 0.003	0.003	0.026	< 0.003

Water use licence standard not met (boxed cells)

Water quality guideline not met (shaded cells)

[a] CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. 1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg. See Appendix Table B.4 for explanatory notes on selected water quality guidelines.

[b] Based on lowest guideline using highest temperature and pH

[c] Based on lowest guideline using highest pH

[d] Based on lowest guideline using lowest hardness

Table B.7: Concentration of chlorophyll *a* measured at five benthic stations in lower Wolverine and lower Minto Creeks, Minto Mine WUL, 2012.

Lower Wolverine Creek (reference)		**Lower Minto Creek (exposure)**	
Station	mg/m^2	Station	mg/m^2
LWC-1	11.6	LMC-1	0.25
LWC-2	6.7	LMC-2	1.21
LWC-3	1.1	LMC-3	0.39
LWC-4	27.0	LMC-4	0.28
LWC-5	24.6	LMC-5	0.39
Mean	14.2	Mean	0.51
Standard Deviation	11.3	Standard Deviation	0.40

APPENDIX C

SEDIMENT, PERIPHYTON AND BENTHIC INVERTEBRATE QUALITY DATA

Table C.1: Sediment chemistry data collected at exposed and reference areas, Minto Mine WUL, 2012.

	Analytes	Units	CSQG [a]		Upper McGinty Creek (Reference)					Lower Wolverine Creek (Reference)				
					URC-1	URC-2	URC-3	URC-4	URC-5	LWC-1	LWC-2	LWC-3	LWC-4	LWC-5
			ISQG	PEL	8-Sep-12	8-Sep-12	8-Sep-12	8-Sep-12	8-Sep-12	8-Sep-12	8-Sep-12	8-Sep-12	8-Sep-12	8-Sep-12
Particle size, TKN, carbon analytes and pH	Loss on Ignition @ 550 C	%			-	-	-	-	-	24	14	21	20	24
	pH (1:2 soil:water)	pH units			7.19	7.29	6.86	7.03	6.83	7.71	6.93	7.27	6.99	7.46
	% Gravel (>2mm)	%			-	-	-	-	-	< 0.1	< 0.1	< 0.1	0.5	< 0.1
	% Sand (2.0mm - 0.063mm)	%			-	-	-	-	-	1.0	42.4	10.1	18.8	2.0
	% Silt (0.063mm - 4um)	%			-	-	-	-	-	85.7	50.9	79.1	69.2	85.8
	% Clay (<4um)	%			-	-	-	-	-	13.4	6.74	10.8	11.5	12.2
	Total Kjeldahl Nitrogen (TKN)	%			0.67	0.50	0.48	0.31	0.47	0.60	0.32	0.52	0.43	0.65
	Total Organic Carbon	%			-	-	-	-	-	11.30	6.10	9.91	9.58	10.90
Total Metals	Aluminum (Al)	mg/kg			13,400	15,400	16,700	14,400	14,900	20,700	17,600	17,800	14,800	18,000
	Antimony (Sb)	mg/kg			0.57	0.53	0.57	0.45	0.57	0.59	0.58	0.56	0.54	0.53
	Arsenic (As)	mg/kg	5.9	17	8.81	12.2	9.41	7.77	10.7	6.21	7.27	6.10	6.21	6.38
	Barium (Ba)	mg/kg			359	399	355	287	340	335	309	307	260	290
	Beryllium (Be)	mg/kg			0.52	0.52	0.51	0.41	0.50	0.94	0.88	0.87	0.81	0.80
	Bismuth (Bi)	mg/kg			< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	Cadmium (Cd)	mg/kg	0.6	3.5	0.31	0.26	0.24	0.17	0.25	0.37	0.37	0.34	0.30	0.34
	Calcium (Ca)	mg/kg			14,300	12,800	11,100	9,500	12,300	13,900	12,000	12,500	11,700	11,600
	Chromium (Cr)	mg/kg	37.3	90	29.8	32.4	34.4	28.6	31.9	60.4	54.7	55.7	44.8	53.8
	Cobalt (Co)	mg/kg			14.0	16.3	13.8	12.6	12.5	15.9	14.9	14.9	13.3	15.0
	Copper (Cu)	mg/kg	35.7	197	38	34	34	26	35	42	39	39	34	38
	Iron (Fe)	mg/kg			28,800	35,500	32,700	27,300	31,400	31,300	30,600	29,700	26,500	29,500
	Lead (Pb)	mg/kg	35	91.3	5.92	6.18	6.52	5.77	6.15	8.01	7.62	7.57	10.4	6.88
	Lithium (Li)	mg/kg			7.9	9.3	10.3	8.8	9.0	13.7	12.1	12.1	10.3	11.3
	Magnesium (Mg)	mg/kg			4,900	5,280	5,640	5,080	4,990	10,300	9,280	9,790	8,560	10,100
	Manganese (Mn)	mg/kg			1,870	2,430	1,320	1,370	1,090	792	827	718	716	785
	Mercury (Hg)	mg/kg	0.17	0.49	0.099	0.068	0.064	0.050	0.073	0.061	0.063	0.059	0.056	0.059
	Molybdenum (Mo)	mg/kg			1.13	0.71	0.63	0.53	0.66	0.52	0.52	0.53	0.53	< 0.50
	Nickel (Ni)	mg/kg			23	24	24	20	22	45	41	42	37	42
	Phosphorus (P)	mg/kg			916	1,030	982	877	1,050	977	1,010	982	941	995
	Potassium (K)	mg/kg			630	730	780	710	690	950	850	860	730	890
	Selenium (Se)	mg/kg			0.77	0.80	0.64	0.47	0.57	0.64	0.59	0.63	0.54	0.60
	Silver (Ag)	mg/kg			0.14	0.12	0.12	< 0.1	0.13	0.15	0.14	0.13	0.14	0.13
	Sodium (Na)	mg/kg			190	200	210	210	200	310	300	300	310	330
	Strontium (Sr)	mg/kg			119	107	89	78	96	139	124	123	114	116
	Thallium (Tl)	mg/kg			0.076	0.082	0.084	0.080	0.082	0.108	0.097	0.107	0.078	0.095
	Tin (Sn)	mg/kg			< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
	Titanium (Ti)	mg/kg			537	658	709	738	631	749	696	696	611	725
	Uranium (U)	mg/kg			1.97	1.71	1.39	1.28	1.50	2.69	2.66	2.68	2.83	2.72
	Vanadium (V)	mg/kg			60	63	63	54	60	76	72	71	64	71
	Zinc (Zn)	mg/kg	123	315	49	54	56	52	51	67	62	63	57	64

[a] Canadian Sediment Quality Guidelines - ISQG = interim sediment quality guideline;
PEL = probable effect level (CCME 1999).

Indicates sediment concentration exceeding CSQG ISQG.

Indicates sediment concentration exceeding CSQG PEL.

Table C.1: Sediment chemistry data collected at exposed and reference areas, Minto Mine WUL, 2012.

	Analytes	Units	CSQG [a]		Upper Minto Creek (Exposure)					Lower Minto Creek (Exposure)				
					UMC-1	UMC-2	UMC-3	UMC-4	UMC-5	LMC-1	LMC-2	LMC-3	LMC-4	LMC-5
			ISQG	PEL	13-Sep-11	13-Sep-11	13-Sep-11	13-Sep-11	13-Sep-11	6-Sep-12	6-Sep-12	6-Sep-12	6-Sep-12	6-Sep-12
Particle size, TKN, carbon analytes and pH	Loss on Ignition @ 550 C	%			-	-	-	-	-	7	5	10	12	6
	pH (1:2 soil:water)	pH units			7.72	8.18	8.00	7.83	8.19	8.13	8.19	8.01	7.99	8.08
	% Gravel (>2mm)	%			-	-	-	-	-	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
	% Sand (2.0mm - 0.063mm)	%			-	-	-	-	-	1.0	1.2	5.9	4.2	4.8
	% Silt (0.063mm - 4um)	%			-	-	-	-	-	85.2	90.2	86.0	85.4	86.2
	% Clay (<4um)	%			-	-	-	-	-	13.9	8.59	8.13	10.5	8.98
	Total Kjeldahl Nitrogen (TKN)	%			0.10	0.07	0.08	0.13	0.07	0.17	0.10	0.20	0.25	0.14
	Total Organic Carbon	%			-	-	-	-	-	2.98	1.71	4.07	5.71	2.60
Total Metals	Aluminum (Al)	mg/kg			10,500	9,830	12,000	13,000	10,700	12,100	10,800	10,200	11,400	9,290
	Antimony (Sb)	mg/kg			0.27	0.32	0.34	0.47	0.39	0.52	0.41	0.48	0.56	0.40
	Arsenic (As)	mg/kg	5.9	17	5.25	5.40	5.59	6.31	5.68	6.09	5.16	6.99	7.44	4.85
	Barium (Ba)	mg/kg			181	175	180	238	196	216	167	199	240	151
	Beryllium (Be)	mg/kg			0.32	0.44	0.37	0.54	0.43	0.40	0.35	0.43	0.49	0.32
	Bismuth (Bi)	mg/kg			< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	Cadmium (Cd)	mg/kg	0.6	3.5	0.18	0.15	0.15	0.22	0.17	0.14	0.10	0.16	0.20	0.11
	Calcium (Ca)	mg/kg			5,200	6,400	6,020	8,870	6,890	9,540	7,860	10,300	12,200	7,810
	Chromium (Cr)	mg/kg	37.3	90	24.6	23.8	27.4	30.7	25.1	24.9	21.4	20.1	23.8	18.2
	Cobalt (Co)	mg/kg			10.0	10.1	10.5	12.3	10.5	8.4	6.9	8.1	9.5	6.5
	Copper (Cu)	mg/kg	35.7	197	133	97	103	120	116	21	17	21	25	16
	Iron (Fe)	mg/kg			22,500	22,500	23,300	25,100	22,500	20,900	17,200	19,700	22,100	16,100
	Lead (Pb)	mg/kg	35	91.3	4.22	5.27	4.99	6.49	5.32	5.83	5.02	5.24	5.91	4.42
	Lithium (Li)	mg/kg			5.9	7.2	7.1	9.2	7.4	8.7	7.6	7.8	9.0	6.8
	Magnesium (Mg)	mg/kg			7,420	7,530	7,850	9,430	7,360	5,370	4,620	4,810	5,630	4,220
	Manganese (Mn)	mg/kg			1,470	1,710	1,050	2,010	1,820	445	320	545	631	345
	Mercury (Hg)	mg/kg	0.17	0.49	0.018	0.015	0.023	0.024	0.016	0.032	0.025	0.037	0.044	0.027
	Molybdenum (Mo)	mg/kg			1.05	1.28	0.92	1.59	1.31	0.51	< 0.5	0.57	0.66	< 0.5
	Nickel (Ni)	mg/kg			32	35	34	47	35	20	17	19	22	16
	Phosphorus (P)	mg/kg			1,040	958	1,000	985	985	761	796	860	787	758
	Potassium (K)	mg/kg			1,120	1,130	1,340	1,350	1,330	940	760	810	870	620
	Selenium (Se)	mg/kg			0.36	0.28	0.28	0.49	0.32	0.24	< 0.20	0.27	0.36	< 0.20
	Silver (Ag)	mg/kg			< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
	Sodium (Na)	mg/kg			310	370	350	450	410	280	260	230	240	210
	Strontium (Sr)	mg/kg			48	63	64	94	70	76	60	83	101	59
	Thallium (Tl)	mg/kg			0.052	0.056	0.067	0.082	0.071	0.094	0.066	0.069	0.079	0.055
	Tin (Sn)	mg/kg			< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
	Titanium (Ti)	mg/kg			578	623	661	738	667	644	594	536	568	476
	Uranium (U)	mg/kg			0.53	0.55	0.57	0.93	0.60	0.81	0.65	0.95	1.06	0.66
	Vanadium (V)	mg/kg			50	51	53	57	50	46	39	42	47	36
	Zinc (Zn)	mg/kg	123	315	66	61	63	71	68	49	41	42	49	38

[a] Canadian Sediment Quality Guidelines - ISQG = interim sediment quality guideline; PEL = probable effect level (CCME 1999).

Indicates sediment concentration exceeding CSQG ISQG.

Indicates sediment concentration exceeding CSQG PEL.

Table C.2: Periphyton tissue quality results at reference and exposure areas, Minto Mine WUL, 2012

	Analyte	Units	LWC-1 (reference)	LWC-2 (reference)	LWC-3 (reference)	LWC-4 (reference)	LWC-5 (reference)	LWC Mean	LWC Standard Deviation	LBC (reference)	LMC (exposure)
Physical Tests	Moisture	%	85.7	79.8	75.8	86.9	82.5	82.1	4.5	59.3	51.9
Total Metals	Total Aluminum (Al)	mg/kg dw	32,800	31,600	28,100	33,900	30,800	31,440	2,207	21,500	21,100
	Total Antimony (Sb)	mg/kg dw	0.04	0.04	0.04	0.04	0.04	0.04	0.00	0.03	0.02
	Total Arsenic (As)	mg/kg dw	8.14	8.88	6.18	9.28	8.51	8.20	1.21	13.90	4.24
	Total Barium (Ba)	mg/kg dw	375	371	315	379	363	361	26	260	284
	Total Beryllium (Be)	mg/kg dw	1.33	1.21	1.10	1.29	1.22	1.23	0.09	0.692	0.664
	Total Bismuth (Bi)	mg/kg dw	0.146	0.141	0.132	0.154	0.144	0.143	0.008	0.451	0.125
	Total Boron (B)	mg/kg dw	< 7.0	12.6	5.6	7.5	< 7.0	17.5	20.3	5.6	4.9
	Total Cadmium (Cd)	mg/kg dw	0.40	0.42	0.30	0.36	0.40	0.38	0.05	0.24	0.18
	Total Calcium (Ca)	mg/kg dw	15,400	15,400	13,900	16,700	15,600	15,400	997	11,500	16,200
	Total Cesium (Cs)	mg/kg dw	4.00	3.91	3.36	4.24	3.79	3.86	0.32	2.38	1.65
	Total Chromium (Cr)	mg/kg dw	84.7	81.6	73.8	88.6	79.8	81.7	5.5	43.6	51.4
	Total Cobalt (Co)	mg/kg dw	19.9	20.3	16.8	21.0	19.7	19.5	1.6	10.6	10.3
	Total Copper (Cu)	mg/kg dw	46.2	46.3	38.2	45.9	45.4	44.4	3.5	30.9	26.3
	Total Gallium (Ga)	mg/kg dw	9.32	9.19	8.13	9.98	9.05	9.13	0.66	6.71	6.80
	Total Iron (Fe)	mg/kg dw	38,600	37,800	32,200	40,500	37,900	37,400	3,102	26,000	28,000
	Total Lead (Pb)	mg/kg dw	8.43	8.26	7.69	8.97	8.13	8.30	0.47	7.32	6.72
	Total Lithium (Li)	mg/kg dw	20.4	19.4	17.6	21.2	19.3	19.6	1.4	12.3	12.9
	Total Magnesium (Mg)	mg/kg dw	13,000	13,300	11,900	15,600	13,900	13,540	1,361	8,460	7,230
	Total Manganese (Mn)	mg/kg dw	1,490	1,710	900	1,850	1,680	1,526	373	653	1,130
	Total Mercury (Hg)	mg/kg dw	0.11	0.14	0.01	0.12	0.08	0.09	0.05	0.07	0.06
	Total Molybdenum (Mo)	mg/kg dw	0.49	0.52	0.42	0.49	0.52	0.49	0.04	0.68	0.43
	Total Nickel (Ni)	mg/kg dw	51.8	49.6	44.1	54.6	50.9	50.2	3.9	25.1	23.9
	Total Phosphorus (P)	mg/kg dw	1,310	1,420	1,090	1,510	1,620	1,390	203	1,190	1,060
	Total Potassium (K)	mg/kg dw	3,100	3,100	2,500	4,500	3,500	3,340	740	2,600	2,400
	Total Rhenium (Re)	mg/kg dw	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0	< 0.01	< 0.01
	Total Rubidium (Rb)	mg/kg dw	31.6	30.6	26.3	35.4	30.4	30.9	3.2	19.3	16.5
	Total Selenium (Se)	mg/kg dw	0.97	0.92	0.67	0.95	0.85	0.87	0.12	0.3	0.21
	Total Sodium (Na)	mg/kg dw	< 1,000	< 1,000	< 1,000	< 1,000	< 1,000	< 1,000	0	< 1,000	< 1,000
	Total Strontium (Sr)	mg/kg dw	143	134	122	137	131	133	8	91	104
	Total Tellurium (Te)	mg/kg dw	0.03	0.03	0.02	0.03	0.03	0.03	0.00	0.05	< 0.02
	Total Thallium (Tl)	mg/kg dw	0.21	0.21	0.19	0.24	0.22	0.21	0.02	0.15	0.14
	Total Thorium (Th)	mg/kg dw	5.98	5.58	5.21	6.40	5.51	5.74	0.46	5.50	7.56
	Total Tin (Sn)	mg/kg dw	0.20	0.29	0.18	0.25	0.24	0.23	0.04	0.04	< 0.02
	Total Titanium (Ti)	mg/kg dw	1,480	1,490	1,420	1,580	1,390	1,472	73	1,000	1,020
	Total Uranium (U)	mg/kg dw	2.76	2.69	2.21	2.41	2.52	2.52	0.22	1.08	1.32
	Total Vanadium (V)	mg/kg dw	109	110	92	111	105	105	8	75	81
	Total Yttrium (Y)	mg/kg dw	16.3	16.1	14.6	16.2	15.4	15.7	0.7	13.3	17.1
	Total Zinc (Zn)	mg/kg dw	101	97	86	104	98	97	7	79	73
	Total Zirconium (Zr)	mg/kg dw	23.2	22.4	19.7	24.6	22.4	22.5	1.8	10.6	12.4

bold Indicates periphyton tissue concentration exceeding the higher reference mean by more than 2 times

Table C.3: Benthic tissue quality results at reference and exposure areas, Minto Mine WUL, 2012.

Analyte		Units	LWC (reference)	LBC (reference)	LMC (exposure)
Physical Tests	Moisture	%	80.1	85.4	90.7
Total Metals	Total Aluminum (Al)	mg/kg dw	4,890	2,440	8,720
	Total Antimony (Sb)	mg/kg dw	< 0.01	0.05	0.08
	Total Arsenic (As)	mg/kg dw	2.05	2.86	5.32
	Total Barium (Ba)	mg/kg dw	71	48	**196**
	Total Beryllium (Be)	mg/kg dw	0.23	0.09	0.35
	Total Bismuth (Bi)	mg/kg dw	0.03	0.07	0.07
	Total Boron (B)	mg/kg dw	< 2.0	< 3.0	**20.3**
	Total Cadmium (Cd)	mg/kg dw	0.27	0.37	0.31
	Total Calcium (Ca)	mg/kg dw	3,040	3,630	**9,450**
	Total Cesium (Cs)	mg/kg dw	0.54	0.25	0.82
	Total Chromium (Cr)	mg/kg dw	12.4	17.2	16.9
	Total Cobalt (Co)	mg/kg dw	3.94	2.44	5.38
	Total Copper (Cu)	mg/kg dw	17.3	18.5	33.2
	Total Gallium (Ga)	mg/kg dw	1.57	0.85	2.70
	Total Iron (Fe)	mg/kg dw	7,640	5,400	13,500
	Total Lead (Pb)	mg/kg dw	1.32	1.30	**3.34**
	Total Lithium (Li)	mg/kg dw	2.96	1.87	5.03
	Total Magnesium (Mg)	mg/kg dw	3,120	2,160	3,440
	Total Manganese (Mn)	mg/kg dw	360	256	**782**
	Total Mercury (Hg)	mg/kg dw	0.07	0.06	0.08
	Total Molybdenum (Mo)	mg/kg dw	0.72	1.64	3.21
	Total Nickel (Ni)	mg/kg dw	8.88	5.19	11.3
	Total Phosphorus (P)	mg/kg dw	5,750	5,030	4,250
	Total Potassium (K)	mg/kg dw	6,200	7,300	5,400
	Total Rhenium (Re)	mg/kg dw	< 0.01	< 0.01	< 0.01
	Total Rubidium (Rb)	mg/kg dw	5.93	2.65	9.51
	Total Selenium (Se)	mg/kg dw	1.01	0.83	1.14
	Total Sodium (Na)	mg/kg dw	4,300	6,100	3,000
	Total Strontium (Sr)	mg/kg dw	26.0	34.3	**74.3**
	Total Tellurium (Te)	mg/kg dw	< 0.02	< 0.02	< 0.02
	Total Thallium (Tl)	mg/kg dw	0.04	0.02	0.07
	Total Thorium (Th)	mg/kg dw	1.02	0.66	**2.39**
	Total Tin (Sn)	mg/kg dw	< 0.02	0.03	**0.35**
	Total Titanium (Ti)	mg/kg dw	28	102	**404**
	Total Uranium (U)	mg/kg dw	0.60	1.28	1.29
	Total Vanadium (V)	mg/kg dw	21.5	14.7	37.5
	Total Yttrium (Y)	mg/kg dw	2.70	1.76	**7.37**
	Total Zinc (Zn)	mg/kg dw	93.0	74.0	96.1
	Total Zirconium (Zr)	mg/kg dw	2.89	1.42	**5.80**

bold Indicates periphyton tissue concentration exceeding the higher reference mean by more than 2 times

Table C.4: Slimy sculpin tissue quality results at reference and exposure areas, Minto Mine WUL, 2012.

	Analyte	Units	Lower Big Creek (reference)										Lower Minto Creek (exposure)								
			REF-01	REF-02	REF-03	REF-04	REF-05	REF-06	REF-07	REF-08	Mean	Standard Deviation	EXP-01	EXP-02	EXP-03	EXP-04	EXP-05	EXP-06	EXP-07	Mean	Standard Deviation
Meristics	Weight	g	1.34	1.94	1.40	3.22	1.45	1.54	1.53	1.79	1.78	0.62	8.49	2.36	8.82	5.55	1.59	8.95	7.77	6.22	3.12
	Total Length	mm	54.76	60.06	53.95	72.12	57.05	57.07	54.81	60.01	58.73	5.88	109	66	101	86	59	106	95	88.9	19.6
	Headless Weight	g	0.72	1.09	0.72	1.73	0.82	0.86	0.88	1.01	0.98	0.33	5.03	1.31	5.07	3.22	0.92	4.97	3.65	3.45	1.76
Physical Tests	Moisture	%	-	-	-	86	-	-	-	-	-	-	78	-	77	80	-	79	79	-	-
Total Metals	Total Aluminum (Al)	mg/kg dw	5.9	110.6	20.9	35.1	237.5	35.6	167.1	122.0	91.8	81.9	40.4	81.3	40.3	190.0	69.4	6.5	4.7	61.8	63.4
	Total Antimony (Sb)	mg/kg dw	0.013	0.021	0.021	0.022	0.059	0.019	0.036	0.027	0.027	0.014	0.011	0.024	0.015	0.042	0.022	0.011	0.007	0.019	0.012
	Total Arsenic (As)	mg/kg dw	0.317	0.431	0.531	0.407	0.580	0.387	0.441	0.387	0.435	0.084	0.200	0.342	0.257	0.410	0.540	0.219	0.190	0.308	0.130
	Total Barium (Ba)	mg/kg dw	10.9	15.9	16.2	16.3	16.2	17.6	16.5	13.0	15.3	2.2	9.4	17.0	12.8	24.8	14.3	9.5	6.7	13.5	6.1
	Total Beryllium (Be)	mg/kg dw	0.149	0.099	0.149	0.143	0.149	0.149	0.149	0.149	0.142	0.017	0.091	0.099	0.087	0.100	0.099	0.095	0.095	0.095	0.005
	Total Bismuth (Bi)	mg/kg dw	0.149	0.099	0.149	0.143	0.149	0.149	0.149	0.149	0.142	0.017	0.091	0.099	0.087	0.100	0.099	0.095	0.095	0.095	0.005
	Total Boron (B)	mg/kg dw	2.98	1.98	2.98	2.86	2.98	2.98	2.98	2.98	2.84	0.35	1.82	1.98	1.74	2.00	1.98	1.90	1.90	1.90	0.10
	Total Cadmium (Cd)	mg/kg dw	0.227	0.409	0.095	0.155	0.336	0.132	0.099	0.124	0.197	0.117	0.133	0.158	0.272	0.095	0.366	0.104	0.068	0.171	0.109
	Total Calcium (Ca)	mg/kg dw	31,190	37,091	31,041	30,143	29,107	35,554	31,339	21,620	30,886	4,632	32,727	33,769	38,826	25,950	31,388	36,667	28,238	32,509	4,497
	Total Chromium (Cr)	mg/kg dw	0.298	0.342	0.298	0.286	0.679	0.298	0.540	0.367	0.388	0.144	0.182	0.293	0.204	0.540	0.263	0.190	0.190	0.266	0.128
	Total Cobalt (Co)	mg/kg dw	0.060	0.343	0.074	0.117	0.220	0.087	0.186	0.147	0.154	0.094	0.076	0.206	0.162	0.369	0.258	0.095	0.079	0.178	0.109
	Total Copper (Cu)	mg/kg dw	3.669	6.099	3.679	4.914	5.355	3.575	4.180	4.274	4.468	0.912	3.209	4.463	4.913	5.300	6.397	4.105	3.500	4.555	1.096
	Total Iron (Fe)	mg/kg dw	64	260	89	142	454	133	360	274	222	138	138	238	136	469	196	81	74	190	136
	Total Lead (Pb)	mg/kg dw	0.176	0.142	0.213	0.244	0.540	0.206	0.266	0.201	0.249	0.124	0.130	0.224	0.146	0.264	0.208	0.185	0.092	0.178	0.059
	Total Magnesium (Mg)	mg/kg dw	1,567	1,607	2,008	2,193	2,023	1,899	2,013	1,468	1,847	264	1,541	1,850	1,674	1,875	2,043	1,595	1,352	1,704	234
	Total Manganese (Mn)	mg/kg dw	21	42	28	22	23	30	30	18	27	8	23	78	37	109	42	31	23	49	32
	Total Mercury (Hg)	mg/kg dw	0.156	0.263	0.180	0.265	0.195	0.193	0.193	0.138	0.198	0.045	0.301	0.170	0.211	0.111	0.115	0.171	0.153	0.176	0.065
	Total Molybdenum (Mo)	mg/kg dw	0.079	0.119	0.119	0.107	0.154	0.104	0.099	0.089	0.109	0.023	0.150	0.114	0.113	0.155	0.218	0.110	0.110	0.138	0.040
	Total Nickel (Ni)	mg/kg dw	0.203	0.397	0.565	0.900	0.714	0.238	0.615	0.679	0.539	0.242	0.164	0.397	0.278	0.645	0.362	0.138	0.133	0.302	0.185
	Total Phosphorus (P)	mg/kg dw	21,868	24,545	24,744	29,214	25,785	26,727	24,545	17,802	24,404	3,394	25,045	26,926	29,043	24,850	26,331	27,333	22,143	25,953	2,202
	Total Potassium (K)	mg/kg dw	12,050	11,157	17,455	21,071	19,438	16,364	17,107	12,347	15,874	3,651	12,455	14,628	13,913	16,900	18,248	13,905	12,238	14,612	2,226
	Total Selenium (Se)	mg/kg dw	3.8	4.2	2.7	4.5	3.4	3.2	2.6	2.6	3.4	0.7	4.5	5.3	5.4	5.4	7.4	4.8	4.0	5.2	1.1
	Total Silver (Ag)	mg/kg dw	0.030	0.020	0.030	0.029	0.030	0.030	0.030	0.030	0.028	0.003	0.018	0.020	0.017	0.020	0.020	0.019	0.019	0.019	0.001
	Total Sodium (Na)	mg/kg dw	3,694	3,352	4,359	5,600	4,909	4,726	4,235	3,248	4,265	812	4,955	5,901	6,348	6,700	7,140	6,333	5,333	6,101	764
	Total Strontium (Sr)	mg/kg dw	54	66	97	100	94	126	92	64	87	24	69	63	73	55	50	70	51	62	9
	Total Thallium (Tl)	mg/kg dw	0.017	0.021	0.018	0.026	0.020	0.018	0.017	0.015	0.019	0.003	0.009	0.017	0.018	0.012	0.030	0.010	0.009	0.015	0.008
	Total Tin (Sn)	mg/kg dw	0.149	0.099	0.149	0.143	0.149	0.149	0.149	0.149	0.142	0.017	0.209	0.099	0.243	0.200	0.119	0.471	0.314	0.237	0.127
	Total Titanium (Ti)	mg/kg dw	3.0	8.3	3.9	5.7	14.8	4.6	12.1	9.7	7.8	4.2	5.7	9.0	5.8	15.8	6.4	3.5	3.2	7.1	4.3
	Total Uranium (U)	mg/kg dw	0.018	0.071	0.040	0.032	0.058	0.031	0.042	0.050	0.043	0.017	0.027	0.033	0.035	0.068	0.035	0.017	0.012	0.032	0.018
	Total Vanadium (V)	mg/kg dw	0.511	0.779	0.521	0.986	1.145	0.516	0.893	0.863	0.777	0.241	0.582	1.230	0.683	1.325	0.927	0.729	0.610	0.869	0.302
	Total Zinc (Zn)	mg/kg dw	120	113	109	142	96	116	111	81	111	18	96	114	107	117	121	127	103	112	11

(green) indicates a mean concentration in lower Minto Creek that is significantly lower than the mean concentration in lower Big Creek (t-test; p=0.05)

(orange) indicates a mean concentration in lower Minto Creek that is significantly greater than the mean concentration in lower Big Creek (t-test; p=0.05)

APPENDIX D

BENTHIC INVERTEBRATE COMMUNITY DATA

Table D.1: Benthic Invertebrates collected by Hess sampler and screened through a 500 µM sieve. Values reported as number of organisms per m^2, Minto Mine WUL, 2012.

Invertebrate	Reference					Exopsure				
	LMC-1	LMC-2	LMC-3	LMC-4	LMC-5	LWC-1	LWC-2	LWC-3	LWC-4	LWC-5
Phylum: Arthropoda										
Subphylum: Hexapoda										
Class: Insecta										
Order: Ephemeroptera										
Family: Ameletidae										
Ameletus sp.			7							
Family: Baetidae										
Baetis sp.	3	3		3		233	167	127	90	500
Baetis tricaudatus group						100	47			
Family: Ephemerellidae										
Drunella spinifera						67				57
Ephemerella sp.							23			
Serratella sp.			3							
Family: Heptageniidae			3			33	23	27		57
Epeorus sp.									30	
Order: Plecoptera						33	23			
Family: Capniidae		3		17		567	333	283	333	333
Family: Chloroperlidae										
Suwallia sp.			3			67				
Sweltsa sp.									30	
Family: Nemouridae	40	23	130	23	20					
Nemoura	17	13	20							
Ostrocerca sp.	7	57	67	10	7					
Podmosta sp.	43	13	133	53	83					
Zapada sp.										57
Family: Perlodidae						267	23	50		223
Family: Taeniopterygidae										
Taenionema sp.							23		30	
Order: Trichoptera										
Family: Brachycentridae										
Family: Limnephilidae	10	7	3	7						
Ecclisomyia sp.				3						110
Order: Coleoptera				3						
Family: Hydraenidae										
Order: Diptera	10	13	13	13	20					57
Family: Ceratopogonidae										
Atrichopogon sp.		3								
Culicoides sp.										
Sphaeromias sp.				7	13					
Family: Chironomidae										
Subfamily: Chironominae										
Tribe: Tanytarsini										
Micropsectra/Tanytarsus							23		90	
Paratanytarsus sp.		20			20					
Tanytarsus sp.	20									
Subfamily: Diamesinae										
Tribe: Diamesini										
Diamesa sp.		20			37	433			90	
Pagastia sp.		3				867		27		610
Pseudodiamesa sp.	3				13					
Subfamily: Orthocladiinae						800				
Cardiocladius sp.	13									
Cricotopus sp.	17									
Diplocladius cultriger										
Eukiefferiella sp.	207	450	317	117	937	733	263		243	223
Hydrobaenus sp.		17	13	10	30					
Limnophyes sp.		10	7	10						
Metriocnemus sp.		7		13	27					
Orthocladius complex						2,133	3,453	3,820	5,393	9,723
Parakiefferiella sp.										
Parorthocladius sp.	7									
Psectrocladius sp.			3	7						
Family: Empididae							23			
Chelifera/ Metachela	10		23	10	7	0	23	27		
Clinocera sp.	7		3							
Family: Simuliidae	3				27					
Simulium sp.	3				13					
Family: Tipulidae										
Antocha sp.							23			
Dicranota sp.	3	3		3		67	47		120	223
Tipula sp.			7							
Order: Lepidoptera				3						
Class: Entognatha										
Order: Collembola										
Family: Poduridae	3	103		3				27		

Table D.1: Benthic Invertebrates collected by Hess sampler and screened through a 500 µM sieve. Values reported as number of organisms per m^2, Minto Mine WUL, 2012.

Invertebrate	Reference					Exopsure				
	LMC-1	LMC-2	LMC-3	LMC-4	LMC-5	LWC-1	LWC-2	LWC-3	LWC-4	LWC-5
Subphylum: Crustacea										
Class: Ostracoda			3							
Class: Copepoda		3								
Order: Cyclopoida				13	7					
Order: Harpacticoida				3						
Class: Malacostraca										
Order: Amphipoda										
Family: Hyalellidae										
Hyalella sp.			3							
Subphylum: Chelicerata										
Class: Arachnida										
Order: Trombidiformes	3	3	3	7						
Family: Aturidae										
Aturus sp.										
Family: Feltriidae										
Feltria sp.										
Family: Hydryphantidae										
Protzia sp.										57
Family: Lebertiidae										
Lebertia sp.	7									
Family: Sperchontidae										
Sperchon sp.	10		7	7						
Order: Oribatei										
Family: Halacaridae										
Order: Sarcoptiformes										
Family: Hydrozetidae										
Phylum: Mollusca										
Class: Gastropoda										
Order: Hypsogastropoda										
Family: Hydrobiidae					7					
Phylum: Annelida										
Subphylum: Clitellata										
Class: Oligochaeta										
Order: Lumbriculida										
Family: Lumbriculidae	77		7	3	20	1,267	333	820		
Order: Tubificida										
Family: Enchytraeidae										
Enchytraeus		77	3	3	13	300	213	693		
Family: Naididae			57	13	7					
Phylum: Nemata	10		23	3	313	100	47	27		110
Phylum: Platyhelminthes										
Class: Turbellaria					37					
Order: Tricladida										
Family: Planariidae										
Polycelis coronata		3								
Totals:	**533**	**857**	**863**	**370**	**1,657**	**8,067**	**5,113**	**5,927**	**6,450**	**12,340**

Table D.2: Benthic invertebrate community metrics by station for samples collected by Hess sampler, Minto Mine WUL, 2012.

Area	Station	Density (individuals per m^2)	Number of Taxa	BC Diss. to LWC Median	Simpson's E[a]	Ephemeroptera (%)	Plecoptera (%)	Trichoptera (%)	EPT (%)
Lower Minto Creek (Exposure)	LMC-1	533	19	0.90	0.25	1	20	2	23
	LMC-2	857	20	0.89	0.16	0	13	1	14
	LMC-3	863	22	0.91	0.20	2	41	0	43
	LMC-4	370	23	0.94	0.26	1	28	3	32
	LMC-5	1,657	18	0.91	0.15	0	7	0	7
Lower Wolverine Creek (Reference)	LWC-1	8,067	14	0.36	0.40	5	12	0	17
	LWC-2	5,113	15	0.06	0.14	5	8	0	13
	LWC-3	5,927	11	0.13	0.20	3	6	0	8
	LWC-4	6,450	10	0.22	0.14	2	6	0	8
	LWC-5	12,340	13	0.46	0.12	5	5	1	11

[a] calculated as recommnended by Environment Canada 2011.

Table D.2: Benthic invertebrate community metrics by station for samples collected by Hess sampler, Minto Mine WUL, 2012.

Area	Station	Chironomids (%)	Oligochaetes (%)	Nemata (%)	CA Axis-1 (38.2%)	CA Axis-2 (14.1%)	CA Axis-3 (12.1%)
Lower Minto Creek (Exposure)	LMC-1	50	14	2	-0.63	-0.51	0.45
	LMC-2	61	9	0	-0.77	0.03	-0.21
	LMC-3	39	8	3	-1.01	-0.80	-0.04
	LMC-4	42	5	1	-0.93	-0.25	-0.14
	LMC-5	64	2	19	-1.01	1.06	0.06
Lower Wolverine Creek (Reference)	LWC-1	62	19	1	0.60	0.16	-0.40
	LWC-2	73	11	1	0.54	0.01	0.43
	LWC-3	65	26	0	0.56	0.06	-0.22
	LWC-4	90	0	0	0.68	0.05	0.93
	LWC-5	86	0	1	0.61	-0.22	-0.41

[a] calculated as recommnended by Environment Canada 2011.

Table D.3: Summary of Benthic Invertebrate Community Characteristics (500 µm mesh), and Statistical Comparisons Among Areas Minto Mine WUL, 2012.

	Comparison	2-group ANOVA for Estimation of Effect Size						
Metric	**Planned Comparison**	**Mean Square**	**F (ANOVA)**	**Significant Difference Among Areas? (p-value)[a]**		**Power**	**Magnitude of Difference (# of SDs)[b]**	**Minimum Detectable Effect Size (# of SDs)[c]**
Density (Ind./m2)	Wolverine Creek Reference vs. Minto Creek Exposure	113,008,027	26.6	YES	0.001	1.00	-2.3	~
Number of Taxa	Wolverine Creek Reference vs. Minto Creek Exposure	152	35.4	YES	0.000	1.00	3.8	~
EPT (%)	Wolverine Creek Reference vs. Minto Creek Exposure	367.5	3.4	NO	0.103	0.51	~	6.1
Chironomids (%)	Wolverine Creek Reference vs. Minto Creek Exposure	1,391.4	9.9	YES	0.014	0.89	-1.9	~
Oligochaetes (%)	Wolverine Creek Reference vs. Minto Creek Exposure	28.2	0.4	NO	0.558	0.15	~	1.6
Nemata (%)	Wolverine Creek Reference vs. Minto Creek Exposure	43.7	1.4	NO	0.272	0.29	~	25.3
BC Distance to Median Ref.	Wolverine Creek Reference vs. Minto Creek Exposure	1.1	81.6	YES	0.000	1.00	4.1	~
Simpson's D	Wolverine Creek Reference vs. Minto Creek Exposure	0.1	5.3	YES	0.050	0.68	1.1	~
Simpson's E[d]	Wolverine Creek Reference vs. Minto Creek Exposure	0.000	0.001	NO	0.981	0.10	~	1.7
CA Axis-1 (38.2%)	Wolverine Creek Reference vs. Minto Creek Exposure	5.4	347.0	YES	0.000	1.00	-26.2	~
CA Axis-2 (14.1%)	Wolverine Creek Reference vs. Minto Creek Exposure	0.03	0.11	NO	0.749	0.12	~	7.9
CA Axis-3 (12.1%)	Wolverine Creek Reference vs. Minto Creek Exposure	0.005	0.022	NO	0.885	0.10	~	1.7

[a] p-value obtained from 1-way ANOVA

[b] Magnitude calculated by comparing the difference between the reference and exposure area means to the reference area standard deviation (SD) [(exposure mean - reference mean) / standard deviation of the reference mean]

[c] Minimum effect size detectable calculated based on variance as square root of MSE from ANOVA and alpha = beta = 0.10. Minimum effect size reported as the minimum number of standard deviations detectable based on reference area standard deviation.

[d] Calculated as recommended by Environment Canada 2011

Table D.4: Benthic Taxon Scores from Correspondence Analysis of (500 µM mesh) Samples Collected at Minto MIne WUL Stations, 2012.

	CA Axis-1 (38.2%)	CA Axis-2 (14.1%)	CA Axis-3 (12.1%)	CA Axis-4 (9.5%)
Baetis sp. (incl. B. tricaudatus group)	0.65	-0.04	0.03	0.00
Drunella spinifera	0.83	-0.05	-0.98	0.67
| Family: Heptageniidae (incl. Epeorus sp.)	0.70	-0.09	0.08	0.05
| Family: Capniidae	0.63	0.00	0.09	-0.03
Suwallia sp.	0.41	-0.03	-0.81	0.09
Nemoura	-1.10	-1.04	0.20	-0.51
Ostrocerca sp.	-1.20	-0.52	-0.06	-0.35
Podmosta sp.	-1.22	-0.28	0.10	0.17
| Family: Perlodidae	0.80	0.00	-0.57	0.07
Taenionema sp.	0.84	0.08	1.68	-0.06
| Family: Limnephilidae (incl. Ecclisomyia sp.)	-0.26	-0.66	-0.38	0.47
Sphaeromias sp.	-1.34	1.17	-0.06	0.82
Micropsectra/Tanytarsus (incl. Tanytarsus sp.)	0.40	-0.25	1.61	0.08
Paratanytarsus sp.	-1.21	1.23	-0.18	-0.74
Diamesa sp.	0.12	0.65	0.17	-0.09
Pagastia sp.	0.72	-0.02	-0.88	0.18
Pseudodiamesa sp.	-1.22	1.31	0.43	0.63
Eukiefferiella sp.	-0.29	-0.02	0.14	0.08
Hydrobaenus sp.	-1.28	0.26	-0.17	-0.11
Limnophyes sp.	-1.22	-0.69	-0.33	-0.44
Metriocnemus sp.	-1.27	0.88	-0.16	0.14
Orthocladius complex	0.82	0.02	0.16	0.00
Psectrocladius sp.	-1.31	-1.04	-0.24	0.59
Chelifera/ Metachela	-0.35	-0.29	0.25	-0.14
Clinocera sp.	-1.06	-1.40	0.63	0.21
| Family: Simuliidae (incl. Simulium sp.)	-1.22	1.32	0.43	0.63
Dicranota sp.	0.58	-0.11	0.26	0.31
| Family: Poduridae	-0.49	-0.09	-0.34	-1.45
| Order: Cyclopoida	-1.32	0.63	-0.14	0.84
| Order: Trombidiformes (incl. Protzia sp., Lebertia sp., and Sperchon sp.)	-0.46	-0.83	-0.21	0.50
| Family: Lumbriculidae	0.20	0.07	-0.02	-0.27
Enchytraeus	0.17	0.24	-0.22	-0.71
| Family: Naididae	-1.35	-0.62	-0.11	0.47
Phylum: Nemata	-0.09	0.24	-0.17	0.26
| Class: Turbellaria (incl. Polycelis coronata)	-1.31	1.88	0.01	0.12

Indicates heavy positively-weighted variable on respective CA axis (blue)
Indicates heavy negatively-weighted variable on respective CA axis (green)

Table D.5: Benthic Analyses - ANOVA results (500 µM mesh), Minto Mine WUL, 2012.

Dependent Variable	Mean Square	F (ANOVA)	p-value	Observed Power
Density (Ind./m2)	113,008,026.66	26.61	0.00	1.00
Number of Taxa	152.10	35.37	0.00	1.00
EPT Pct.	367.47	3.38	0.10	0.51
Chironomids Pct.	1,391.40	9.93	0.01	0.89
Oligochaetes Pct.	28.16	0.37	0.56	0.15
Nemata Pct.	43.67	1.39	0.27	0.29
Simpson's D	0.13	5.31	0.05	0.68
Simpson's E	0.00	0.00	0.98	0.10
BC Distance to Median Ref.	1.10	81.55	0.00	1.00
Minto 500 µM CA-1 (38.2%)	5.37	347.04	0.00	1.00
Minto 500 µM CA-2 (14.1%)	0.03	0.11	0.75	0.12
Minto 500 µM CA-3 (12.1%)	0.00	0.02	0.89	0.10
Median Intermediate Axis Length (cm)	0.00	0.01	0.92	0.10
Median Embeddedness (%)	75.21	4.67	0.07	0.60
Water Velocity (m/s)	0.00	0.01	0.91	0.10
Depth (m)	0.00	0.10	0.76	0.11
Temperature (°C)	5.36	32.44	0.00	1.00
DO (mg/L)	1.02	3.24	0.12	0.48
DO (%)	179.59	10.92	0.02	0.90
Specific Conductivity (µS/cm)	11,623.01	238.94	0.00	1.00
pH	0.96	22.85	0.00	0.99
% cobble	16.88	0.27	0.62	0.14
% gravel	187.50	2.05	0.20	0.36
% sand and finer	1.88	0.56	0.48	0.17

Indicates p value < 0.1

Table D.6: Eigenvalues of Correspondence Analysis for samples collected by Hess sampler (500 µm mesh). Minto Mine WUL, 2012.

	CA Axis-1 (38.2%)	CA Axis-2 (14.1%)	CA Axis-3 (12.1%)	CA Axis-4 (9.5%)
Eigenvalue	0.53	0.20	0.17	0.13
Relative Inertia (%)	38.23	14.06	12.14	9.54
Cumulative Inertia (%)	38.23	52.29	64.43	73.97

Table D.7: Benthic Invertebrates collected by Hess sampler and screened through a 250 µm sieve. Values reported as number of organisms per m^2, Minto Mine WUL, 2012.

Invertebrate	Reference					Exopsure				
	LMC-1	LMC-2	LMC-3	LMC-4	LMC-5	LWC-1	LWC-2	LWC-3	LWC-4	LWC-5
Phylum: Arthropoda										
Subphylum: Hexapoda										
Class: Insecta										
Order: Ephemeroptera										
Family: Ameletidae										
Ameletus sp.			7			10				
Family: Baetidae										
Baetis sp.	3	7	7	3		597	230	133	150	640
Baetis tricaudatus group						100	47			
Family: Ephemerellidae			3						7	
Drunella spinifera						67				57
Ephemerella sp.							23			
Serratella sp.			3							
Family: Heptageniidae			3			87	23	30	7	57
Epeorus sp.									30	
Order: Plecoptera	37	3	23	3	13	70	30			27
Family: Capniidae		3	3	20	3	850	353	290	423	373
Family: Chloroperlidae										
Suwallia sp.			3			67				
Sweltsa sp.									30	
Family: Nemouridae	40	23	130	27	20					
Nemoura	17	13	20							
Ostrocerca sp.	7	57	67	10	7					
Podmosta sp.	43	13	133	53	83					
Zapada sp.					3	10				57
Family: Perlodidae						277	23	50	7	230
Family: Taeniopterygidae										
Taenionema sp.							23		30	
Order: Trichoptera							0			7
Family: Brachycentridae							7			
Family: Limnephilidae	10	7	3	7						
Ecclisomyia sp.				3						110
Order: Coleoptera				3						
Family: Hydraenidae		3								
Order: Diptera	37	20	20	20	33	10		13		57
Family: Ceratopogonidae										
Atrichopogon sp.		3								
Culicoides sp.			3							
Sphaeromias sp.	10			7	13					
Family: Chironomidae										
Subfamily: Chironominae										
Tribe: Tanytarsini										
Micropsectra/Tanytarsus							113	10	190	
Paratanytarsus sp.	10	20	7	10	23	43				
Tanytarsus sp.	37	10								
Subfamily: Diamesinae										
Tribe: Diamesini										
Diamesa sp.		20			53	567			90	
Pagastia sp.		3				867		27		610
Pseudodiamesa sp.	3				13					
Subfamily: Orthocladiinae		3	30			1,067				1,267
Cardiocladius sp.	13									
Cricotopus sp.	87	13	20							
Diplocladius cultriger				7						13
Eukiefferiella sp.	793	590	597	167	1,283	1,203	323		433	223
Hydrobaenus sp.		17	23	10	43					
Limnophyes sp.		10	7	17						
Metriocnemus sp.		7		13	37					
Orthocladius complex						2,417	3,633	4,003	6,650	9,990
Parakiefferiella sp.							20			
Parorthocladius sp.	7									
Psectrocladius sp.			3	7						
Family: Empididae							30	0		
Chelifera/ Metachela	10		23	10	7	10	23	47		
Clinocera sp.	7		7							
Family: Simuliidae	3				27					
Simulium sp.	3				17			3		
Family: Tipulidae										
Antocha sp.							23			
Dicranota sp.	3	3		3		77	47		120	223
Tipula sp.			7							
Order: Lepidoptera				3						
Class: Entognatha										
Order: Collembola										
Family: Poduridae	627	177	13	7	3			33	7	

Table D.7: Benthic Invertebrates collected by Hess sampler and screened through a 250 µm sieve. Values reported as number of organisms per m^2, Minto Mine WUL, 2012.

Invertebrate	Reference					Exopsure				
	LMC-1	LMC-2	LMC-3	LMC-4	LMC-5	LWC-1	LWC-2	LWC-3	LWC-4	LWC-5
Subphylum: Crustacea										
Class: Ostracoda		7	20	83	67	17	47	10		
Class: Copepoda		3								
Order: Cyclopoida	150	53	47	57	73		17	30	23	
Order: Harpacticoida	37		3	40	27			20	7	
Class: Malacostraca										
Order: Amphipoda										
Family: Hyalellidae										
Hyalella sp.			3							
Subphylum: Chelicerata										
Class: Arachnida										
Order: Trombidiformes	13	3	7	10		53	7	10		
Family: Aturidae										
Aturus sp.								3		
Family: Feltriidae										
Feltria sp.			10	3	10		10	3	7	20
Family: Hydryphantidae										
Protzia sp.										57
Family: Lebertiidae										
Lebertia sp.	7							3		
Family: Sperchontidae										
Sperchon sp.	10		7	7						
Order: Oribatei										
Family: Halacaridae			3							
Order: Sarcoptiformes										
Family: Hydrozetidae	150		27	23	7					7
Phylum: Mollusca										
Class: Gastropoda										
Order: Hypsogastropoda										
Family: Hydrobiidae					7					
Phylum: Annelida										
Subphylum: Clitellata										
Class: Oligochaeta										
Order: Lumbriculida										
Family: Lumbriculidae	93		7	3	30	1,267	333	850	7	
Order: Tubificida										
Family: Enchytraeidae										
Enchytraeus	213	110	77	10	37	2,023	940	1,057	17	13
Family: Naididae			293	27	20	70				
Phylum: Nemata	773	223	180	100	480	143	137	57	37	157
Phylum: Platyhelminthes										
Class: Turbellaria					70					
Order: Tricladida										
Family: Planariidae										
Polycelis coronata		3			3					
Totals:	**3,253**	**1,430**	**1,850**	**773**	**2,513**	**11,967**	**6,463**	**6,683**	**8,270**	**14,193**

Table D.8: Benthic invertebrate community metrics by station for samples collected by Hess sampler and screened through a 250 µm sieve, Minto Mine WUL, 2012.

Area	Station	Density (individuals per m^2)	Number of Taxa	BC Diss. to LWC Median	Simpson's E^a	Ephemeroptera (%)	Plecoptera (%)	Trichoptera (%)	EPT (%)
Lower Minto Creek (Exposure)	LMC-1	3,253	25	0.83	0.24	0	4	0	5
	LMC-2	1,430	26	0.85	0.17	0	8	0	9
	LMC-3	1,850	32	0.85	0.18	1	21	0	22
	LMC-4	773	27	0.90	0.35	0	15	1	16
	LMC-5	2,513	25	0.88	0.13	0	5	0	5
Lower Wolverine Creek (Reference)	LWC-1	11,967	21	0.38	0.33	7	11	0	18
	LWC-2	6,463	20	0.06	0.14	5	7	0	12
	LWC-3	6,683	17	0.11	0.15	2	5	0	8
	LWC-4	8,270	19	0.32	0.08	2	6	0	8
	LWC-5	14,193	16	0.49	0.10	5	5	1	11

[a] calculated as recommnended by Environment Canada 2011.

Table D.8: Benthic invertebrate community metrics by station for samples collected by Hess sampler and screened through a 250 µm sieve, Minto Mine WUL, 2012.

Area	Station	Chironomids (%)	Oligochaetes (%)	Nemata (%)	CA Axis-1 (40.0%)	CA Axis-2 (13.8%)	CA Axis-3 (13.0%)
Lower Minto Creek (Exposure)	LMC-1	29	9	24	0.66	-0.51	0.27
	LMC-2	48	8	16	0.64	-0.13	0.17
	LMC-3	37	20	10	0.69	0.06	0.48
	LMC-4	30	5	13	0.68	0.31	0.12
	LMC-5	58	3	19	0.76	0.39	-0.86
Lower Wolverine Creek (Reference)	LWC-1	52	28	1	-0.56	0.37	-0.01
	LWC-2	63	20	2	-0.55	-0.42	-0.19
	LWC-3	60	29	1	-0.46	-0.29	-0.15
	LWC-4	89	0	0	-0.62	-0.49	-0.25
	LWC-5	85	0	1	-0.80	0.49	0.40

[a] calculated as recommnended by Environment Canada 2011.

Table D.9: Descriptive statistics of benthic metrics by are for samples collected by Hess sampler and screened through a 250 µm sieve, Minto Mine WUL, 2012.

Variable	Area	n	Median	Mean	Standard Deviation	Standard Error	95% Confidence Interval (Mean)		Minimum	Maximum
							Lower Bound	Upper Bound		
Density (Individuals/m2)	LMC	5	8,270	9,515	3,420	1,529	5,269	13,762	6,463	14,193
	LWC	5	1,850	1,964	959	429	773	3,155	773	3,253
Number of Taxa	LMC	5	19.00	18.60	2.07	0.93	16.03	21.17	16.00	21.00
	LWC	5	26.00	27.00	2.92	1.30	23.38	30.62	25.00	32.00
EPT (%)	LMC	5	10.97	11.27	4.07	1.82	6.21	16.33	7.53	17.83
	LWC	5	8.86	11.44	7.51	3.36	2.12	20.76	4.82	21.98
Chironomids (%)	LMC	5	63.28	69.91	16.39	7.33	49.56	90.26	51.50	89.04
	LWC	5	37.12	40.47	12.44	5.56	25.03	55.92	29.20	57.82
Oligochaetes (%)	LMC	5	19.70	15.34	14.27	6.38	-2.38	33.05	0.09	28.53
	LWC	5	7.69	9.22	6.64	2.97	0.98	17.46	3.45	20.36
Nemata (%)	LMC	5	1.10	1.14	0.62	0.28	0.37	1.91	0.44	2.11
	LWC	5	15.62	16.23	5.45	2.44	9.47	22.99	9.73	23.77
BC Diss to WC Median	LMC	5	0.32	0.27	0.18	0.08	0.04	0.50	0.06	0.49
	LWC	5	0.85	0.86	0.03	0.01	0.83	0.89	0.83	0.90
Simpson's D	LMC	5	0.60	0.56	0.21	0.10	0.30	0.83	0.35	0.86
	LWC	5	0.82	0.80	0.08	0.04	0.70	0.90	0.68	0.89
Simpson's E[a]	LMC	5	0.14	0.16	0.10	0.05	0.03	0.29	0.08	0.33
	LWC	5	0.18	0.21	0.09	0.04	0.10	0.32	0.13	0.35
CA Axis-1 (40.0%)	LMC	5	-0.56	-0.60	0.13	0.06	-0.76	-0.44	-0.80	-0.46
	LWC	5	0.68	0.68	0.04	0.02	0.63	0.74	0.64	0.76
CA Axis-2 (13.8%)	LMC	5	-0.29	-0.07	0.46	0.21	-0.64	0.51	-0.49	0.49
	LWC	5	0.06	0.03	0.36	0.16	-0.42	0.47	-0.51	0.39
CA Axis-3 (13.0%)	LMC	5	-0.15	-0.04	0.26	0.12	-0.36	0.28	-0.25	0.40
	LWC	5	0.17	0.04	0.52	0.23	-0.61	0.68	-0.86	0.48

[a] Calculated as recommended by Environment Canada 2011.

Table D.10: Summary of Benthic Invertebrate Community Characteristics (250 µm mesh), and Statistical Comparisons Among Areas Minto Mine WUL, 2012.

	Comparison	2-group ANOVA for Estimation of Effect Size						
Metric	**Planned Comparison**	**Mean Square**	**F (ANOVA)**	**Significant Difference Among Areas? (p-value)[a]**		**Power**	**Magnitude of Difference (# of SDs)[b]**	**Minimum Detectable Effect Size (# of SDs)[c]**
Density (Ind./m2)	Wolverine Creek Reference vs. Minto Creek Exposure	142,556,588	22.60	YES	0.00	1.00	-2.2	~
Number of Taxa	Wolverine Creek Reference vs. Minto Creek Exposure	176	27.56	YES	0.00	1.00	4.1	~
EPT Pct.	Wolverine Creek Reference vs. Minto Creek Exposure	0.07	0.00	NO	0.97	0.10	~	3.2
Chironomids Pct.	Wolverine Creek Reference vs. Minto Creek Exposure	2,166.06	10.24	YES	0.01	0.90	-1.8	~
Oligochaetes Pct.	Wolverine Creek Reference vs. Minto Creek Exposure	93.54	0.76	NO	0.41	0.21	~	1.7
Nemata Pct.	Wolverine Creek Reference vs. Minto Creek Exposure	569.12	37.90	YES	0.00	1.00	24.4	~
BC Distance to Median Ref.	Wolverine Creek Reference vs. Minto Creek Exposure	0.87	51.05	YES	0.00	1.00	3.2	~
Simpson's D	Wolverine Creek Reference vs. Minto Creek Exposure	0.14	5.44	YES	0.05	0.69	1.1	~
Simpson's E[d]	Wolverine Creek Reference vs. Minto Creek Exposure	0.01	0.72	NO	0.42	0.20	~	2.0
Minto 250 µM CA-1 (40.0%)	Wolverine Creek Reference vs. Minto Creek Exposure	4.12	452.19	YES	0.00	1.00	10.0	~
Minto 250 µM CA-2 (13.8%)	Wolverine Creek Reference vs. Minto Creek Exposure	0.02	0.13	NO	0.73	0.12	~	1.9
Minto 250 µM CA-3 (13.0%)	Wolverine Creek Reference vs. Minto Creek Exposure	0.01	0.08	NO	0.78	0.11	~	3.5

[a] p-value obtained from 1-way ANOVA

[b] Magnitude calculated by comparing the difference between the reference and exposure area means to the reference area standard deviation (SD) [(exposure mean - reference mean) / standard deviation of the reference mean]

[c] Minimum effect size detectable calculated based on variance as square root of MSE from ANOVA and alpha = beta = 0.10. Minimum effect size reported as the minimum number of standard deviations detectable based on reference area standard deviation.

[d] Calculated as recommended by Environment Canada 2011

Table D.11: Benthic Taxon Scores from Correspondence Analysis of Samples Collected (250 µm mesh) at Minto Mine EEM Stations, 2012.

	CA Axis-1 (40.0%)	CA Axis-2 (13.8%)	CA Axis-3 (13.0%)
Ameletus sp.	-0.01	0.62	0.57
Baetis sp. (incl. B. tricaudatus group)	-0.67	-0.05	0.07
| Family: Ephemerellidae (incl. Drunella spinifera, Ephemerella sp., Serratella sp.)	-0.77	0.31	0.26
| Family: Heptageniidae (incl. Epeorus sp.)	-0.84	-0.01	0.02
| Family: Capniidae	-0.64	-0.04	-0.08
Suwallia sp.	-0.50	0.82	0.23
Nemoura	1.03	-0.52	0.87
Ostrocerca sp.	1.05	0.00	0.42
Podmosta sp.	1.07	0.12	0.10
Zapada sp.	-0.74	1.17	0.21
| Family: Perlodidae	-0.95	0.27	0.10
Taenionema sp.	-0.91	-1.20	-0.59
| Family: Limnephilidae (incl. Ecclisomyia sp.)	0.03	0.45	0.83
| Order: Coleoptera (incl. Family Hydraenidae)	1.02	0.24	0.40
Sphaeromias sp.	1.09	0.17	-0.58
Micropsectra/Tanytarsus (incl. identified Tanytarsus sp.)	-0.30	-1.09	-0.20
Paratanytarsus sp.	0.59	0.33	-0.10
Diamesa sp.	-0.18	0.23	-0.61
Pagastia sp.	-0.89	0.75	0.36
Pseudodiamesa sp.	1.12	0.31	-1.41
Cricotopus sp.	1.03	-0.67	0.83
Diplocladius cultriger	-0.32	1.10	0.77
Eukiefferiella sp.	0.18	0.03	-0.01
Hydrobaenus sp.	1.08	0.45	-0.26
Limnophyes sp.	1.03	0.28	0.63
Metriocnemus sp.	1.09	0.67	-0.91
Orthocladius complex	-0.93	-0.16	-0.08
Psectrocladius sp.	1.05	0.56	0.71
Chelifera/ Metachela	0.07	-0.24	-0.07
Clinocera sp.	1.04	-0.58	1.02
Simulium sp.	0.84	0.16	-1.28
Dicranota sp.	-0.73	0.02	0.11
| Family: Poduridae	0.64	-0.60	0.30
| Class: Ostracoda	0.35	0.22	-0.33
| Order: Cyclopoida	0.52	-0.30	-0.09
| Order: Harpacticoida	0.56	-0.16	-0.29
| Order: Trombidiformes (incl. Aturus, Feltria, Protzia, Lebertia, and Sperchon sp.)	-0.08	0.11	0.16
| Family: Hydrozetidae	0.81	-0.05	0.48
| Family: Lumbriculidae	-0.25	-0.26	-0.28
Enchytraeus	-0.07	-0.20	-0.04
| Family: Naididae	0.57	0.64	0.17
Phylum: Nemata	0.20	-0.02	0.00
Family Planariidae: Polycelis coronata	1.14	0.78	-1.84

Indicates heavy positively-weighted variable on respective CA axis (blue)
Indicates heavy negatively-weighted variable on respective CA axis (green)

Table D.12: Benthic Analyses (250 µm mesh) - ANOVA results, Minto Mine WUL 2012.

Dependent Variable	Mean Square	F (ANOVA)	p-value	Observed Power
Density (Ind./m2)	142,556,588	22.60	0.00	1.00
Number of Taxa	176.40	27.56	0.00	1.00
EPT Pct.	0.07	0.00	0.97	0.10
Chironomids Pct.	2,166.06	10.24	0.01	0.90
Oligochaetes Pct.	93.54	0.76	0.41	0.21
Nemata Pct.	569.12	37.90	0.00	1.00
Simpson's D	0.14	5.44	0.05	0.69
Simpson's E	0.01	0.72	0.42	0.20
BC Distance to Median Ref.	0.87	51.05	0.00	1.00
Minto 250 µM CA-1 (40.0%)	4.12	452.19	0.00	1.00
Minto 250 µM CA-2 (13.8%)	0.02	0.13	0.73	0.12
Minto 250 µM CA-3 (13.0%)	0.01	0.08	0.78	0.11
Median Intermediate Axis Length (cm)	0.00	0.01	0.92	0.10
Median Embeddedness (%)	75.21	4.67	0.07	0.60
Water Velocity (m/s)	0.00	0.01	0.91	0.10
Depth (m)	0.00	0.10	0.76	0.11
Temperature (°C)	5.36	32.44	0.00	1.00
DO (mg/L)	1.02	3.24	0.12	0.48
DO (%)	179.59	10.92	0.02	0.90
Specific Conductivity (µS/cm)	11,623.01	238.94	0.00	1.00
pH	0.96	22.85	0.00	0.99
% cobble	16.88	0.27	0.62	0.14
% gravel	187.50	2.05	0.20	0.36
% sand and finer	1.88	0.56	0.48	0.17
% organic	0.00	-	-	-

[shaded] Indicates p value < 0.1

Table D.13: Eigenvalues of Correspondence Analysis for samples collected by Hess sampler (250 µm mesh). Minto Mine WUL, 2012.

	CA Axis-1 (40.0%)	CA Axis-2 (13.8%)	CA Axis-3 (13.0%)	CA Axis-4
Eigenvalue	0.419	0.144	0.136	0.097
Relative Inertia (%)	39.990	13.750	12.960	9.310
Cumulative Inertia (%)	39.990	53.740	66.700	76.000

Table D.14: Intermediate axis length and embededdness of 100 cobble washed during Hess sampling at benthic invertebrate stations, Minto Mine WUL, 2012.

Cobble Number	LWC-1		LWC-2		LWC-3		LWC-4	
	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)
1	3.2		7.4		5.6		6.6	
2	5.9		5.7		5.4		7.6	
3	6.1		6.4		7.2		7.7	
4	5.2		4.1		8.1		3.7	
5	3.8		7.0		6.8		4.7	
6	4.5		6.9		10.3		3.9	
7	3.7		3.8		5.4		3.5	
8	3.9		5.2		4.9		5.5	
9	7.9		7.3		6.4		4.3	
10	5.4		9.2	20	7.0	30	4.4	20
11	3.5		4.1		5.8		5.1	
12	4.2		7.4		4.0		7.3	
13	5.3		5.4		3.8		8.3	
14	5.0		6.5		11.2		7.4	
15	3.8		4.9		5.4		3.4	
16	6.8		6.0		7.9		4.6	
17	6.8		6.9		5.7		6.0	
18	4.6		8.2		8.5		7.9	
19	5.9		5.6		5.0		3.5	
20	5.7		6.5	10	4.9	30	3.3	20
21	4.9		4.9		3.7		7.8	
22	5.2		2.9		3.1		4.4	
23	5.2		3.7		3.4		4.7	
24	4.7		3.8		5.6		5.3	
25	5.4		4.1		7.4		5.1	
26	5.9		6.9		4.1		5.4	
27	4.5		7.4		4.9		4.3	
28	4.6		3.5		6.7		4.6	
29	4.6		10.2		8.7		5.4	
30	3.0		6.2	20	4.4	20	2.9	30
31	6.0		2.7		4.2		4.7	
32	3.1		3.7		6.6		5.6	
33	3.3		3.9		3.9		3.4	
34	3.9		5.3		3.4		4.8	
35	3.5		4.4		5.5		5.1	
36	8.1		6.9		11.5		3.6	
37	4.6		4.6		5.4		4.4	
38	3.6		3.9		7.6		3.8	
39	3.1		3.7		10.9		6.6	
40	5.0		4.8	30	6.5	30	6.4	30
41	4.1		4.6		6.6		4.7	
42	4.7		8.9		6.4		4.4	
43	5.7		8.1		2.1		6.6	
44	4.2		5.5		3.4		4.1	
45	5.1		7.5		7.9		4.5	
46	3.1		6.2		2.6		4.7	
47	3.0		3.9		4.0		4.4	
48	5.1		4.3		4.3		4.1	
49	4.4		5.8		3.2		3.5	
50	5.2		6.9	20	3.9	10	7.4	20
51	5.6		3.4		5.6		7.3	
52	4.9		5.2		3.6		5.5	
53	3.2		3.8		4.2		5.2	
54	3.8		3.4		2.6		6.3	
55	2.7		3.4		2.9		8.2	
56	3.9		3.6		4.3		3.1	
57	4.4		3.6		8.3		4.9	
58	4.1		4.2		5.9		2.9	
59	6.3		8.4		6.7		3.6	
60	5.4		6.1	10	6.2	20	5.8	20
61	3.5		4.9		6.6		3.5	
62	4.0		8.7		4.9		4.0	
63	6.2		6.4		2.9		3.9	
64	5.8		6.9		2.7		6.2	
65	6.1		4.4		5.8		4.1	
66	2.9		5.6		5.2		7.4	
67	4.0		7.9		10.4		3.9	
68	4.9		5.3		6.9		4.4	
69	3.0		4.9		9.0		9.1	
70	9.6		5.1	20	7.5	30	3.4	30
71	5.3		6.7		5.2		3.3	
72	3.8		8.1		3.9		3.4	
73	3.1		3.5		3.7		4.3	
74	3.6		5.5		4.3		3.2	
75	3.8		3.5		8.0		8.1	
76	4.7		3.5		4.6		8.3	
77	2.8		6.0		4.7		5.2	
78	3.1		7.9		3.8		5.1	
79	3.5		5.4		10.4		3.6	
80	6.7		11.0	20	5.0	30	5.7	20
81	6.7		8.0		4.7		6.7	
82	7.6		7.0		7.9		5.3	
83	7.0		5.4		8.2		4.9	
84	5.4		9.0		10.1		4.4	
85	4.3		3.2		4.5		6.1	
86	6.9		9.8		2.5		2.4	
87	4.4		5.7		2.7		7.9	
88	5.6		6.0		6.8		5.6	
89	5.0		3.1		9.0		6.9	
90	4.3		11.5	20	5.8	20	8.6	30
91	3.6		8.8		3.4		7.1	
92	3.4		5.1		7.6		8.8	
93	6.4		3.6		3.8		3.2	
94	4.0		8.2		6.7		3.9	
95	7.4		4.3		5.8		6.8	
96	4.9		8.2		5.9		5.4	
97	5.1		6.2		8.1		3.3	
98	4.8		14.6		7.5		7.2	
99	4.5		4.5		4.1		9.8	
100	4.1		5.1	30	4.7		10.1	30
Minimum	**2.7**		**2.7**		**2.1**		**2.4**	
Maximum	**9.6**		**14.6**		**11.5**		**10.1**	
Mean	**4.8**		**5.9**		**5.8**		**5.3**	
Geometric mean	**4.6**		**5.5**		**5.4**		**5.1**	
Median	**4.6**		**5.5**	**20**	**5.5**	**30**	**4.9**	**25**
Description of Surrounding material								

Note: intermediate axis length is the second longest axis on a cobble. Embeddedness refers to how deeply the cobble is surrounded or buried by other substrate.

Table D.14: Intermediate axis length and embededdness of 100 cobble washed during Hess sampling at benthic invertebrate stations, Minto Mine WUL, 2012.

Cobble Number	LWC-5		LMC-1		LMC-2		LMC-3	
	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)	Intermediate Axis Length (cm)	Embeddedness (%)
1	9.5		6.0		4.9		7.5	
2	6.0		5.8		6.4		3.9	
3	8.0		4.9		4.9		10.6	
4	10.0		5.0		4.1		9.6	
5	7.0		4.0		3.5		7.5	
6	6.0		3.4		4.3		4.5	
7	7.2		2.7		6.4		4.7	
8	3.3		3.8		6.3		6.9	
9	5.4		2.9		7.4		4.4	
10	5.7	20	7.3	40	3.6	30	4.2	20
11	5.3		10.6		8.0		6.7	
12	6.7		5.1		5.5		3.5	
13	3.5		8.3		9.0		3.0	
14	3.9		6.1		9.3		5.2	
15	3.7		5.7		6.0		5.8	
16	3.5		5.8		8.0		6.7	
17	6.8		3.6		6.7		4.1	
18	3.6		3.8		5.1		4.6	
19	6.3		5.7		3.1		2.1	
20	3.6	30	5.1	30	5.2	10	2.4	40
21	4.2		4.6		4.3		2.4	
22	4.3		4.3		4.3		3.2	
23	5.4		5.9		7.8		3.5	
24	5.4		4.2		7.4		3.1	
25	4.5		4.4		5.2		8.0	
26	7.4		5.3		3.3		6.4	
27	9.5		4.0		2.7		5.8	
28	4.6		5.2		3.3		7.1	
29	5.8		4.6		3.8		3.7	
30	4.9	10	5.0	20	3.2	15	4.3	30
31	5.9		4.8		13.6		2.5	
32	9.7		4.2		6.9		3.3	
33	5.1		4.5		6.4		5.1	
34	5.4		3.6		4.6		2.7	
35	5.9		4.0		4.9		5.0	
36	5.5		4.3		3.8		7.6	
37	4.6		11.1		2.9		11.7	
38	4.0		11.4		3.3		11.0	
39	3.9		8.0		3.6		4.4	
40	8.2	10	6.1	30	4.6	5	2.7	70
41	4.4		4.3		3.9		6.2	
42	6.3		3.5		5.7		6.7	
43	4.4		3.1		4.9		6.3	
44	4.3		5.0		4.4		2.3	
45	4.0		6.9		5.6		9.5	
46	3.7		4.2		3.6		5.3	
47	3.9		6.8		5.5		4.9	
48	6.8		2.9		5.4		3.0	
49	4.6		4.1		4.6		3.8	
50	3.4	30	5.4	40	4.0	10	4.2	
51	4.4		4.0		10.5		3.2	
52	2.5		2.4		4.0		6.2	
53	2.7		8.5		5.5		3.1	
54	6.5		6.4		4.3		3.4	
55	4.3		3.8		2.7		2.4	
56	4.3		5.0		4.1		2.6	
57	6.5		5.1		3.6		2.3	
58	4.1		5.9		4.1		2.9	
59	2.8		4.3		3.7		2.6	
60	2.4	10	2.9	30	5.2	20	2.4	40
61	4.7		8.3		4.6		2.7	
62	2.8		3.9		5.7		3.7	
63	3.7		5.1		4.6		15.6	
64	4.6		3.4		3.5		11.6	
65	2.8		3.6		3.9		4.7	
66	3.3		4.2		4.0		4.6	
67	3.4		3.3		4.6		16.1	
68	4.5		3.4		3.7		6.2	
69	3.8		3.8		5.3		4.1	
70	2.8	20	9.0	20	4.2	30	7.2	30
71	2.7		5.5		3.3		7.1	
72	3.2		8.6		3.0		5.4	
73	2.9		5.5		4.7		9.8	
74	2.4		6.2		3.9		5.8	
75	3.5		4.4		3.8		5.4	
76	4.1		4.7		3.0		5.6	
77	2.9		4.7		3.7		7.1	
78	2.7		5.5		3.3		6.4	
79	2.8		4.3		3.7		11.9	
80	3.3	10	3.8	30	3.6	20	6.8	30
81	7.5		4.4		7.5		4.3	
82	7.9		4.1		7.0		8.7	
83	8.5		5.6		3.0		11.4	
84	8.2		5.8		5.0		11.2	
85	9.2		3.5		4.1		7.5	
86	4.0		3.6		7.2		7.0	
87	6.9		5.8		6.2		2.8	
88	3.2		5.4		6.4		9.5	
89	3.6		4.8		3.4		7.2	
90	5.0	30	3.3	20	10.5	60	4.2	40
91	5.6		5.2		8.1		5.5	
92	4.2		3.7		8.7		8.3	
93	2.6		4.3		10.2		3.5	
94	5.7		4.6		4.2		3.6	
95	8.4		4.7		3.9		2.9	
96	6.3		3.8		8.2		12.3	
97	5.0		4.5		4.3		7.1	
98	2.8		3.7		4.5		10.0	
99	8.7		4.7		5.6		3.7	
100	5.4	20	6.3	20	3.9	25	4.5	30
Minimum	**2.4**		**2.4**		**2.7**		**2.1**	
Maximum	**10.0**		**11.4**		**13.6**		**16.1**	
Mean	**5.0**		**5.0**		**5.1**		**5.8**	
Geometric mean	**4.7**		**4.8**		**4.8**		**5.1**	
Median	**4.5**	**20**	**4.7**	**30**	**4.6**	**20**	**5.1**	**30**
Description of Surrounding material							fine, some sediment (turbidity)	

Note: intermediate axis length is the second longest axis on a cobble. Embeddedness refers to how deeply the cobble is surrounded or buried by other substrate.

Table D.14: Intermediate axis length and embededdness of 100 cobble washed during Hess sampling at benthic invertebrate stations, Minto Mine WUL, 2012.

Cobble Number	LMC-4 Intermediate Axis Length (cm)	LMC-4 Embeddedness (%)	LMC-5 Intermediate Axis Length (cm)	LMC-5 Embeddedness (%)
1	5.8		10.4	
2	8.0		9.4	
3	6.6		6.0	
4	7.5		9.1	
5	5.4		7.4	
6	5.3		6.5	
7	4.0		6.4	
8	7.6		4.7	
9	5.3		4.4	
10	6.1	40	5.6	30
11	11.8		10.7	
12	8.8		8.2	
13	7.7		5.1	
14	4.8		5.1	
15	4.4		5.2	
16	3.7		3.8	
17	5.3		4.8	
18	4.3		7.0	
19	4.1		8.3	
20	5.3	20	8.0	25
21	6.3		4.5	
22	5.5		3.9	
23	5.8		6.3	
24	5.7		3.9	
25	5.8		3.5	
26	6.2		7.4	
27	4.6		8.0	
28	4.0		11.6	
29	3.9		7.1	
30	5.4	40	8.5	40
31	6.5		8.5	
32	4.1		6.5	
33	4.4		5.1	
34	4.3		7.2	
35	5.5		5.0	
36	5.0		5.4	
37	4.2		5.7	
38	2.9		7.5	
39	5.5		4.3	
40	9.7	15	3.9	25
41	5.5		4.5	
42	6.0		5.4	
43	3.8		4.3	
44	9.5		4.7	
45	3.2		5.8	
46	6.0		4.4	
47	4.9		4.4	
48	4.2		4.3	
49	3.8		4.6	
50	3.9	30	5.5	30
51	3.6		4.8	
52	2.3		5.1	
53	3.2		3.4	
54	4.3		5.0	
55	9.3		6.0	
56	5.0		5.3	
57	7.9		3.7	
58	4.4		3.4	
59	8.7		4.4	
60	5.2	30	4.2	
61	9.9		4.0	
62	4.7		4.1	
63	8.5		4.2	
64	6.2		4.8	
65	14.7		3.9	
66	8.2		3.8	
67	7.7		3.7	
68	7.8		4.0	
69	8.5		3.6	
70	3.1	45	3.1	
71	3.9		4.5	
72	4.7		3.9	
73	4.7		3.4	
74	10.9		3.6	
75	8.1		6.4	
76	8.8		6.5	
77	5.6		7.3	
78	7.6		14.2	
79	6.3		6.6	
80	7.6	10	4.6	50
81	7.6		4.9	
82	8.7		4.7	
83	7.2		3.2	
84	6.4		4.1	
85	6.2		7.8	
86	5.1		3.2	
87	5.2		6.7	
88	5.9		4.4	
89	3.4		4.4	
90	6.5	90	5.1	35
91	6.0		5.6	
92	9.7		6.8	
93	6.0		4.7	
94	4.4		8.5	
95	3.6		3.5	
96	3.9		6.3	
97	3.2		7.3	
98	4.8		7.5	
99	3.7		9.3	
100	2.9		4.9	30
Minimum	**2.3**		**3.1**	
Maximum	**14.7**		**14.2**	
Mean	**5.9**		**5.7**	
Geometric mean	**5.5**		**5.4**	
Median	**5.5**	**30**	**5.1**	**30**
Description of Surrounding material	fines			

Note: intermediate axis length is the second longest axis on a cobble. Embeddedness refers to how deeply the cobble is surrounded or buried by other substrate.

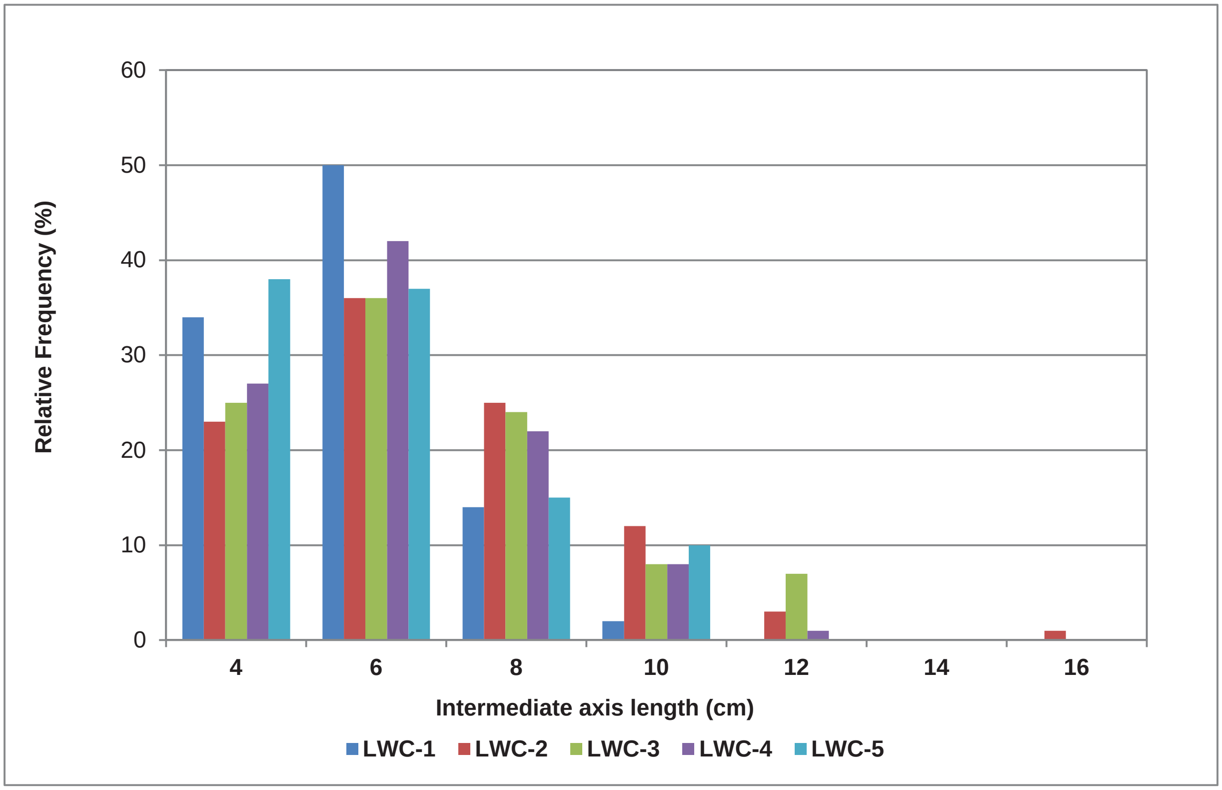


Figure D.1a: Intermediate axis length of 100 rocks measured at five benthic stations in Lower Wolverine Creek.

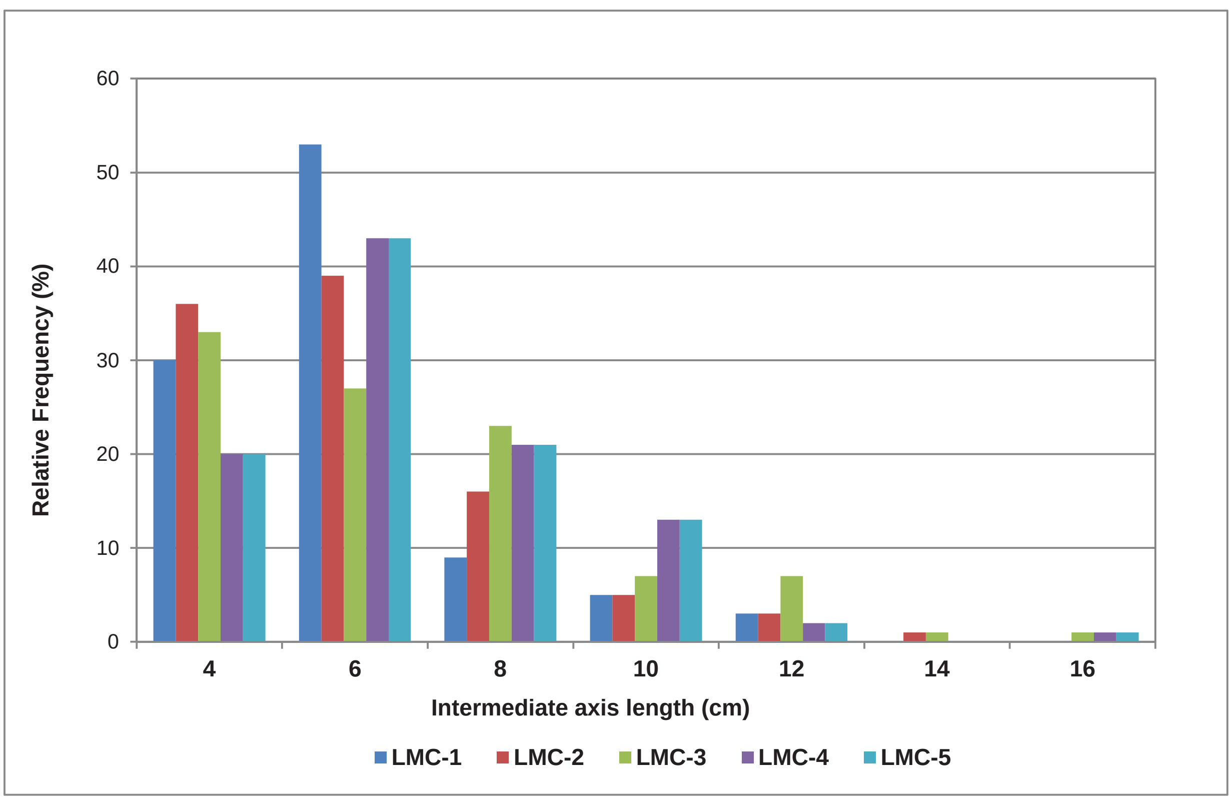
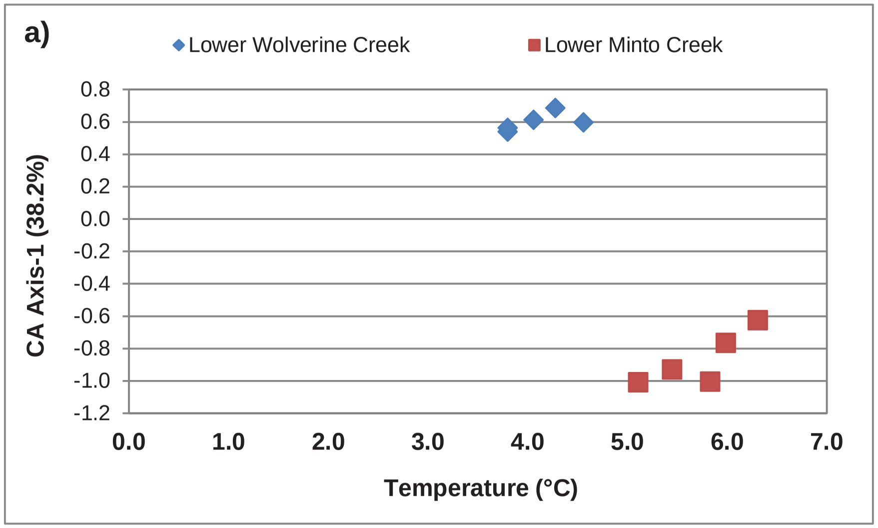
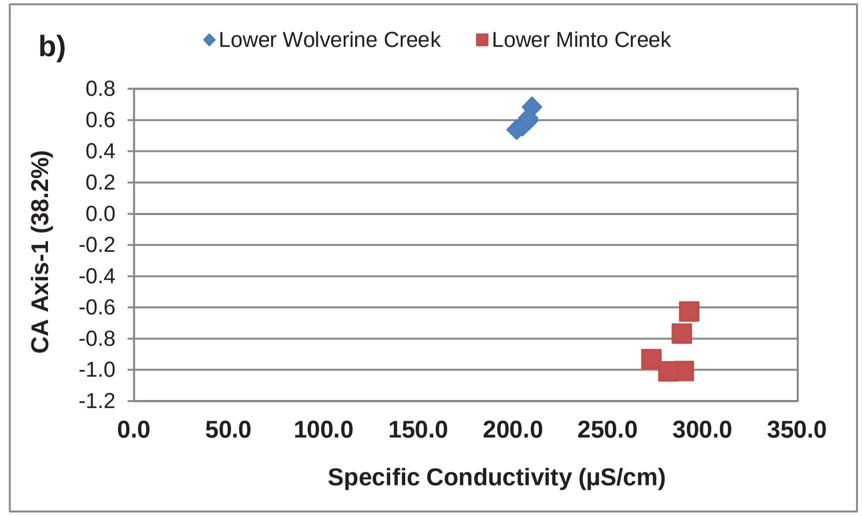


Figure D.1b: Intermediate axis length of 100 rocks measured at five benthic stations in Lower Minto Creek.





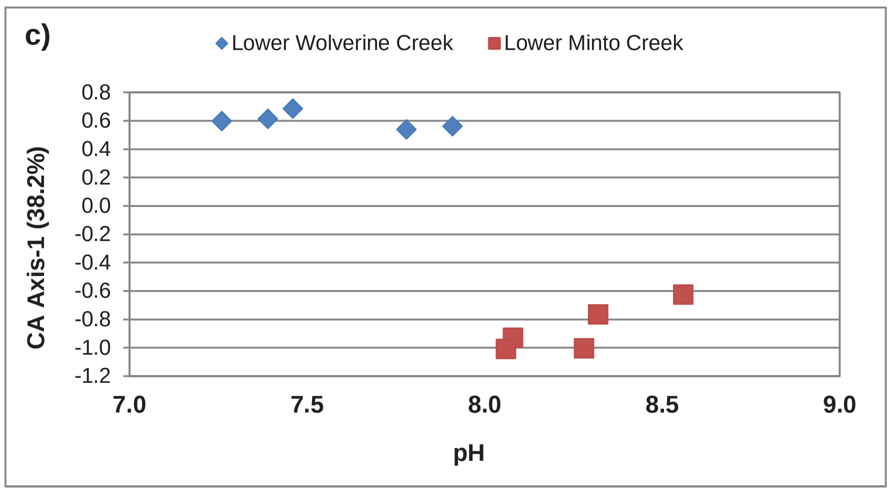
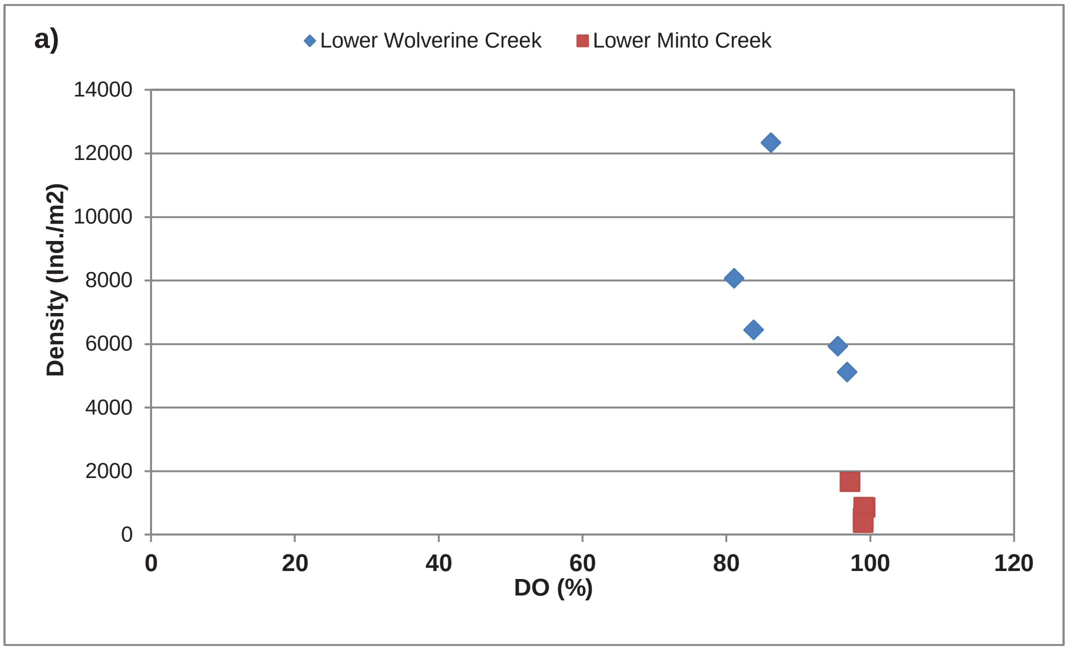


Figure D.2: Scatterplot of benthic invertebrate community compared to CA Axis-1 a) Temperature, b) Specific Conductivity and c) pH



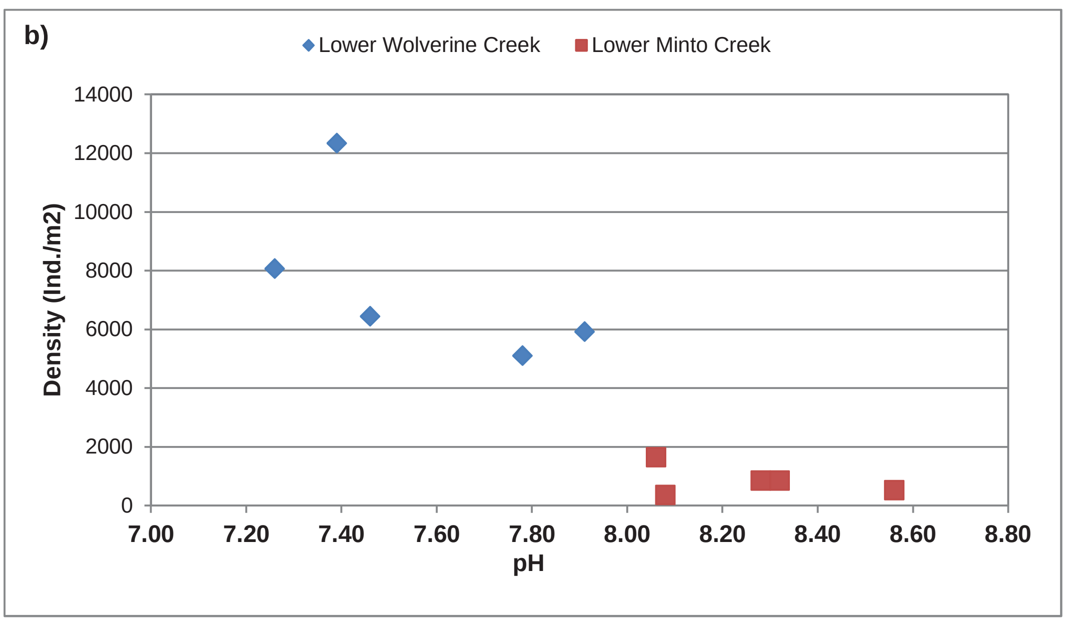


Figure D.3: Scatterplot of benthic invertebrate community compared to Density a) Dissolved Oxygen (%), b) pH

APPENDIX G

MINTO CREEK BENTHIC MACROINVERTEBRATE DATA SUMMARY, 1994

TABLE F1: BENTHIC INVERTEBRATES CAPTURED AT THE MINTO MINE, 1994 (HALLAM KNIGHT PIESOLD LTD.)

Station	B1			B2			B3			B4			B5			B6		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Ephemeroptera																		
Ameletus sp.	1	2	12			1				1	1	2						
Baetis sp.	7	5	4	3	1	1	38	16	7	71	40	159	51	16	8	8	1	5
Cinygmula sp.	2						3	1	1	15		9	1	4				
Ephemerella doddsi																		
Ephemerella grandis																		
Ephemerella infrequens																		
Ephemerella sp.																		
Heptagenia sp.																		
Rhithrogena sp.																		
Plecoptera, unid Juv	10	30	143	266	66	196	26	27	21	1	12	144	144	88	142	24	8	37
Arcynopteryx sp.																		
Capnia sp.	33	30	87	52	83	36	103	32	29	142 9	404	155 5	46	63	50	5	8	
Isoperla sp.																		
Podmosta sp.	2	1	2	147	60	49	5	1	1	41	7	127	10	16	12			
Setvena (bradleyi)																		
Sweltsa sp. group		1																
Taenionema sp.																		
Utaperla sp.																		
Zapada sp.																		
Trichoptera, unid Juv/dam						1												
Adult trichoptera																		
Dicosmoecus sp.	11		1	1	2	5		1										
Ecclisomyia sp.																		
Glossosoma sp.																		
Grensia sp.																		
Facultative organisms																		
Diptera unid Adult																		
Chironomidae, unid Juv/dam	3	86	72	56	41	49	58	11	15	66	1	34	121	409	231	881	670	417
Chironomidae pupae		2	4	3	2					33	56		4	5	35	8	10	2
Chironomidae adult									1									
S.F. Chironominae																		
Chironomus sp.																		1
Micropsectra sp.		1															8	
Phaenopsectra sp.	2					2										8	31	36
Rheotanytarsus sp.		1		2		2											1	
S.F. Diamesinae																		
Diamesa sp.										8		8	4			4		1
Odontomesa sp.																	1	1
Prodiamesa sp.																		
S.F. Orthocladiinae																		
Cardiocladius sp.			2		2	7									2			
Corynoneura sp.																		
Crocotopus sp.	1	4	18	68	17	89	3	3	1	17	33	59	2		1	32	73	6
Diplocladius sp.		2	4	4		5	2			4	1	4	24	15	12	8	16	5
Eukiefferiella sp.		44	64	95	23	138	9	11	10	44	50	68	158	155	76	67	117	36
Euryhapsis sp.	14	32		4	5	27	9	3	2	29	51	63	60	27	17	17	29	3
Heleniella sp.		10		2	2	1				4	8	16		4	10			
Metriocnemus cf. fuscipes															1			
Orthocladius sp.																		
Rheocricotopus sp.																		

TABLE F1: BENTHIC INVERTEBRATES CAPTURED AT THE MINTO MINE, 1994 (HALLAM KNIGHT PIESOLD LTD.)

Station	B1			B2			B3			B4			B5			B6		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Symposiocladius sp.				6	1				1						4			
Synorthocladius sp.		2		2	2	17	6	3	4		1							
Thienemanniella sp.																		
Ceratopogonidae																		
Palpomyia sp.																1		
Culicidae A																		
Empididae																		
Chelifera sp.																		
Clinocera sp.				1														
Weidemannia sp.																		
Muscidae, unid J/D				1	1	1		1				2			1			8
Lispe sp.						1				1					2			
Psychodidae																		
Pericoma sp.								1										
Simulidae unid J/D										1								
Gymnopais sp.																		
Prosimulium sp.	1	7	12					1				2						
Prosimulium sp. P			1															
Simulium sp.		8	18				5	8	12	3	1	8						
Simulium sp. P			7						1									
Syrphidae																		
Syrphus sp.																	1	
Tipulidae unid J/D												1						
Antocha sp.																		
Dicranota sp.	8	8	3	22	24	12	10	10	3	12	13	18	6	19	26	60	6	2
Hesperoconopa sp.																		
Hexatoma sp.																		
Tipula sp.				1	2							1	1					
Homoptera unid A	1		1															
Aphididae	1	1	2	2	2	1	3	1	1	4				4	10	14	14	55
Hymenoptera unid A			2				1											
Coleoptera unid L/A					1													
Thysanoptera																		
Colembola																		
Bourletiella spinata					1													
Hypogastrura sp.				4	9	82		1	1									
Isotoma sp.		24	10	28	68	176	13	4	5		4	8		4				
Podura aquatica							5	2	8					4	30			
Lepidoptera unid L Terr.		1																
Aranea																		
Hydracarina unid J		2	2	2	3	6	4	1		4	8		18		4	4		
Lebertia sp.																		
Sperchon sp.		2		1		3									1		1	
Torrentico la sp.			2		1	2	1	1			4							
Wandesia sp.																		
Oribatei		6	2		1	4	1	1						20	6		8	
Copepoda																		
Cyclopoida	20	26	28	26	18	8		2	2	4	12	8	16	48	30	124	112	8
Harpacticoida		8	2	8	9	14	10	1		32	72	120	4	24	16	12	24	

TABLE F1: BENTHIC INVERTEBRATES CAPTURED AT THE MINTO MINE, 1994 (HALLAM KNIGHT PIESOLD LTD.)

Station	B1			B2			B3			B4			B5			B6		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Ostracoda																		
Candona sp.	1	11	6		1	16		1	1	16	24	16	476	323	141	64	21	20
Cypria sp.	1	1			1				1									
Tardigrada			1															
Gastropoda unid Terr.					1													
Oligochaeta, Naididae																		
Nais (communis)																12		
Pristina so	4	2	10	2						4	8		8		8	13		
Nematoda	7	254	90	193	94	80	39	5	5	33	44	153	20	81	162	139	333	249
Turbellaria									1						1			
Tolerant organisms																		
Oligochaeta																		
Enchytraeidae	8	15	23	2	1			4	4	37	4	29	5	24	25	9	17	4
Lumbriculidae	1		2				1	1									1	
Kincaidiana hexatheca								1										
Tubificidae	2	9	57	3	2	2	9	11	6	105	21	16	42	145	60	157	24	22
Density (#/m²)																		
Sensitive		1381			3489			1302			14453			2342			345	
Facultative		3496			5802			1173			4673			10395			13608	
Tolerant		421			36			162			1014			1277			950	
Total		5298			9327			2637			20140			14014			14903	
%																		
Sensitive		26.07			37.41			49.39			71.76			16.71			2.32	
Facultative		65.99			62.21			44.47			23.20			74.18			91.31	
Tolerant		7.94			0.39			6.14			5.04			9.11			6.37	
# of Species		44			43			38			34			33			31	
Shannon Weiner Diversity		3.88			3.69			3.76			2.59			3.56			2.82	
Dominance		0.11			0.11			0.13			0.38			0.13			0.27	
Equitability		0.71			0.68			0.72			0.51			0.71			0.57	
Richness		5.89			5.34			5.61			3.82			3.87			3.60	
TU Diversity		0.892			0.894			0.873			0.623			0.871			0.732	
Variance		0.027			0.015			0.049			0.319			0.030			0.165	

Adapted from Tables 7.2 & 7.3 in MintoEx's IEE (1994)

APPENDIX H

MCGINTY CREEK BENTHIC INVERTEBRATE DATA, 2010

Area coordinates and habitat characterization data summary, Minto North, September 201

Characteristics	Mid McGuinty Creek	Upper McGuinty Creek
Latitude (degrees, minutes, seconds)	62° 40' 33.7"	62° 39' 53.2"
Longitude (degrees, minutes, seconds)	137° 14' 12.6"	137° 14' 24.6"
Average depth (m)	0.15	0.15
Maximum depth (m)	0.32	0.35
Wetted width (m)	1.65	0.5
Bankfull width (m)	3.5	5 - 7
Water appearance (colour/clarity)	clear	clear
General morphology	-	30% riffle, 70% run
Geomorphic type	A	A
Bank condition	-	moderately stable
Substrate	5% boulder, 70% cobble, 20% gravel, 5% sand&finer	20% cobble, 60% gravel, 20% sand&finer
Instream cover	1% undercut banks, 1% boulder, 5% woody debris	5% undercut banks, 10% woody debris
Residual pool depth (m)	0.32	0.35
Other in-stream features	none	small log jams
Overhead canopy (% surface)	30% dense, 70% partially open	80% dense, 20% partially open
Riparian vegetation	willow, aspen, spruce, alder	willow, aspen, spruce, alder
Aquatic vegetation (%areal coverage and dominant species)	0%	0%
Surrounding land use	forest	black spruce forest/none
Evidence of anthropogenic disturbance	none	none
Weather notes	overcast	sunny

Summary of erosional substrate characterization, McGuinty Creek, September

Variable		Mid McGuinty Creek (MNE)	Upper McGuinty Creek (MNU)
Summary Statistics	Median length (cm)	5.05	2.9
	Geometric mean length (cm)	4.8	2.7
	Median substrate embeddedness (%)	30	20
Percent Composition of Substrate Lengths	< 0.1 cm	0	0
	0.1 - 0.2 cm	0	0
	0.2 - 1.6 cm	4	20
	1.6 - 3.2 cm	21	38
	3.2 - 6.4 cm	42	36
	6.4 - 12.8 cm	29	6
	12.8 - 25.6 cm	4	0
	> 25.6 cm	0	0
	bedrock	0	0

2010 Benthic data, McGinty Creek, Minto Mine.

Major Taxon	Family	Subfamily/Tribe	Genus/Species	Mid McGinty Creek							Upper McGinty Creek						
				#1	#2	#3	#4	# 5	TOTAL	SD	#1	#2	#3	#4	# 5	TOTAL	SD
Nematoda				280	1027	200	613	300	2420	342	0	3	0	80	90	173	46
Tricladida				40	0	0	0	0	40	18	0	0	0	53	47	100	27
Oligochaeta (i/d)				53	80	0	0	0	133	38	13	27	0	53	0	93	22
Oligochaeta	Enchytraeidae			0	0	0	27	93	120	40	147	53	23	427	0	650	175
Oligochaeta	Haplotaxidae		*Haplotaxis*	0	0	0	0	3	3	1	0	0	0	0	0	0	0
Oligochaeta	Lumbriculidae			317	487	873	87	233	1997	302	140	30	27	23	1547	1767	669
Oligochaeta	Tubificidae			0	0	13	0	0	13	6	53	293	223	430	0	999	176
Tardigrada				0	0	0	0	0	0	0	0	0	0	27	0	27	12
Hydracarina				0	40	40	0	53	133	25	0	0	0	0	0	0	0
Ostracoda				0	0	0	53	0	53	24	0	0	0	27	43	70	20
Copepoda-Cyclopoida				13	0	0	53	0	66	23	0	0	0	27	0	27	12
Copepoda-Harpacticoida				0	0	0	0	27	27	12	67	0	0	27	90	184	40
Collembola	Isotomidae		*Agrenia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collembola	Isotomidae		*Isotomus*	0	0	13	0	27	40	12	0	0	0	0	0	0	0
Ephemeroptera	Ameletidae		*Ameletus celer*	7	0	0	0	3	10	3	0	0	0	0	0	0	0
Ephemeroptera	Ameletidae		*Ameletus* sp.	13	0	0	0	0	13	6	0	0	0	0	0	0	0
Ephemeroptera	Baetidae		*Baetis*	0	7	0	0	0	7	3	0	3	0	0	0	3	1
Ephemeroptera	Ephemerellidae		*Drunella doddsi*	13	0	0	0	0	13	6	0	0	0	0	0	0	0
Plecoptera (i/d)				40	0	0	0	0	40	18	0	0	0	0	0	0	0
Plecoptera	Capniidae			140	160	190	80	323	893	90	353	327	537	197	230	1644	133
Plecoptera	Nemouridae (i/d)			27	27	93	53	240	440	89	133	107	157	107	223	727	48
Plecoptera	Nemouridae		*Nemoura*	113	153	13	110	243	632	83	73	173	210	47	117	620	68
Plecoptera	Nemouridae		*Shipsa rotunda*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Limnephilidae		*Dicosmoecus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera	Noctuidae		-	0	3	0	0	0	3	1	0	0	0	0	0	0	0
Diptera	Ceratopogonidae		*Culicoides*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Dolichopodidae		*Rhaphium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Empididae		*Chelifera / Metachela*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Empididae		*Clinocera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Empididae		*Proclinopyga* ?	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Muscidae		*Limnophora*	0	0	0	0	0	0	0	3	0	0	0	0	3	1
Diptera	Simulidae - Pupa			0	3	0	7	3	13	3	0	0	0	0	0	0	0
Diptera	Simulidae (i/d)			13	13	0	0	0	26	7	0	0	0	0	0	0	0
Diptera	Simulidae		*Gymnopais*	0	0	0	0	3	3	1	0	0	3	0	0	3	1
Diptera	Simulidae		*Prosimulium*	0	0	0	3	0	3	1	0	0	0	0	0	0	0
Diptera	Simulidae		*Ectemnia*	13	27	107	143	27	317	58	0	0	0	0	0	0	0
Diptera	Tipulidae		*Dicranota*	0	3	0	0	13	16	6	3	0	20	0	0	23	9
Diptera	Tipulidae		*Erioptera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Tipulidae		*Hexatoma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Tipulidae		*Rhabdomastix*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Tipulidae		*Tipula*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae - Pupa			0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Chironomini	*Polypedilum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Chironomini	*Sergentia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Chironomini	*Stictochironomus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Tanypodinae	*Procladius*	0	0	0	0	0	0	0	0	0	0	3	0	3	1
Diptera	Chironomidae	Tanytarsini	*Micropsectra*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Tanytarsini	*Neostempellina*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*	0	0	0	0	27	27	12	0	0	0	0	0	0	0
Diptera	Chironomidae	Orthocladiinae (i/d)		40	0	0	0	80	120	36	0	0	0	0	0	0	0
Diptera	Chironomidae	Orthocladiinae	*Brillia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Orthocladiinae	*Cricotopus / Orthocladius*	133	40	120	80	107	480	37	93	507	267	187	267	1321	153
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*	13	0	0	0	0	13	6	0	0	0	0	0	0	0
Diptera	Chironomidae	Orthocladiinae	*Diplocladius*	67	80	13	27	293	480	114	107	0	90	213	533	943	207
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*	1003	1107	640	533	2347	5630	724	827	1157	830	1377	110	4301	480
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Orthocladiinae	*Hydrobaenus*	0	0	0	0	0	0	0	13	0	0	0	0	13	6
Diptera	Chironomidae	Orthocladiinae	*Krenosmittia*	0	0	0	83	27	110	36	13	0	23	27	0	63	13
Diptera	Chironomidae	Orthocladiinae	*Lymnophyes*	0	0	0	0	3	3	1	0	0	0	0	0	0	0
Diptera	Chironomidae	Orthocladiinae	*Metriocnemus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Orthocladiinae	*Orthocladius lignicola*	0	0	0	0	0	0	0	13	0	0	0	0	13	6
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*	0	0	0	0	0	0	0	13	0	0	0	0	13	6
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*	0	13	0	80	0	93	35	0	10	13	3	133	159	57
Diptera	Chironomidae	Orthocladiinae	*Paraphaenocladius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*	13	0	13	0	80	106	34	0	0	0	0	0	0	0
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*	0	0	0	0	0	0	0	0	0	0	0	3	3	1
Diptera	Chironomidae	Podonominae	*Trichotanypus*	0	0	0	27	0	27	12	13	0	0	0	0	13	6
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Diamesinae	*Diamesa*	7	43	50	0	7	107	23	0	30	27	0	43	100	19
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*	0	27	0	0	0	27	12	0	0	0	0	0	0	0
Terrestrial										SD							SD
			Total Number of Organisms	2358	3340	2378	2059	4562	2939	1027	2077	2720	2450	3335	3476	2812	590
			Total Number of Taxa [a]	21	19	14	17	24	**40**		18	13	14	19	14	**29**	
			Mean Number of Taxa						19	4						15.6	3
			Simpson's Diversity (1-D)	0.775	0.768	0.772	0.826	0.712	0.771	0.041	0.791	0.752	0.804	0.783	0.759	0.778	0.022
			Simpson's Diversity (D)	0.225	0.232	0.228	0.174	0.288	0.229	0.041	0.209	0.248	0.196	0.217	0.241	0.222	0.022
			Simpson's Evenness (E) EEM	0.212	0.227	0.314	0.338	0.145	0.247	0.079	0.266	0.310	0.364	0.243	0.296	0.296	0.046
			Simpson's Evenness (E) Krebs	0.814	0.811	0.832	0.878	0.743	0.815	0.049	0.838	0.815	0.866	0.827	0.817	0.832	0.021
			Percent Composition														
			% Nematodes	12%	31%	8%	30%	7%	17%	12%	0%	0%	0%	2%	3%	1%	1%
			% Oligochaetes	16%	17%	37%	6%	7%	17%	13%	17%	15%	11%	28%	45%	23%	14%
			% Chironomids	54%	39%	35%	40%	65%	47%	12%	53%	63%	51%	54%	31%	50%	12%
			% Tipulids	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
			% ETP	15%	10%	12%	12%	18%	13%	3%	27%	22%	37%	11%	16%	23%	10%

Proclinopyga = undescribed Empidid larva possibly belongs to this genus
i/d - small or deamaged individuals

APPENDIX I

MINTO CREEK PERIPHYTON DATA, 1994

MINTO CREEK PERIPHYTON STUDY RESULTS (HKP, 1994)

Species	Site P3 Replicate						Site P2 Replicate						Site P3 Replicate					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2*	3*	4*	5*	6
Cyanophyceae																		
Chamaesiphon incrustans										10%	10%							
Lyngbya digueti										25%	5%	1%						
Lyngbya nordgaardii																		
Nostoc sp.										+							+	+
Phormidium sp.										+		+	35%	+	+			5%
Plectonema notatum			10%			+				5%	5%							
(unidentified filament)																		
Chlorophyceae																		
Closterium sp.	+						+		+		+							
Microspora amoena																		
Stigeoclonium sp.																		
(unidentified – 15 µm)																		
Chrysophyceae																		
Hydrurus foetidus						+							+					
Rhodophyceae																		
Audouinella violacea	25%	50%	10%	59%	5%	25%		+	1%	1%	2%		35%	+		+	+	5%
Bacillariophyceae																		
Achnanthes spp.	++	++	+	+	+	+		+		+		+	+	+			+	+
Amphora sp.					+							+						
Caloneis ventricosa								+										
Cymbella spp.	+		+				+	+	+	+	+	+				+		
Eunotia sp.			+															
Fragilaria cf. *capucina*																		
Gomphonema spp.				+			+	+	+	+	+	+	+		+	+	+	+
Hannaea arcus																	+	
Meridion circulaire	+	+	+	+	+		+	+	+	+	+	+						+
Navicula spp.	+++	+++	+++	+	+++	+++	+	++	+	+	+	+++	+	+	+		+	+++
Nitzschia spp. (30-50 µm)	+	+	+	+	+	+	++	+++	+++	++	++	++				+	+	++
Nitzschia sp. (100x6 µm)			+			+	+++	+++	++	++	+++	+++						
Nitzschia sp. (100x10 µm)								++	++	++	++	+++			++	+	+	+++
Nitzschia acicularis									+	+		++						
Pinnularia sp.	+				+	+		+										
Stauroneis sp.			+							+		+						+
Surirella angustata					+		+	+	+	+	+	+						+
Synedra cf. *incisa*	+	+++	++	+++	+	++				+		+	++		++	+	+	++
Synedra rumpens	+				+		+		+		+	+	+	+	+	+	++	++
Synedra ulna					+							+						+
% Bacillariophyceae	75	50	80	50	95	75	>99	>99	99	59	78	99	30					90

Key to abundance: +++ Dominant, ++ Common, + Present
* too little in sample to estimate % abundance
i sample not collected quantitatively

MINTO CREEK PERIPHYTON STUDY RESULTS (HKP, 1994)

Species	Site P4[i] Replicate						Site P5 Replicate						Site P6 Replicate					
	1	2	3	4	5	6	1*	2*	3	4	5	6	1*	2*	3*	4*	5*	6*
Cyanophyceae																		
Chamaesiphon incrustans															30%	10%	10%	25%
Lyngbya digueti	20%				5%								5%	5%	5%	5%	5%	5%
Lyngbya nordgaardii																		
Nostoc sp.										+	10%	+						
Phormidium sp.							+			1%								
Plectonema notatum																		
(unidentified filament)														1%	1%	1%	10%	+
Chlorophyceae																		
Closterium sp.	5%	1%	+	+	1%	+		+					+	+	+	5%	5%	+
Microspora amoena	+												+					
Stigeoclonium sp.														1%				
(unidentified - 15 µm)																	+	
Chrysophyceae																		
Hydrurus foetidus				50%							+		40%		5%	5%	25%	5%
Rhodophyceae																		
Audouinella violacea										+	+	5%						
Bacillariophyceae																		
Achnanthes spp.	+	+	+	+	+	+	+	+	++	+	+	+	+	+	++	+	+	+
Amphora sp.																		
Caloneis ventricosa			+															
Cymbella spp.	+	+	+	+	+	+			+			+	+		+	+	+	+
Eunotia sp.	+				+	+												
Fragilaria cf. *capucina*		+																
Gomphonema spp.	++	+		+	+	+				++	+		+++	+++	+++	+++	++	++
Hannaea arcus																		
Meridion circulaire	++ +	+	+	+	+	++		+	+	+		+	++	+	++	+	+	++
Navicula spp.	++	++	++	++	++	++	+	++	+	+++	++	++	++	++	++	++	+	+
Nitzschia spp. (30-50 µm)	+	++	+++	+++	+++	+++	+	+		+	+	+	+		+	+	+	+
Nitzschia sp. (100x6 µm)	++	+	++	++	++	++					+				+	+	+	+
Nitzschia sp. (100x10 µm)	++	+++	+++	++	+++	++		+				+						+
Nitzschia acicularis							+	+	+	++	+	+						
Pinnularia sp.																		
Stauroneis sp.	+	+							+									
Surirella angustata	+	+	+	+		+	+				+	+			+			
Synedra cf. *incisa*	+	+				+	+	+			+	+	+					+
Synedra rumpens							++	++	++	+	+	+	+				++	++
Synedra ulna	+	+		+	+	+											+	
% Bacillariophyceae	75	99	>99	50	95	>99			100	99	90	95						

Key to abundance: +++ Dominant, ++ Common, + Present
* too little in sample to estimate % abundance
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