BENTHIC INVERTEBRATE COMMUNITIES AT THE MT. NANSEN MINE SITE

EDI ENVIRONMENTAL DYNAMICS INC.
Natural Resource Consultants

PREPARED FOR:

YUKON ENERGY MINES AND RESOURCES

ABANDONED MINES PROJECT OFFICE (TYPE II)

BOX 2703 (K-149)

WHITHEORSE, YT Y1A 2C6

PREPARED BY:

EDI ENVIRONMENTAL DYNAMICS INC.

402 HAWKINS ST

WHITEHORSE, YT

YIA 1X8

EDI CONTACT:

PAT TOBLER, R.P.BIO (867) 393-4882

LYNDSAY DOETZEL, M.SC. (867) 393-4882

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ABSTRACT

This study investigated benthic invertebrate community composition in the upstream and receiving environments at the Mt. Nansen mine site, including Victoria and Dome Creeks. The Mt. Nansen mine site is a former gold and silver mine located 60 km west of Carmacks, Yukon. Ore production at Mt. Nansen ceased in 1999; however, placer mining is ongoing in Back Creek, a tributary to Victoria Creek. Monitoring the aquatic effects of the mine site is one component of ongoing reclamation efforts. Benthic invertebrates are a valuable indicator in aquatic ecosystems because they are known to be sensitive to elevated metals levels, which are often associated with hard-rock mining activity, as well as elevated sediment levels, which are often associated with disturbances, especially placer mining.

Benthic invertebrate samples were collected from four sampling locations, one in Dome Creek and three in Victoria Creek, selected to represent upstream and downstream aquatic environments, influenced both by past hard-rock mining activity as well as ongoing placer mining activity. Benthic invertebrates in each sub-sample were identified to family for individuals within the four major orders (Diptera, Ephemeroptera, Trichoptera, and Plecoptera) and to order for all other individuals.

Results showed the benthic invertebrate community in Dome Creek to be distinct from Victoria Creek, with Victoria Creek being dominated by Diptera and Dome Creek by Plecoptera. Dome Creek is smaller, and physically different than Victoria Creek, and is influenced by past mining activity, but isolated from ongoing placer mining. In comparison with historical data, Diptera (primarily the family Chironomidae) has replaced Ephemeroptera and/or Plecoptera as the dominant order in all Victoria Creek sampling locations since 1988 and in Victoria Creek downstream of Dome Creek since 2000.

In Dome Creek, Diptera (primarily Chironomidae) replaced Plecoptera as the dominant order in 1997 and 2000, during and just following the most recent period of mining activity at Mt. Nansen. However, relative abundance of Plecoptera in Dome Creek has now returned to a level similar to that found in 1988, prior to the most recent period of mining activity at Mt. Nansen. Past studies have linked declines in the abundance of Ephemeroptera and Plecoptera to increased exposure to sediment and to elevated metals levels, while Chironomidae are known to become relatively more abundant in response to disturbance.

Functional feeding group analysis showed a relatively greater abundance of shredders in Dome Creek in comparison to Victoria Creek. This finding is linked to the dominance of the Plecoptera families Nemouridae and Taeniopterygidae at this location (both of which are shredders), and is likely related to the relatively greater abundance of coarse organic material in this stream.

Richness of benthic invertebrate taxa generally declined with increased downstream disturbance in Victoria Creek, a finding which may be related to the placer mining on Back Creek, and/or to the downstream effects of historically elevated metals levels in Dome Creek.

The findings from this study suggest that benthic invertebrate communities in Dome Creek may be responding to improved aquatic conditions, whereas benthic invertebrate communities in Victoria Creek may be influenced by sediment release associated with upstream placer activity in Back Creek.

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1 INTRODUCTION

The Yukon Government's Assessment and Abandoned Mines Branch is currently working towards reclamation of the Mt. Nansen gold and silver mine site. In 2007, EDI Environmental Dynamics Inc. (EDI) was retained by the Yukon Government, Department of Energy, Mines and Resources, to investigate benthic invertebrate communities on the Mt. Nansen mine site.

Benthic invertebrate communities can be a valuable ecological indicator in aquatic systems. As sedentary, bottom-dwelling and detritus-feeding aquatic organisms, benthic invertebrates sustain exposure to stream sediments and stream water throughout their life cycle. They are also an important food source for fish. Some species of invertebrates are known to be intolerant to the elevated concentrations of metals often associated with mining activity, while other, more tolerant species become more dominant in contaminated sites (Maret et al., 1994). Benthic invertebrates also demonstrate sensitivity to sediment exposure and increased stream sediment levels associated with placer mining (Madison, 1981; Shaw and Richardson, 2003; Weber, 1986). Monitoring of benthic invertebrates provides a time-integrated look at watercourse conditions rather than the snap-shot view provided by chemical and physical water sampling and analyses.

The objective of this study was to document the benthic invertebrate communities in both upstream and receiving environments at the Mt. Nansen mine site. Characterizing the benthic invertebrate communities in the upstream and downstream environments at the Mt. Nansen mine site may help to understand the ecological effects of past mining activity, as well as ongoing placer mining activity, and aid in ongoing reclamation work at the mine site.

1.1 STUDY AREA

The Mt. Nansen mine is located approximately 60 kilometres west of Carmacks, Yukon. The site is accessed via a gravel-surface road connecting the mine site to Carmacks (Figure 1). The Mt. Nansen mine site lies within the watershed of Victoria Creek, a tributary stream to the Nisling River, which is a medium sized river in the Donjek/White Rivers drainage basin.

Two small streams drain the majority of the mine footprint. The primary drainage is Dome Creek which flows from above the mill site, past the tailings facilities into Victoria Creek. In addition, Pony Creek drains a small portion of the mine site north of the Brown-McDade Pit and eventually flows into Back Creek, which is a tributary to Victoria Creek. It should be noted that there is an active placer operation is present on Back Creek upstream of the mouth of Pony Creek.

Water quality within the mine site drainages has been a concern. The tailings facilities adjacent to Dome Creek have had high levels of cyanide, ammonia, dissolved arsenic and other metals. Leakage of the tailing facilities leading to contamination of Dome and Victoria Creeks was documented in the late 1990's. Since management of the site was taken over by DIAND in 1999 (and subsequently by the Yukon Government), tailings water has been contained and released only when levels have been within water license standards. While there is limited data on Pony Creek, Gartner Lee (2005) noted that water quality in Pony Creek degrades as it flows downstream through a waste rock pile (near the adit). The sampling site farthest downstream had concentrations of arsenic, cadmium, copper and zinc that exceeded CCME guidelines.

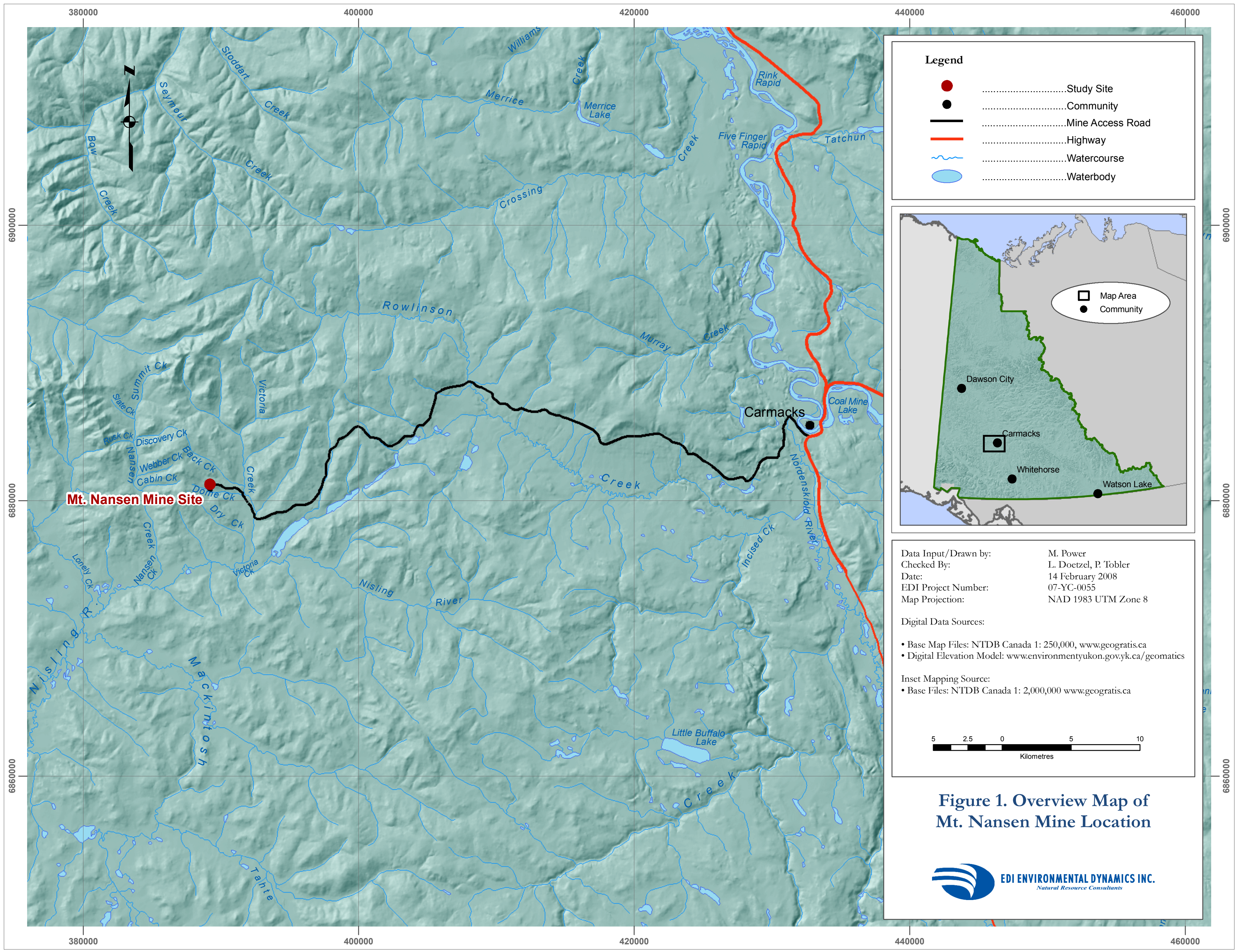

Figure 1. Overview Map of Mt. Nansen Mine Location

2 METHODS

2.1 STUDY DESIGN

2.1.1 SAMPLING LOCATIONS

Sampling locations were established at four sites representing the upstream and receiving environments at the mine site (Table 1; Figure 2). The first sampling location at Victoria Creek upstream of Dome and Back Creeks was selected to represent an environment upstream of the impacts of the mine site. A second sampling location at Victoria Creek between Dome and Back Creeks was selected to represent the receiving environment of Pony Creek, as well as a site influenced by upstream placer activity in Back Creek. The third and fourth sampling locations were established at Victoria Creek downstream of Dome Creek and within the lower portion of Dome Creek to represent the receiving environment.

Table 1: Benthic Invertebrate Sampling Locations

Location	UTM Coordinates	Rationale for Sampling
Victoria Creek upstream of Dome and Back Creeks	08 391681 6880888	Upstream of impacts from the mine site
Victoria Creek between Dome and Back Creeks	08 391686 6880693	Partial receiver (via Pony Creek) and also influenced by upstream placer activity in Back Creek.
Victoria Creek downstream of Dome Creek	08 392439 6879101	Part of the receiving environment
Lower Dome Creek	08 391271 6880458	Part of the receiving environment

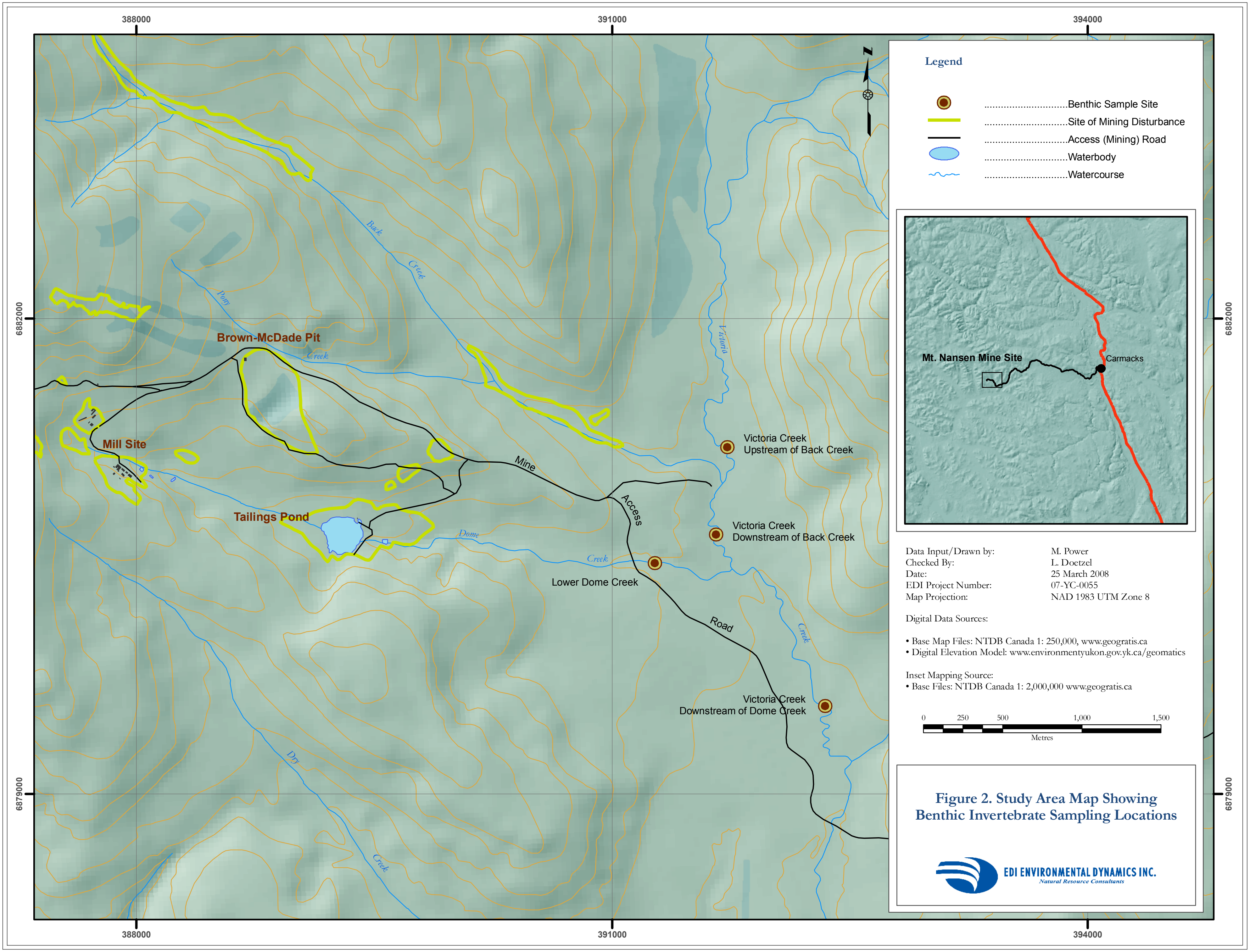

Figure 2. Study Area Map Showing Benthic Invertebrate Sampling Locations

2.1.2 FIELD SAMPLING METHODS

Benthic invertebrate sampling followed the field procedures outlined in the Canadian Aquatic Biomonitoring Network Invertebrate Biomonitoring Field and Laboratory Manual (Reynoldson et al., 2003). This method involved sampling a stream reach equal to six bankfull widths of the stream at the sampling location, using a kick-net. Samples were then placed in 70% ethanol for storage prior to identification. Additional data were collected at each sampling location to characterize the attributes of the sample stream, including stream velocities, water quality parameters, substrate dimensions, and vegetation conditions.

2.1.3 SUB-SAMPLING METHODS AND SAMPLE IDENTIFICATION

The benthic invertebrate samples collected at three of the four sampling locations were further sub-sampled to achieve efficiencies in identification. Samples from Victoria Creek upstream of Back Creek were not sub-sampled. Sub-sampling was conducted using a greenhouse planter box with 72 numbered cells, each 2.5 cm by 2.5 cm by 5 cm. Each kick-net sample was agitated in a large jar and then poured into the cells in the planter box. In addition to benthic invertebrates, the samples contained sediments, water, and organic matter. The planter box cells were further divided into five categories of media based on the relative composition of sediment, water, and organic matter in each. A random number generator was used to select cells within each of the five media categories in the planter box for sub-sampling. Benthic invertebrates in each sub-sample were enumerated using a click counter and identified to family for individuals within the four major orders (Diptera, Ephemeroptera, Trichoptera, and Plecoptera) and to order for all other individuals, following Clifford (1991). These families/orders were then further categorized into functional feeding groups, following Merritt and Cummins (1995). Densities from sub-sampled sites were extrapolated to estimate the actual densities within the entire sample.

2.1.4 DATA ANALYSIS

The following analyses were performed on the extrapolated dataset:

Diversity

1. **Total taxa richness:** The total number of distinct taxa counted at each site. Distinct taxa include individuals identified only to family/order (Resh and Jackson 1993, Karr and Chu 1999).

2. **Ephemeroptera taxa richness:** Number of distinct Ephemeroptera families counted at each site (Karr and Chu 1999).

3. **Plecoptera taxa richness:** Number of distinct Plecoptera families counted at each site (Karr and Chu 1999).

4. **Trichoptera taxa richness:** Number of distinct Trichoptera families counted at each site (Karr and Chu 1999).

5. **Diptera taxa richness:** Number of distinct Diptera families counted at each site (Karr and Chu 1999).

Relative Abundance

1. **% Ephemeroptera:** The number of Ephemeroptera individuals divided by the total number of individuals in each sample (Karr and Chu 1999).

2. **% Plecoptera:** The number of Plecoptera individuals divided by the total number of individuals in each sample (Karr and Chu 1999).

3. **% Trichoptera:** The number of Trichoptera individuals divided by the total number of individuals in each sample (Karr and Chu 1999).

4. **% Diptera:** The number of Diptera individuals divided by the total number of individuals in each sample (Karr and Chu 1999).

5. **% Predators:** The number of predators divided by the total number of individuals in each sample (Karr and Chu 1999).

6. **% Collector-gatherers:** The number of collector-gatherers divided by the total number of individuals in each sample (Karr and Chu 1999).

7. **% Collector-filterer:** The number of Collector-filterers divided by the total number of individuals in each sample (Karr and Chu 1999).

8. **% Scrapers:** The number of scrapers divided by the total number of individuals in each sample (Karr and Chu 1999).

9. **% Shredders:** The number of shredders divided by the total number of individuals in each sample (Karr and Chu 1999).

3 RESULTS

3.1 STREAM CHARACTERISTICS

Victoria Creek, at all three sampling locations, was wider and faster-flowing than Dome Creek. Victoria Creek had a channel width ranging from 6 to 9 m and an average velocity of 0.20-0.40 m/s at the three sampling locations, whereas Dome Creek had a channel width of 2 m and an average flow velocity of 0.15 m/s. The substrate at all three sample locations in Victoria Creek was composed of cobbles, gravels and some fines, while fines comprised the dominant substrate at Dome Creek. Visual observations indicated that turbidity of Victoria Creek increased downstream of Back Creek and was even greater downstream of Dome Creek. Dome Creek had greater overhanging vegetation (predominantly grasses) with estimated 40-50% canopy coverage; whereas Victoria Creek had little overhanging vegetation with 5-20% estimated canopy coverage at all three sampling locations. Detailed stream attribute data for all sampling locations are provided in Appendix B.

3.2 ORDER LEVEL RELATIVE ABUNDANCE ANALYSIS

Figure 3 through Figure 6 show the relative abundance of the benthic invertebrate orders at each sampling location. Diptera was dominant at all three Victoria Creek sampling locations, and sub-dominant at Dome Creek, where Plecoptera was dominant.

The relative abundance of the four major orders was similar at each of the three sampling locations on Victoria Creek, with the least disturbed site upstream of Back Creek and the site furthest downstream below Dome Creek showing the greatest similarities. Other notable results from Victoria Creek sites are listed below.

- Diptera ranged from 68% of the community composition in Victoria Creek downstream of Dome Creek to 81% in Victoria Creek between Back and Dome Creeks, and comprised 71% of the community in the least disturbed location upstream of Back Creek.

- Plecoptera ranged from 12% in Victoria Creek downstream of Back Creek to 17% in Victoria Creek downstream of Dome Creek, and comprised 15% of the community at the least disturbed location upstream of Back Creek.

- Ephemeroptera ranged from 4% in Victoria Creek downstream of Back Creek to 14% in Victoria Creek downstream of Dome Creek, and comprised 8% of the community in the least disturbed location upstream of Back Creek.

Relative abundance of the four major orders in Dome Creek differed from Victoria Creek. Plecoptera was the dominant order at this site (64%), followed by Diptera (27%). Ephemeroptera and Trichoptera were absent (Figure 5).

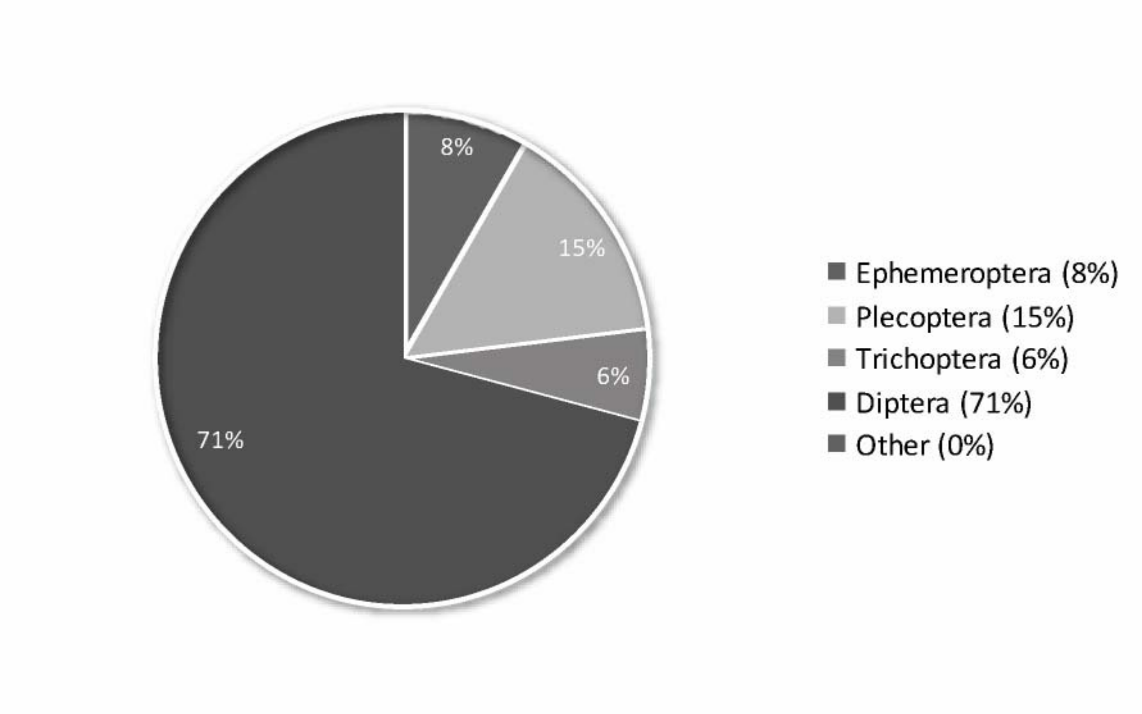

Figure 3. The relative abundance (%) of the benthic invertebrate orders at Victoria Creek upstream of Back Creek.

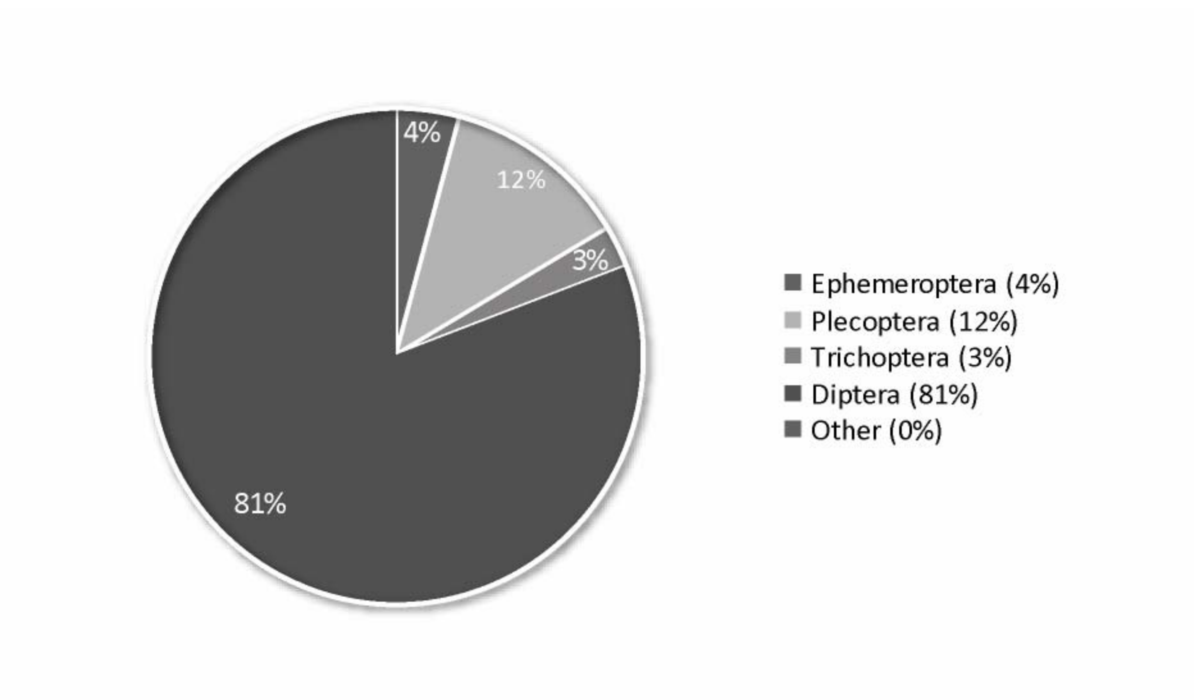

Figure 4. The relative abundance (%) of the benthic invertebrate orders at Victoria Creek downstream of Back Creek.

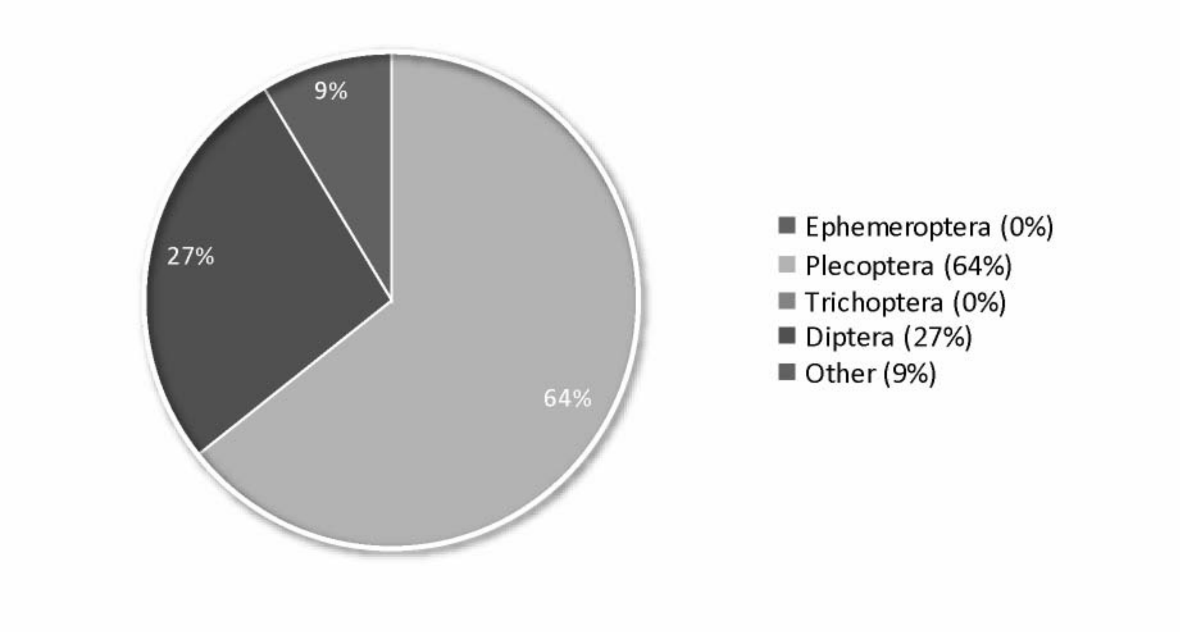

Figure 5. The relative abundance (%) of the benthic invertebrate orders at Lower Dome Creek.

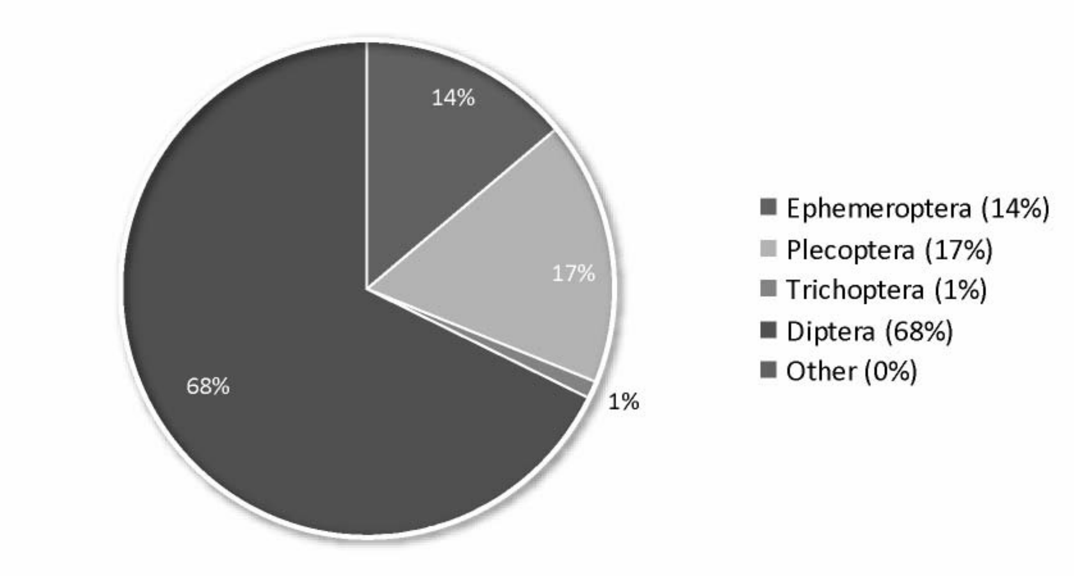

Figure 6. The relative abundance (%) of the benthic invertebrate orders at Victoria downstream of Dome Creek.

3.3 FUNCTIONAL FEEDING GROUP ANALYSIS

Analysis of relative abundance of five functional feeding groups at the three sites on Victoria Creek yielded the following results. Collector-gatherers were the most abundant feeding group at all three sampling locations in Victoria Creek, and comprised a similar percentage of the community at each (43 - 47%). Predators were the next most abundant functional feeding group at all three Victoria sites, and comprised a similar percentage of the community at each (17 - 21%). Shredders and scrapers were marginally less abundant than predators at all three sites, with shredders comprising 14 - 16% of the community and scrapers comprising 12 - 15% of the community at all three locations in Victoria Creek. Collector-filterers were the least abundant feeding group, comprising 5 - 6% of the community at each of these three locations.

The relative abundance of functional feeding groups at Dome Creek differed from the three Victoria Creek sampling locations (Figure 9). Shredders were the dominant feeding group, comprising 53% of the community, followed by collector-gatherers, which comprised 27% of the community. Predators were the next most abundant feeding group (6%), followed by scrapers and collector-filterers (2%), each comprising a smaller percentage of the community than in the Victoria Creek locations.

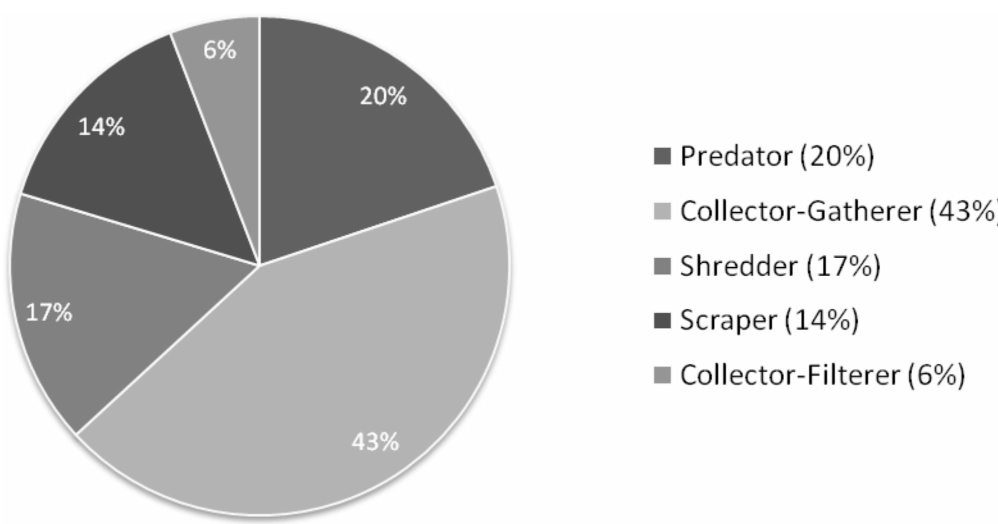

Figure 7. The relative abundance (%) of the five functional feeding groups at Victoria Creek upstream of Back Creek.

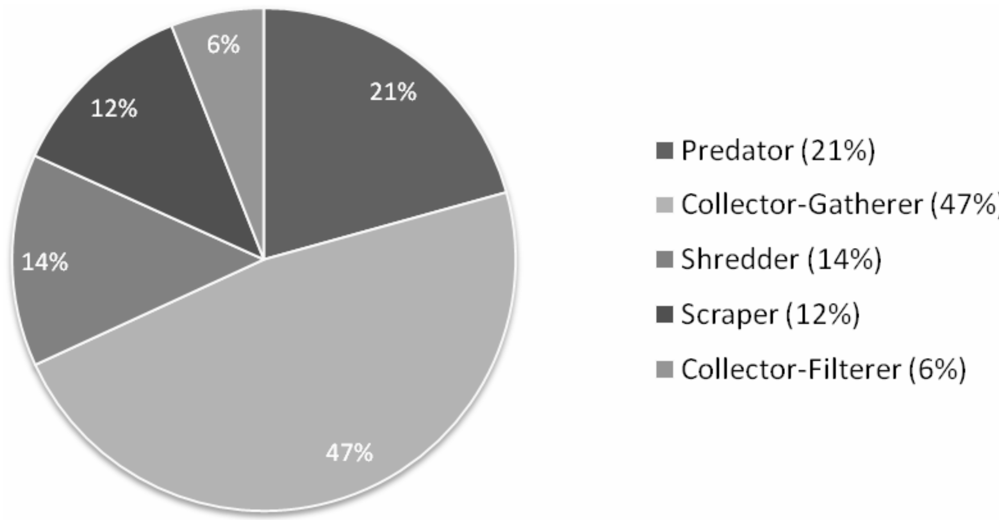

Figure 8. The relative abundance (%) of the five functional feeding groups at Victoria Creek downstream of Back Creek.

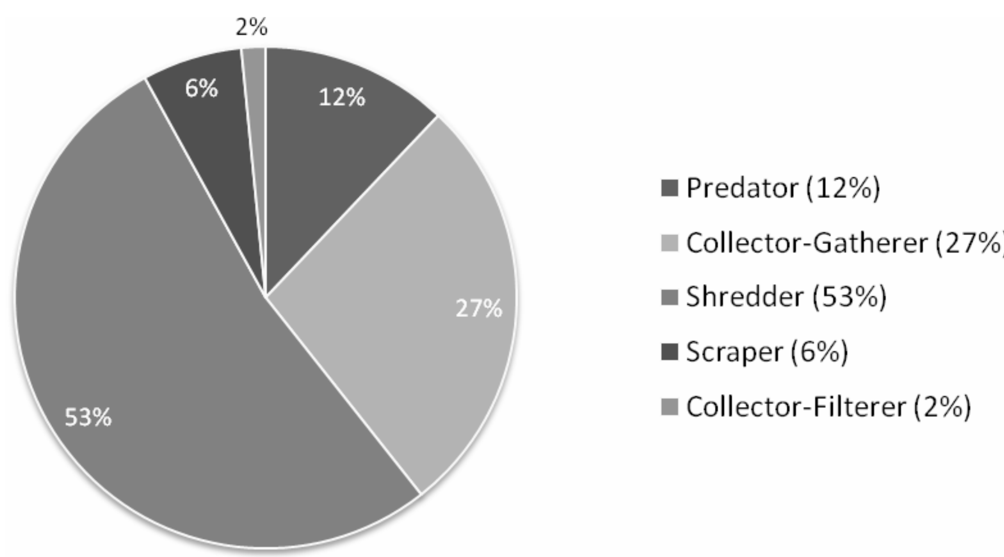

Figure 9. The relative abundance (%) of the five functional feeding groups at Lower Dome Creek.

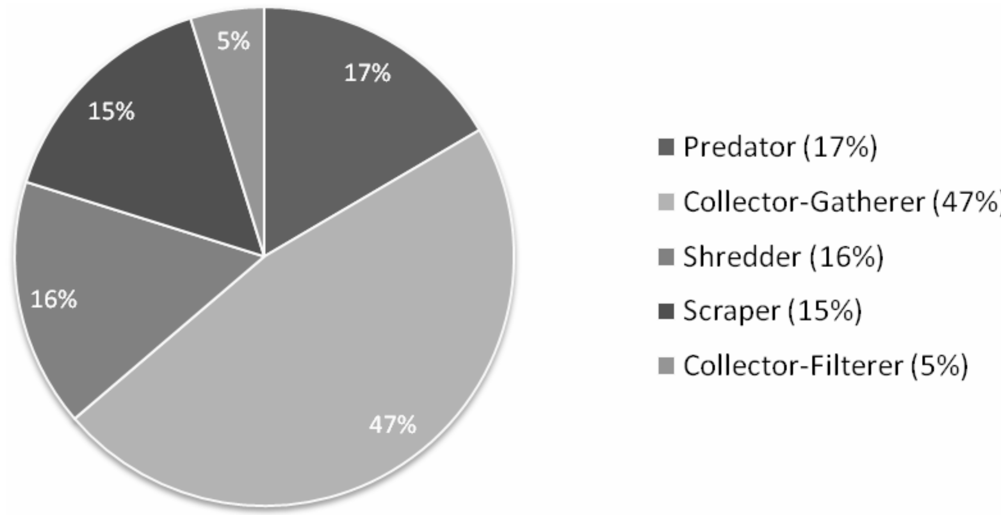

Figure 10. The relative abundance (%) of the five functional feeding groups at Victoria Creek downstream of Dome Creek.

3.4 TOTAL TAXA ANALYSIS

Taxa richness of benthic invertebrates identified to family/order was greatest at the least disturbed site in Victoria Creek upstream of Back Creek (Figure 10), where a total of 20 taxa were identified. Taxa richness declined marginally in Victoria Creek downstream of Back Creek (18 taxa), and declined slightly further in Victoria Creek downstream of Dome Creek (15 taxa). Lower Dome Creek exhibited the lowest taxa richness overall (14 taxa).

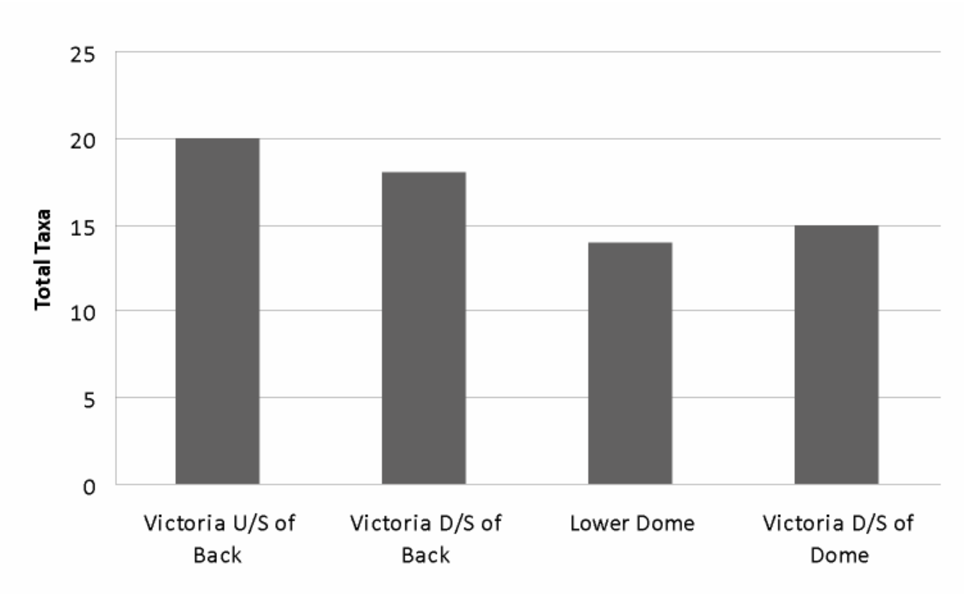

Figure 11. Taxa richness (total number of distinct taxa) at each sampling location. Distinct taxa include individuals identified to family/order.

Trends in richness of each of the four major orders of benthic invertebrates were as follows. The number of distinct Diptera families was similar in Victoria Creek upstream of Back Creek, Victoria Creek downstream of Back Creek and Lower Dome Creek (5 taxa), and was slightly lower in Victoria Creek downstream of Dome Creek (3 taxa). The number of distinct Plecoptera families found was the same in all three Victoria Creek sampling locations (6 taxa) and slightly lower in Dome Creek (4 taxa). The number of Ephemeroptera taxa found varied slightly among sampling locations, with Victoria Creek upstream of Back Creek showing the greatest number (4 taxa), followed by Victoria Creek downstream of Dome Creek (2 taxa), Victoria Creek downstream of Back Creek (1 taxon) and Dome Creek (no taxa). The number of Trichoptera taxa also varied slightly among sampling locations, with the greatest number of taxa found in Victoria Creek downstream of Back Creek (3 taxa), followed by Victoria Creek downstream of Dome Creek (2 taxa), Victoria Creek upstream of Back Creek and Lower Dome Creek (no taxa).

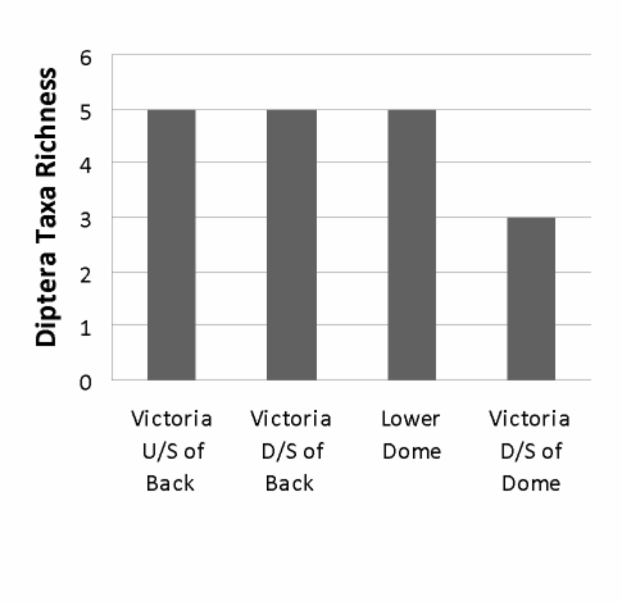

Figure 12. Diptera taxa richness at each sampling location.

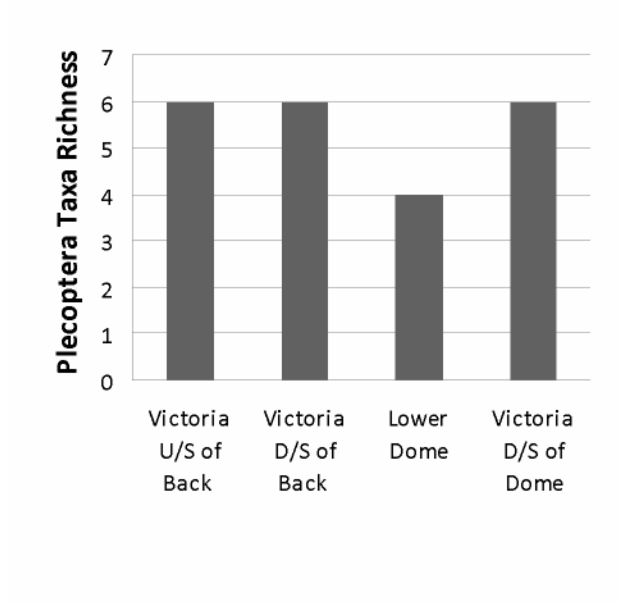

Figure 14. Plecoptera taxa richness at each sampling location.

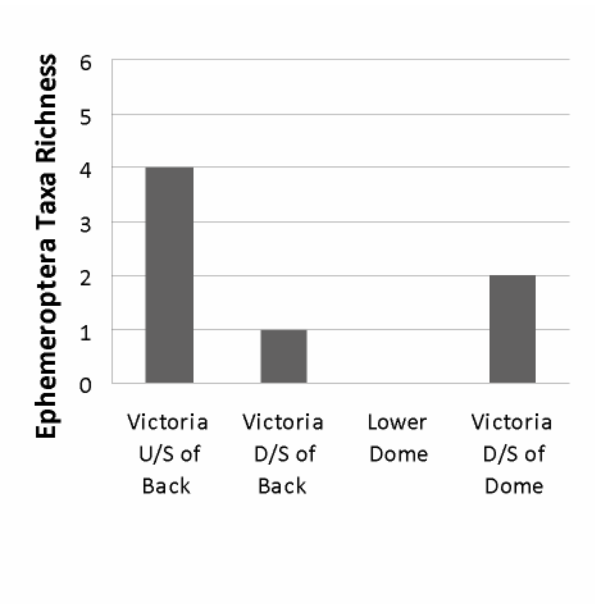

Figure 13. Ephemeroptera taxa richness at each sampling location.

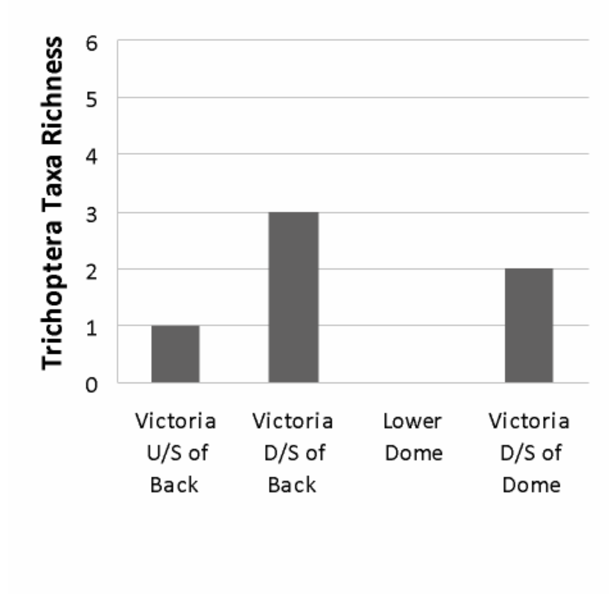

Figure 15. Trichoptera taxa richness at each sampling location.

4 DISCUSSION

4.1 ORDER LEVEL RELATIVE ABUNDANCE ANALYSIS

4.1.1 VICTORIA CREEK

Diptera was found to be the dominant order of benthic invertebrates in all sampling locations in Victoria Creek. Aquatic invertebrates of the order Diptera have diverse life histories and are adapted to a variety of conditions. In a summary of published and unpublished data, Oswood (1989) describes Diptera as the dominant order in interior Alaskan streams, followed by Ephemeroptera and Plecoptera, with Trichoptera being very scarce. The relative abundance of the four major orders in Victoria Creek followed this general pattern.

In this study, relative abundance of the four major orders was similar among the three sampling locations in Victoria Creek, with some slight variations. Within Victoria Creek, the relative abundance of Plecoptera and Ephemeroptera was lowest just downstream of Back Creek (12% and 4%, respectively). These values were slightly lower than Victoria Creek upstream of Back Creek (15% and 8%, respectively) and Victoria Creek downstream of Dome Creek (17% and 14%, respectively). The relative abundance of Trichoptera was low overall, and declined slightly with increasing downstream disturbance.

Results of kicknet sampling[1] conducted in Victoria Creek downstream of the mine site in 2000 provide a temporal comparison with results of the sampling location in Victoria Creek downstream of Dome Creek in this study. The 2000 data showed Ephemeroptera to be the dominant order, comprising 46.5% of the community at this location, followed by Diptera, comprising 13.7% of the community, and then Plecoptera, comprising 6.6% of the community. In this study, the relative abundance of Diptera was higher (68%) at the downstream location on Victoria Creek and the relative abundance of Ephemeroptera was lower (14%). It should be noted that the 2000 sampling location was further downstream of the sampling location in the present study.

An additional temporal comparison is provided by a study carried out in 1988 by the Environmental Protection Service (EPS) (using surber sampling), which also found Ephemeroptera to be dominant, comprising 43% of the community in Victoria Creek downstream of Dome Creek. In comparison with the 1988 data, Diptera has replaced Plecoptera as the dominant order of benthic invertebrates at the other two Victoria Creek sampling locations (cited in T.W. Higgs and Associates, 1994).

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[1] Sampling was conducted for approximately 3 minutes over 10 m of stream channel, mesh size 363 μm (D. Davidge, Pers. Comm, 2008).

Victoria Creek downstream of Dome Creek was identified as very turbid in this study. Victoria Creek downstream of Back Creek was also identified as lightly turbid through visual observation during the field sampling component of this study, and is in closest proximity to a potential source of sediment originating from upstream placer mining activity in Back Creek. Although Victoria Creek upstream of Back Creek is not currently exposed to placer mining activity, some exploration activity was conducted upstream of this sampling location in 2007. It is possible that this activity could have resulted in release of sediment into the stream. As well, a new natural channel (avulsion approximately 100 m long, estimated to have occurred within the past 5 years) was recently forged upstream of this sampling location, which may also have released sediment into the stream. Thus, it is possible that all three of the sampling locations in Victoria Creek may have been influenced by recent sediment releases.

Ephemeroptera and Plecoptera are considered to be sensitive to disturbance, and particularly to fine sediments. In one Alaskan study, Weber (1986) found Ephemeroptera and Plecoptera to be most common in clear water sites and least common in sites directly downstream of active placer activity. Benthic invertebrate density was also significantly and negatively correlated with increased turbidity and total suspended solids (TSS).

Madison (1981) describes the effects of increased stream sedimentation resulting from placer mining as follows:

> *Reduction in the abundance and diversity of benthos as a result of reduction in available food supply (plant life), increased drift and susceptibility to predation, clogging of the feeding apparatus by fine sediments, and loss of available or suitable substrate habitat; and changes in community composition from clean-water species to species more adaptable to higher sediment levels but possibly less suitable as fish-food organisms (p.6).*

The slightly lower relative abundance of Plecoptera and Ephemeroptera in Victoria Creek downstream of Back Creek relative to the other Victoria Creek sampling locations in this study, and the replacement of Plecoptera and Ephemeroptera with Diptera over time as the dominant order at all Victoria Creek locations, are potentially attributable to increased sediment, particularly in the vicinity of the mouth of Back Creek.

The apparent increase in relative abundance of Diptera since 2000 appears to be the result of an increase in the relative abundance of members of the family Chironomidae. In 2000, individuals of the family Chironomidae comprised 52% of the Diptera sampled in Victoria Creek downstream of the mine site, whereas in this study, Chironomidae comprised 94% of the Diptera. In 1988, individuals of the family Chironomidae comprised less than 50% of the Diptera at each Victoria Creek sampling location, whereas Chironomidae comprised over 80% of the Diptera at each Victoria Creek location in this study. In a study of experimental exposure of benthic invertebrates to sediment, Chironomidae was the only taxon found to increase in abundance with elevated sediment exposure (Shaw and Richardson, 2001). Weber (1986) also found Chironomidae to be common across all sites, including undisturbed sites and those disturbed by placer mining.

Apparent temporal trends (and minor spatial trends) in relative abundance of Diptera (Chironomidae), as well as sediment-sensitive taxa (Ephemeroptera and Plecoptera) suggest that it is possible that benthic invertebrate community composition has been influenced by sediment release associated with placer mining activity in Back Creek (as well as natural sources of sediment). These comparisons should be interpreted with caution, given that the sampling method applied in 1988 differed from the current study and that the sample sizes in the 2000 and present studies varied considerably. Further study is needed to confirm this possibility.

4.1.2 DOME CREEK

In contrast to the dominance of Diptera in the community composition of benthic invertebrates in Victoria Creek, Plecoptera was the dominant order in Dome Creek (64%), followed by Diptera (27%). Results from kicknet sampling for benthic invertebrates in 1997[2] and 2000 in Dome Creek showed Diptera to be the dominant order, comprising 71% and 87%, respectively, of the community composition at this location (Environment Canada, 2008). Members of the family Chironomidae comprised over 80% of the Diptera in Dome Creek in 1997, and in 2000, almost 100% of the Diptera were Chironomidae. Plecoptera comprised 3.6% of the community in 1997 and was absent from Dome Creek in 2000, whereas in 1988, Plecoptera comprised 92.7% of the community in Dome Creek. The present benthic invertebrate community composition in Dome Creek appears to be more similar to that found in 1988 than that noted in 1997 and 2000. In 1997 and 2000, Diptera (primarily Chironomidae) replaced Plecoptera as the dominant order.

Dome Creek is isolated from the ongoing placer mining activity in Back Creek, and thus from sediment that may be released through these activities. However, Dome Creek is influenced most directly by upstream disturbance associated with the mine site. The most recent period of mining activity upstream on Dome Creek occurred between 1995 and 1999, after the 1988 benthic invertebrate study, but during and just prior to the 1997 and 2000 studies. Disturbance of aquatic systems following the 1997 study was evident from a fish kill documented in 1998 in Victoria Creek just downstream of Dome Creek. This event was attributed to ammonia, cyanate and nitrate contamination originating from tailings pond leakage into Dome Creek (Environmental Protection Service, 1999).

As noted in the previous section, members of the order Plecoptera are considered to be sensitive to disturbance, including exposure to contaminants associated with hard rock mining (Maret et al., 2003). Members of the family Chironomidae (Diptera) are considered common across disturbed and undisturbed sites. Disproportionate abundance of Chironomidae has also been suggested as an indicator of environmental stress (Mandaville, 2002). The apparent decline in relative abundance of Plecoptera and increase in relative abundance of Diptera (and specifically Chironomidae), in 1997 and 2000, suggests a

[2] Using a mesh size 363 μm kicknet.

response to disturbance. In contrast, the apparent similarity in relative abundance of Plecoptera in 1988 (prior to the most recent mining activity) and the present study (following almost a decade of remediation efforts), suggests that the community composition of benthic invertebrates in Dome Creek may be responding to improved aquatic conditions.

4.2 FUNCTIONAL FEEDING GROUP ANALYSIS

The relative abundance of benthic invertebrates in each of the five functional feeding groups showed great similarity among all Victoria Creek locations. However, Dome Creek showed a considerably greater proportion of shredders in comparison to Victoria Creek. This is not surprising, given the dominance at this location of Plecoptera, and more specifically the families Nemouridae and Taeniopterygida, both of which are shredders. In this study, a greater presence of overhanging vegetation was documented at Dome Creek in comparison to Victoria Creek. The presence of additional vegetation likely results in greater deposition of coarse plant material into the stream. Dome Creek is also a slower moving and narrower stream; thus, leaves and other plant material accumulate more readily in this creek than in Victoria Creek. Consequently, this plant material provides an abundant food source for shredders and support the dominance of this functional group of benthic invertebrates in Dome Creek.

4.3 TOTAL TAXA ANALYSIS

Total taxa richness declined marginally with increasing downstream disturbance. Reduction in benthic invertebrate species diversity has been linked to sedimentation (Shaw and Richardson, 2001), including sediment release associated with placer mining (Madison, 1981). The sampling locations in Victoria Creek downstream of Back Creek were visibly more turbid than the sampling location upstream of Back Creek, likely as a result of sediment released through placer mining activity in Back Creek. It is possible that sediment release may be a factor influencing the differences in taxa richness between upstream and downstream environments.

Taxa richness was lowest in Dome Creek, a finding that is likely related primarily to the physical characteristics of this creek. Smaller streams have been shown to have lower benthic invertebrate diversity than larger streams (Slack et al., 1979). Dome Creek is a narrower channel and has lower flow velocities in comparison to Victoria Creek. Benthic invertebrate taxa richness has consistently been found to be lower in Dome Creek than in Victoria Creek in past sampling events. Kicknet sampling conducted in 2000 and 1997 showed lower taxa (family/order) richness in Dome Creek than in Victoria Creek upstream of Back Creek (Environment Canada, 2008). Taxa richness was also low overall in Dome Creek in the Mt. Nansen Environmental Evaluation conducted by EPS in 1988 (cited in T.W. Higgs and Associates, 1995). This author also references a 1976-77 study by the Environmental Protection Service (EPS) that found low benthic invertebrate diversity in Dome Creek. Thus, it appears that this trend has not changed over time.

In the 2000 study, a similar number of families (15) were identified in Victoria Creek downstream of Dome Creek as in this study (14). In Dome Creek, however, only seven families/orders were found in 2000, in comparison with 13 families in 1997 and 15 families in this study. The notable reduction in taxa richness in

1997 occurred one year after the documented release of contaminants into Dome Creek. Maret et al. (2003) have noted lower benthic invertebrate taxa richness at sites downstream of intensive hard-rock mining and associated contaminants.

Since the 1997-2000 benthic invertebrate surveys were completed, water quality in Dome Creek has improved. A water quality study at Mt. Nansen completed in February 2008 (based on sampling conducted from 1999 to 2007) found levels of metals in Dome and Victoria Creeks to be generally within CCME guidelines (EDI, 2008). However, the detection levels for arsenic, cadmium, lead and silver were above CCME guidelines from 2003-2007, so the study did not ascertain whether these metal concentrations exceeded these water quality guidelines. Historical water quality information referenced in the EDI (2008) report indicates that, between 1999 and 2003, levels of lead and arsenic exceeded CCME guidelines in Dome Creek. The receiving environment in Victoria Creek also had silver levels exceeding CCME guidelines between 1995 and 2005. A 2005-06 Terrestrial and Aquatic Effects Study of the Mt. Nansen Mine Site found elevated levels of arsenic in sediments in Dome Creek (51.9 μg/g), which exceeded CCME guidelines for sediment arsenic concentrations (5.9 μg/g) (EDI, 2007). Sediments are a primary source of metals exposure for bottom-dwelling benthic invertebrates. Thus, it is possible that elevated metals levels in sediment and/or water may have influenced the taxa richness of benthic invertebrates in Dome Creek.

4.4 ORDER LEVEL TAXA ANALYSIS

Dome Creek exhibited slight differences from Victoria Creek in taxa (family) richness within each of the four major orders. Although Plecoptera dominated Dome Creek (in terms of relative abundance), the number of taxa within this order was slightly lower (4 taxa) than in all sampling locations in Victoria Creek (6 taxa). Plecoptera in Dome Creek was dominated by two families, Nemouridae and Taeniopterygida. In the 1997 benthic invertebrate survey, only one Plecoptera genus (*Podmosta*) in the family Nemouridae was identified (Environment Canada, 2008). No Plecoptera were found in Dome Creek in the 2000 survey. In the 1988 survey, the Plecoptera all belonged to Nemouridae (*Podmosta*) as well (cited in T.W. Higgs and Associates, 1995). Thus, it appears that the richness of Plecoptera may have increased slightly over time. As discussed previously, the lower richness of Plecoptera may be primarily related to the physical characteristics of Dome Creek. It may be that the natural conditions in Dome Creek do not support as wide a diversity of families within these orders as Victoria Creek.

Taxa (family) richness of Diptera was similar in Dome and Victoria Creeks. In comparison with the 2000 data, richness of Diptera appears to have increased in Dome Creek, from one family (Chironomidae) to five families (Environment Canada, 2008). As discussed previously, dominance of Chironomidae is associated with environmental stress and disturbance. Thus, the apparent increase in the number of Diptera families may correspond with recovery from disturbance associated with past contamination.

In Victoria Creek, richness of Diptera and Plecoptera was similar across all sites. In comparison with the 2000 study, Plecoptera richness may have increased slightly in Victoria Creek. Six Plecoptera families were found in Victoria Creek downstream of Dome Creek in this study, in contrast to three families in 2000. Spatial and temporal trends in richness of Ephemeroptera and Trichoptera are difficult to interpret, due to the low overall abundance of these taxa. However, no notable spatial or temporal trends in Ephemeroptera or Trichoptera richness are readily apparent.

5 CONCLUSIONS

Based on the results of this study, we offer the following conclusions.

- The community composition of benthic invertebrates in Victoria Creek at the Mt. Nansen mine site is typical of northern streams, with Diptera being the dominant order, followed by Plecoptera and Ephemeroptera, and a limited presence of Trichoptera.

- Diptera (primarily the family Chironomidae) has replaced Ephemeroptera and/or Plecoptera as the dominant order in all Victoria Creek sampling locations since 1988, and in Victoria Creek downstream of Dome Creek since 2000.

- In Dome Creek, Diptera (primarily Chironomidae) also replaced Plecoptera as the dominant order in 1997 and 2000. However, relative abundance of Plecoptera in Dome Creek has now returned to a level similar to that found in 1988, prior to the most recent period of mining activity at Mt. Nansen.

- A link between contamination of Dome Creek in 1998 by ammonia, cyanate and nitrate and the changes in Diptera-Plecoptera relative abundance noted in Dome Creek is plausible.

- Functional feeding group analysis showed highly similar composition of the five functional feeding groups among all Victoria Creek sites, but greater dominance of two families of shredders (Nemouridae and Taeniopterygida) in Dome Creek. The relative abundance of plant material in Dome Creek is suggested as a factor that may support this greater abundance of shredders.

- Total taxa richness declined slightly with increasing downstream disturbance in Victoria Creek. Sediment levels associated with upstream placer mining are suggested as a factor that may be influencing benthic invertebrate diversity in the receiving environment in Victoria Creek. And once again, the possibility of elevated metals levels as an influencing factor in the receiving environment in Victoria, as well as in Dome Creek, cannot be ruled out.

- Taxa richness was lowest in Dome Creek; a trend which has not changed over time. There has, however, been an apparent increase in the number of Plecoptera and Diptera families in Dome Creek since 1997 and 2000, a finding which also suggests recovery from disturbance.

These results provide a good basis for future comparisons that may be valuable in determining the success of reclamation at the Mt. Nansen mine site. Unfortunately, it may be difficult to isolate the effects of historically elevated metals levels from the effects of placer activity in the watershed. As such, there may be value in collecting invertebrates from Pony Creek in future studies, so that this sample and the Dome Creek sample site can be used as a measure of reclamation success, as they are both isolated from placer activity.

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Appendix A. Photos

Photo 1: Dome Creek looking toward the sampling location.

Photo 2: Victoria Creek near sampling location upstream of Back Creek.

Appendix B. Stream Attribute Data

Victoria Creek u/s of Back Creek

08 6880888 391681

Photo Numbers: 673 - 689
flow state: combination of riffle / pool (70% riffle)
macrophytes: none, trace of overhanging terrestrials
canopy coverage: 15 - 20 %
riparian vegetation: grasses, shrubs, coniferous

area kicked: 6 X bankful = 6x6 = 36 meters
average depth: 35 cm
time: 14 minutes
dominant substrates: cobble/gravel (some sand)
average degree of embeddedness: 40/60/60/50/70/60
substrate dimensions:

Rock	length	width	height	Rock	length	width	height
1	100	120	50	**6**	105	30	55
2	120	45	15	**7**	135	40	90
3	80	53	23	**8**	62	25	40
4	195	95	95	**9**	85	75	30
5	115	55	74	**10**	105	55	75

Stream velocities:

Horizontal (m)	Depth (m)	Velocity (m/s)
0.00	0.39	0.14
0.51	0.44	0.33
1.02	0.39	0.31
1.53	0.37	0.47
2.04	0.25	0.43
2.55	0.20	0.38
3.06	0.12	0.15
3.57	0.02	0.00
4.08	0.06	0.00
4.59	0.11	0.00
5.10	0.11	0.00
Average: 2.55	**0.22**	**0.20**

Velocity along Thalweg (m/s):

0 m	1.15
3 m	1.42
6 m	1.04
9 m	0.39
12 m	0.29
15 m	0.23
18 m	0.21
21 m	0.04
24 m	0.23
27 m	0.45
30 m	1.30
33 m	1.07
36 m	0.49

Victoria Upstream of Back Creek - B Replicate

Distance Sampled: 36 m
Time: 13 minutes
Notes: immediately upstream of sample A, 60% pool, 40% riffle

Water Quality Parameters

Temp: 4.4
Conductivity: 142.0 us
PH: 7.9
D/O: 8

Lower Dome Creek

08 6880458 391271

Planned on having site lower in the stream, but it enters a flat area with no definite channel

Photo Numbers:	705-710
flow state:	riffle / pool (60/40)
macrophytes:	trace, but abundant overhanging vegetationg (grasses) [*water lightly turbid]
canopy coverage:	0% (if considering trees), 40-50% (if considering grasses/low shrubs)
riparian vegetation:	grasses, shrubs
area kicked:	6 x bankfull = 6X2 = 12m
average depth:	40cm
time:	11 minutes
dominant substrates:	fines
average degree of embeddedness:	N/A
substrate dimensions:	(L/W/H)=N/A

stream width @ bankfull =1.9m, wetted =1.0m

Stream velocities:

	Horizontal (m)	Depth (m)	Velocity (m/s)
	0.00	0.02	0.00
	0.10	0.12	0.10
	0.20	0.18	0.23
	0.30	0.19	0.34
	0.40	0.23	0.23
	0.50	0.22	0.20
	0.60	0.22	0.20
	0.70	0.21	0.12
	0.80	0.21	0.16
	0.90	0.18	0.08
	1.00	0.15	0.00
Average:	**0.50**	**0.18**	**0.15**

Velocity along Thalweg (m/s):

0 m	0.24
2 m	0.37
4 m	0.52
6 m	0.11
8 m	0.30
10 m	0.65
12 m	0.73

Victoria downstream of Dome Creek

Distance Sampled:	12 m sampled immediately upstream of "a"
Time:	10 minutes
Notes:	

Water Quality Parameters

Temp:	0.8
Conductivity:	868 us
PH:	8.12
D/O:	9

Victoria Creek d/s of Dome Creek

08 6879101 392439

Photo Numbers:	694 - 704
flow state:	riffle / pool (50/50)
macrophytes:	none (*water very turbid)
canopy coverage:	5 - 10 %
riparian vegetation:	primarily shrubs, also some grass and trace coniferous
area kicked:	6 x bankfull = 6X9 = 54m
average depth:	0.4
time:	13
dominant substrates:	cobble/gravel (some sand present)
average degree of embeddedness:	40/50/30/50/40

substrate dimensions:

	length	width	height		length	width	height
Rock 1	92	55	55	**6**	50	75	30
2	65	44	50	**7**	125	70	45
3	115	50	30	**8**	75	95	50
4	90	45	35	**9**	105	75	35
5	50	15	40	**10**	135	65	80

Stream velocities:

	Horizontal (m)	Depth (m)	Velocity (m/s)
	0.00	0.06	0.04
	0.55	0.08	0.13
	1.10	0.16	0.24
	1.65	0.21	0.20
	2.20	0.35	0.32
	2.75	0.39	0.34
	3.30	0.51	0.30
	3.85	0.60	0.36
	4.40	0.61	0.20
	4.95	0.59	0.07
	5.50	0.48	0.02
Average:	**2.75**	**0.37**	**0.20**

Velocity along Thalweg (m/s):

0 m	1.36
5 m	0.72
10 m	0.44
15 m	0.32
20 m	0.78
25 m	1.28
30 m	1.50
35 m	1.06
40 m	0.40
45 m	0.47
50 m	0.42
54 m	0.31

Victoria downstream of Dome Creek

Distance Sampled:	54 m (75% riffle, 25% pool
Time:	13 minutes
Notes:	caught one ARGR

Water Quality Parameters

Temp:	5.2
Conductivity:	174.3 us
PH:	8.14
D/O:	6

Victoria Creek u/s of Dome Creek

08 6880693 391686

Photo Numbers:	714 - 718
flow state:	riffle / pool (30/70)
macrophytes:	none (*water lightly turbid, but substantially clearer then yesterday)
canopy coverage:	5 - 10 %
riparian vegetation:	shrubs, grasses, coniferous
area kicked:	6 x bankfull = 6X6 = 36m
average depth:	35cm
time:	12 mins
dominant substrates:	cobble/gravel (surrounded by sand)
average degree of embeddedness:	30/40/60/30/50
substrate dimensions:	

	length	width	height		length	width	height
rock 1	100	50	60	**6**	85	55	35
2	145	35	80	**7**	90	70	55
3	60	40	35	**8**	105	80	65
4	95	75	10	**9**	130	50	85
5	190	45	80	**10**	95	55	15

stream width @ bankfull - 7.1 m, wetted = 4.0m

Stream velocities:

	Horizontal (m)	Depth (m)	Velocity (m/s)
	0.00	0.06	0.19
	0.40	0.07	0.20
	0.80	0.08	0.26
	1.20	0.12	0.58
	1.60	0.26	0.59
	2.00	0.31	0.61
	2.40	0.41	0.62
	2.80	0.50	0.50
	3.20	0.41	0.40
	3.60	0.34	0.38
	4.00	0.40	0.12
Average:	**2.00**	**0.27**	**0.40**

Velocity along Thalweg (m/s):

0 m	0.34
4 m	0.54
8 m	0.24
12 m	0.56
16 m	0.55
20 m	0.79
24 m	1.65
28 m	1.19
32 m	0.74
36 m	0.50

Victoria upstream of Dome Creek:

Distance Sampled:	36 m immediately ds of "a"
Time:	
Notes:	
Notes:	

Water Quality Parameters

Temp:	1.6
Conductivity:	160.4 us
PH:	7.8
D/O:	8

Appendix C. Benthic Invertebrate Data

Appendix C. Total benthic invertebrate counts and percent community composition for each family, with Victoria d/s of Back, Lower Dome and Victoria d/s of Dome representing sub-sampled populations.

Order	Family	Victoria u/s of Back A (not sub-sampled)	Victoria d/s of Back B (5/32)	Lower Dome A (5/120)	Victoria d/s of Dome A (5/43)	Victoria u/s of Back A (not sub-sampled)	Victoria d/s of Back B (5/32)	Lower Dome A (5/120)	Victoria d/s of Dome A (5/43)
	Anthomyiidae	29	109	24	146	2%	2%	0%	2%
	Ceratopogonidae	0	0	144	0	0%	0%	2%	0%
	Chironomidae	430	2426	696	2640	29%	37%	9%	32%
Diptera	**Psychodidae**	1	6	0	0	0%	0%	0%	0%
	Simuliidae	11	13	0	0	1%	0%	0%	0%
	Tipulidae	17	32	24	17	1%	0%	0%	0%
	Empididae	0	0	72	0	0%	0%	1%	0%
	UNKNOWN	30	90	96	0	2%	1%	1%	0%
Sum of Diptera		**518**	**2675**	**1056**	**2804**	**35%**	**40%**	**14%**	**34%**
	Baetidae	2	0	0	0	0%	0%	0%	0%
	Ephemeridae	5	0	0	60	0%	0%	0%	1%
Ephemeroptera	**Heptageniidae**	47	102	0	516	3%	2%	0%	6%
	Siphlonuridae	2	0	0	0	0%	0%	0%	0%
	UNKNOWN	4	38	0	0	0%	1%	0%	0%
Sum of Ephemeroptera		**60**	**141**	**0**	**576**	**4%**	**2%**	**0%**	**7%**
Plecoptera	**Capniidae**	16	64	0	112	1%	1%	0%	1%
	Chloroperlidae	18	26	48	17	1%	0%	1%	0%
	Leuctridae	10	26	24	155	1%	0%	0%	2%
	Nemouridae	10	32	1008	146	1%	0%	14%	2%
	Peltoperlidae	0	0	0	17	0%	0%	0%	0%
	Perlodidae	16	58	0	0	1%	1%	0%	0%
	Taeniopterygidae	27	77	1152	60	2%	1%	15%	1%
	UNKNOWN	11	122	264	206	1%	2%	4%	2%
Sum of Plecoptera		**108**	**403**	**2496**	**714**	**7%**	**6%**	**34%**	**9%**

Order	Family	Victoria u/s of Back A (not sub-sampled)	Victoria d/s of Back B (5/32)	Lower Dome A (5/120)	Victoria d/s of Dome A (5/43)	Victoria u/s of Back A (not sub-sampled)	Victoria d/s of Back B (5/32)	Lower Dome A (5/120)	Victoria d/s of Dome A (5/43)
Trichoptera	Brachycentridae	0	19	0	0	0%	0%	0%	0%
	Glossosomatidae	0	0	0	9	0%	0%	0%	0%
	Limnephilidae	42	19	0	9	3%	0%	0%	0%
	Lepidostomatidae	0	0	0	0	0%	0%	0%	0%
	Phryganeidae	0	51	0	0	0%	1%	0%	0%
	UNKNOWN	3	0	0	26	0%	0%	0%	0%
Sum of Trichoptera		**45**	**90**	**0**	**43**	**3%**	**1%**	**0%**	**1%**
Hymenoptera		0	0	24	0	0%	0%	0%	0%
Hemiptera		0	0	0	0	0%	0%	0%	0%
Hydrachnidia		0	0	0	0	0%	0%	0%	0%
Ostracoda		0	0	192	0	0%	0%	3%	0%
Copepoda		0	0	120	0	0%	0%	2%	0%
TOTAL		**1462**	**6618**	**7440**	**8273**	**100%**	**100%**	**100%**	**100%**