7.7 Benthos and Periphyton

This section examines potential project effects on benthos and periphyton. Existing conditions in the project area are characterized and effects of project activities predicted based on effects on water and sediment quality described in Section 7.5: Surface Water and Sediment Quality and stream flows described in Section 7.4: Surface Water Hydrology. The findings of this section provide the basis for assessment of potential project effects on fish (Section 7.8: Fish Resources). This section describes project effects under routine construction and operating conditions. Potential effects of project-related accidents and malfunctions are discussed in Section 8: Accidents and Malfunctions.

7.7.1 Scope of Assessment

Periphyton and benthic invertebrate communities are identified as VECCs, given their role as primary and secondary producers and their sensitivity to changes in water chemistry and stream habitat. Many periphyton and benthic invertebrate taxa have known tolerances and responses to metals, nutrients and sediment, making them useful sentinels of changes related to mine operations. They also provide valuable links between water chemistry (Section 7.5) and the fish community (Section 7.8).

Periphyton and benthic invertebrates have been used as indicators of water quality since the early 1900s because of known sensitivity to changes in nutrients, sediment (TSS) and metal levels. They are used in government biomonitoring programs in Canada (Aquamin 1996; Environment Canada 2002) and the United States (Barbour et. al. 1999). A multi-metric assessment method, the benthic index of biotic integrity, has also been developed for a variety of regions (Karr and Chu 1999). Periphyton and benthos community composition and productivity are considered useful indicators of stream health because they integrate individual effects of the project on aquatic resources, including physical habitat changes due to sedimentation, loss of riparian vegetation, and change in stream flows, temperature and water quality and they provide an important link to fish resources. Changes in periphyton and benthos productivity can have an effect on fish (abundance, size, bioaccumulation of metals in tissue), which can, in turn, affect birds and wildlife that consume fish.

The Metal Mining Effluent Regulations (MMER), under the *Fisheries Act*, and associated Environmental Effects Monitoring (EEM) programs, came into effect in 2002 and require three-year cycles of effluent and biological monitoring, including benthic communities. Environment Canada is responsible for administration of MMER. Details are discussed in Section 7.5: Surface Water and Sediment Quality.

Project components that have the potential to influence surface water and sediment quality are described briefly below.

Water treatment plant discharge to Go Creek - Discharge of mine effluent can have adverse effects on periphyton and invertebrates through toxicity of metals, nutrient enrichment (elevated nitrate or ammonia from blasting residues), changes in pH, and release of suspended sediments. Documented effects include excessive periphyton growth, elimination of sensitive species, changes in community structure and morphological deformities of periphyton.

Changes to the Go Creek flow regime - Clean water diversions and site water management (drainage collection, settling ponds) may result in reduced water flows during the summer low flow period. This may affect benthic communities by reducing the amount of wetted habitat, reducing dilution of some metals or altering community structure to favour species better suited to low flows.

Seepage of potentially contaminated groundwater to Wolverine Creek following mine backfill -The effects of elevated metals on biota of Wolverine Creek would be similar to those described above for Go Creek.

Introduction of sediments to receiving waters from construction runoff - Sediment introduced to streams can smother habitat or damage sensitive gill structures of benthic invertebrates or reduce oxygen transport into the substrate. Changes in community structure and degraded habitat can have an effect on fish populations.

A list of aquatic VECCs has been defined for the project environmental assessment based on the EA Report Guidelines (Yukon Executive Council Office 2005), the biophysical workplan submitted to regulators by Yukon Zinc Corporation (YZC) (Yukon Zinc Corp. 2005), review of baseline information, review of a preliminary VECC list by the project Technical Committee (August 23, 2005) and consultation with Benoit Godin (Environment Canada), Sandra Orban (Fisheries and Oceans Canada) and Randy Lamb (Yukon Department of Environment). The VECCs and rationale for their selection are described in Table 7.7-1.

Table 7.7-1 Periphyton and Benthic Invertebrate VECCs, Selection Rationale and Data Sources

VECC	Rationale for Selection	Linkage to EA Report Regulatory Drivers	Baseline Data for EA
Periphyton abundance (chlorophyll *a*)	• Potential for project effects is unknown • Respond to changes in water quality (metals, nutrients, sediment) • Changes in primary productivity, measured as chlorophyll *a* influence benthic invertebrate abundance and composition	• Information requested in EA Report Guidelines and Biophysical Assessment Work Plan	• 2005 field data
Periphyton species composition / diversity	• Potential for project effects is unknown • Taxon-specific responses to changes in water quality (metals, nutrients, sediment) • Changes in composition may influence benthic invertebrates	• Information requested in EA Report Guidelines and Biophysical Assessment Work Plan	• 2005 field data
Benthic invertebrate abundance	• Potential for project effects is unknown • Respond to changes in water quality (metals, sediment) and primary production • Important fish food	• Information requested in EA Report Guidelines and Biophysical Assessment Work Plan • Will be required for Metal Mining Effluent Regulations (MMER) environmental effects monitoring (EEM)	• 1996 data (artificial substrate samples at six sites) • 2005 field data
Benthic invertebrate species composition / diversity	• Potential for project effects is unknown • Species-specific responses and tolerances to changes in water quality (metals, sediment) and primary production • Important fish food	• Information requested in EA Report Guidelines and Biophysical Assessment Work Plan • Will be required for MMER EEM	• 1996 data (artificial substrate samples at 6 sites) • 2005 field data

Temporal Boundaries

The temporal boundaries applicable to periphyton and benthic invertebrates include the period of record for baseline data collection (summer of 1996 to present) and all phases of the project. The potential for introduction of silt and sediment to area streams will be greatest during construction, but also exists during operation and decommissioning. The potential for introduction of metals or nitrogen to area streams will be greatest during operation, but also exists during the other phases. The assessment of the closure phase assumes stabilization of water quality conditions and associated effects on benthos and periphyton at closure. It is anticipated that this will be possible, based on operations phase monitoring and adaptive management to ensure effective long-term management of potential project effects from tailings and groundwater.

Study Area

The local and regional study areas for assessment of project effects on benthos and periphyton are identical to those established for water quality and fish resources (Figure 7.5-1). As discussed in Section 7.5.2, current plans are for discharge of water treatment plant effluent to Go Creek downstream of the Hawkowl Creek confluence.

The local study area (LSA) includes all streams that may be influenced by mine facilities or the access road between the mine and the Robert Campbell Highway:

- the Go Creek watershed, which will be affected by diversions, the tailings pond, airstrip, borrow area and campsite and will receive permitted discharges of treated effluent, and its tributaries Hawkowl and Pup Creeks, which will be affected by access road construction
- the Wolverine Creek watershed, which will be affected by the underground mine and portal area and the industrial complex
- stream reaches affected by the proposed access road (Chip, Bunker, Pitch and Putt Creeks and others within the Money Creek and Light Creek watersheds), defined as 100 m upstream and 200 m downstream of the proposed corridor

The minimum 100 m length of stream habitat assessed in fisheries studies (Section 7.8: Fish Resources) provides information useful for benthic community studies, which are conducted in riffle habitat. The assessment distance includes a range of habitat types (gradient, channel characteristics, erosional and depositional areas) and is comparable to the minimum assessment area defined by British Columbia standards (RISC 2001). The RISC standards evaluation length (100 m or ten times bankfull channel width, whichever is greater) ensures that all habitat types within a reach are sampled. The proposed road alignment has been located in high elevation (headwater) areas wherever possible, to avoid potential or identified fish-bearing streams. Several of these streams were observed to be dry during August and October surveys, and may be ephemeral (see Section 7.8).

The regional study area (RSA) includes water bodies beyond the LSA that reflect the general region to be considered for cumulative effects and that provide suitable reference areas for monitoring potential project effects:

- Money Creek, from downstream of the Go Creek confluence to Francis Lake, and tributaries crossed by the access road
- Wolverine and Little Wolverine Lakes and Nougha Creek, from Wolverine Lake to the Finlayson River

- Light Creek and tributaries crossed by the access road

7.7.2 Baseline Conditions

Existing information from previous studies conducted for YZC are summarized in the Wolverine Project Description Report (Gartner Lee 2004) and historic programs (Westmin 1996, 1997). This information has been augmented with data collected in the 2005 benthic monitoring program and a review of Yukon Government and Environment Canada databases. All data collected to date are compiled in Appendix 7.7. Results for 2005 will be discussed in a separate addendum report to be submitted in early 2006, as results for analytical work were not available in time for the EA report submission.

Table 7.7-2 describes benthic sampling dates and collection sites and Figure 7.7-1 shows site locations. Benthos samples were collected and analyzed in 1996 (several streams and lakes) and 1997 (Wolverine Creek). Nine sites have been assessed for periphyton and benthic invertebrates in 2005. Periphyton communities were not assessed until 2005.

Figure 7.7-1 Benthic Sampling Sites (Vol. 2)

7.7.2.1 Methods

1996 Program

For the 1996 program, high water depth, high velocities and large boulder substrates precluded the use of Hess or Surber samplers. Stream invertebrates were collected at six sites (Table 7.7-2) using artificial substrate samplers (26 cm long by 17 cm diameter wire baskets filled with rocks) submerged for five weeks, between July 15/16 and August 21/22, 1996. Three samplers were placed at each site. Samplers were retrieved by placing a screened bucket with a 300 micron mesh downstream and under the basket. The basket was opened on shore, rocks were emptied into a screened bucket, and individual rocks carefully washed in the bucket to collect all invertebrates from that sample. Detritus and benthic organisms in the bucket were placed in a 1 L nalgene bottle and preserved with 10% formalin. Lake benthic organisms were collected from three sites in Wolverine Lake (B-3, B-5, B-7), one in Little Wolverine Lake (B-10) and one in Little Jimmy Lake (B-1) using an Ekman dredge (5.2 cm x 15.2 cm x 15.2 cm). Triplicate samples were collected at various depths at each site. Sediment in the dredge was emptied into the screened bucket to drain off all water, placed in a 1 L nalgene bottle and preserved with 10% formalin.

All benthos samples were sent to Charles Low, Ph.D. (Victoria, BC) for enumeration and identification. At the lab, all samples were washed through two screens with mesh sizes 1 mm and 180 mm. All organisms retained by the coarse screen were counted and identified, and organisms on the 180 micron screen were sub-sampled as necessary using a Folsom plankton splitter. Most organisms were identified to genus.

Zooplankton samples were collected in August 1996 from Little Jimmy, Little Wolverine and Wolverine Lakes. A Wisconsin tow-net with a truncated cone (mesh size 76 µm) was hauled horizontally at 1-2 m depth behind an inflatable boat. Five replicates were collected from each lake. Zooplankton were anaesthetized, preserved with 10% formalin, and shipped to Limnotek (Vancouver, BC) for identification and enumeration. In the laboratory, samples were split using a Folsom plankton splitter to a volume containing a minimum of 100 post naupliar stages of the most abundant taxa of crustaceans.

Table 7.7-2 Periphyton, Benthos and Zooplankton Sampling Program for the Wolverine Project, 1996 to 2005

Site	Location / Relevance to Project	Stream Benthos			Lake Benthos	Lake Zooplankton	Periphyton
		1996[1]	1997[2]	2005[2]	1996[3]	1996[4]	Sept 2005
W01	Nougha Cr. at outlet of Wolverine Lake / Reference site, regional cumulative effects monitoring	X		X			X
W09	Wolverine Cr. at Wolverine Lake / Monitoring effects of mine portal and dewatering		X 3 dates	X			X
W11	Money Cr. u/s of Go Cr. / Reference site for potential effects on Money Cr.			X			X
W12	Go Cr. u/s of Money Cr. / Project effects on Go Cr.	X		X			X
W14	Money Cr. d/s of Go Cr. / Project effects on Money	X		X			X
W16	Go u/s of Hawkowl Cr. / Project effects on Go Cr.			X			X
W21	Nougha Cr. at Highway / Reference site, regional cumulative effects monitoring	X					
W23	Money Cr. u/s of Dollar Cr. / Reference site, regional monitoring	X					
W26	Wind Cr. / Reference site on tributary of Wolverine Lake	X					
W72	Light Cr. near Highway/ Project effects of road			X			X
W73	Bunker Cr. / Project effects of road			X			X
W75	Creek entering Jimmy Lake / Reference site			X			X
	Wolverine Lake / Reference site, regional cumulative effects monitoring				X	X	
	Little Wolverine Lake / Monitoring effects of mine portal and dewatering				X	X	
	Little Jimmy Lake / Reference site for effects on Little Wolverine Lake				X	X	

Notes:
1. Artificial substrates, July 15/16 to August 21/22, 1996, 300 µm mesh net, 3 replicates per site
2. Hess sampler, May, July and Sept. 1997, September 2005, 3 replicates per site (except 1 replicate/site at W72 and W73)
3. Ekman dredge, August 20 – 23, 1996, 3 replicates per site
4. Wisconsin tow-net, August 1996, horizontal tow at 1-2 m

1997 Program

The 1997 benthic program focused on seasonal trends in Wolverine Creek (W9). Samples were collected using a Surber sampler (three replicates per date) in May, July and September, 1997, preserved with 10% formalin and sent to Charles Low, Ph.D. for identification and enumeration.

2005 Program

Benthic invertebrate and periphyton samples were collected between September 6 and 11, 2005. Samples were collected at nine sites, listed in Table 7.7-2, using standard methods (RISC 1997; Freshwater Biological Sampling Manual). Results will be provided in an addendum report in early 2006.

Benthic invertebrates in riffle habitat were collected using a Hess sampler with 210 µm mesh size. Three samples were collected at each site, each sample a composite of three Hess settings, with the exception of samples from Sites W72 and W73 (one Hess setting per sample). Samples were preserved in 10% formalin, shipped to taxonomist Charles Low, sorted and identified to lowest practical level (genus for most insects, family for oligochaetes). QA/QC includes checks for sorting and splitting efficiency.

Periphyton were collected from natural substrates: cobble in riffle habitat. Three samples were taken at each site by scraping a known area, with each sample a composite of three scrapings. Samples were analyzed for biomass (chlorophyll *a*, phaeopigment) and taxonomy. Biomass samples were filtered through a 0.45 um membrane filter, frozen, and shipped to ALS Environmental (Vancouver, BC). Taxonomy samples were preserved with Lugol’s and sent to Karen Munro, Jacques Whitford Limited (Burnaby, BC) for identification and qualitative assessment (ranking of predominant, common and present species). QA/QC included comparison of triplicate field samples.

1996 and 1997 Stream Benthos Data Interpretation

Benthic communities sampled in 1996 and 1997 were assessed using Tolerance Categories, Equitability Index, Richness Index, Shannon-Wiener Diversity Index, Keefe-Bergersen TU Diversity Index, and Dominance Index to enable comparison of sites and evaluation of community health. Formulae and details are provided in Table 7.7-3.

Zooplankton Analysis and Data Interpretation

Random sub-samples comprising a known sample portion were examined. Species were enumerated and size, sex, stage of maturity and reproductive condition were determined at 5-100x magnification under a GSZ-Zeiss stereo microscope. The number of eggs was counted and size of female was measured for the first ten adults of the dominant species. Rotifers were identified to genus. Cladoceran sizing was included as part of regular lab procedures; copepod sizing was added because of their high relative abundance.

2005 Stream Benthos Data Interpretation

The approach to be used for 2005 data will differ from that described in Table 7.7-3, given that samples will be collected from natural rather than artificial substrates and that data will ultimately be used for MMER environmental effects monitoring. To be consistent with EEM requirements (Environment Canada 2002), total abundance, taxon richness, diversity (Simpson’s diversity index, evenness (similar to equitability) and dominance will be described. Similarity among sites will be compared using the Bray-Curtis index, if appropriate. Additional ecological indicators will be discussed in terms of family and genus abundance, tolerance categories and indicator species, as appropriate.

Table 7.7-3 1996, 1997 Benthic Invertebrate Programs - Ecological Indicators

Tolerance Categories (Beak 1965)	• Sensitive species include Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), which have low tolerance for habitat degradation, susceptible to disturbance • Facultative species include Diptera (true flies), Homoptera (aphids), Coleoptera (beetles), Collembola (springtails) and non-insect families, which have a moderate tolerance range for temperature, water quality and substrate types. These species use a wide variety of habitats from poor to good water quality conditions • Tolerant species consist mainly of the Oligochaetae (freshwater segmented worms and earthworms), which can survive under conditions adverse to most species
Equitability index (Pielou 1966)	• Measures evenness with which individuals are distributed in the sample. Ranges from 0 to 1, with low values indicating dominance of one species $J = \frac{\bar{d}}{K \log s}$ J = Equitability Index $\bar{d}$ = Shannon - Wiener diversity index (see below) K = 3.321928 (constant) s = number of taxa in the sample
Richness index (Margalef 1958)	• Measures the "taxonomic wealth" in a benthic community. Species richness indicates number of taxa represented relative to the population size. Higher richness = more taxa = greater habitat complexity, number of habitat niches variety of taxa able to colonize, survive and reproduce in a given area $R = \frac{s-1}{\ln N}$ R = Richness Index s = number of taxa in the sample N = number of individuals in the sample
Shannon-Wiener Diversity Index (Shannon, Wiener 1949)	• Measures complexity of a community. Sum of relative proportions of individuals of one species in the whole sample population. Index is less reliable with smaller sample size; does not consider taxonomic category of fauna; reduction in diversity value may be recorded only in the most severe cases of habitat degradation $\bar{d} = -\sum_{i-1}^{s} \left[\frac{N_i}{N} K \log\left(\frac{N_i}{N} \right) \right]$ $\bar{d}$ = Shannon - Wiener Diversity Index s = number of taxa N_i = number of individuals in the i^{th} taxon N = number of individuals in the sample K = 3.321928 (constant)
Keefe-Bergersen TU Diversity Index (Keefe and Bergersen 1977)	• Variation of Shannon-Weiner Index. Proportion of taxa to number of individuals in sample $TU = 1 - \left(\frac{N}{N-1} \right) \left[\sum_{i-1}^{s} P_i^2 - \frac{1}{N} \right]$ TU = Keefe - Bergersen diversity index N = number of individuals in the sample s = number of taxa in the sample P_i = proportion of individuals in i^{th} taxon
Dominance Index (Simpson 1949)	• Extent to which one or a few species dominate the sample. Proportion of population in one taxon related to whole population. High value indicates high density of one taxon, low value shows more even distribution of individuals among taxa $C = \sum_{i=1}^{s} \left[\frac{N_i}{N} \right]^2$ C = Dominance Index s = number of taxa in the sample N_i = number of individuals in the i^{th} taxon N = number of individuals in the sample

Periphyton Analysis and Data Interpretation

Periphyton results will be discussed in terms of species richness, relative abundance of species and classes of algae, ecological tolerance, and similarities among sites. Abundance will be discussed in terms of chlorophyll *a* and phaeopigment concentrations.

7.7.2.2 Results

The invertebrate taxa described for the project area are commonly reported in streams and lakes of North America, including the Yukon (Biomonitoring Information System for the Yukon). Stream samples (artificial and natural substrates) contained a diverse assemblage of invertebrates typical of undisturbed habitat (mainly facultative and sensitive taxa), including midges (Chironomidae: Diptera), mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera) and blackflies (Simuliidae: Diptera). Lake samples contained primarily worms (Nematoda, Oligochaeta), crustaceans (Cladocera, Copepoda, Ostracoda) and midges (Chironomidae). Zooplankton samples contained crustaceans and rotifers.

Invertebrate data are reported in Appendix 7.7 and summarized here. Because the use of artificial substrates to collected benthos in 1996 were not considered sufficient to characterize creeks in the Go, Money and Wolverine watersheds, additional data were collected from natural substrates using Hess samplers in 2005 m which should yield more representative numbers for total and taxon abundance for comparisons over time.

1996 Stream Benthos

Enumeration and taxonomic identification data for stream benthic samples are presented in Appendix 7.7-1. Total abundance, taxon richness and common taxa are summarized in Table 7.7-4. Abundance was greatest at sites W1 and W26.

In situ water quality and site conditions are described in Table 7.7-5, and indicate that there are basic differences in temperature, conductivity, pH and stream flow over the artificial substrates. For example, temperature and conductivity were highest and stream flow lowest at Site W26, on Wind Creek. Water quality and flows were similar at the two sites on Nougha Creek (W1 and W23). The three sites on Money and Go Creeks (W12, W14 and W23) were similar in their low temperatures, conductivity and flows over substrates.

Table 7.7-4 1996 Benthic Invertebrate Program - Summary Information

Site	Abundance		# of Taxa	Common Taxa (>10% abundance)
	mean/sampler	st. dev.		
W1, Nougha Cr. at outlet of Wolverine Lake	10,616	3837	45	*Hydra* sp. (Cnidaria) *Simulium* sp. (Simulidae) unidentified Chironomidae larvae
W21, Nougha Cr. upstream of Robert Campbell Highway	1894	440	52	*Baetis* sp. (Ephemeroptera) *Simulium* sp. (Simulidae) unidentified Chironomidae larvae
W12, Go Cr. upstream of Money Ck confluence	1604	933	46	*Zapada* (Plectoptera) unidentified Chironomidae larvae *Cricotopus* sp. (Chironomidae) *Eukiefferiella* sp. (Chironomidae)
W14, Money Cr. downstream of Go Ck confluence	3295	2099	50	*Baetis* sp. (Ephemeroptera) unidentified Chironomidae larvae *Cricotopus* sp. (Chironomidae) *Eukiefferiella* sp. (Chironomidae)
W23, Money Cr. upstream of Dollar Ck	3418	2159	50	unidentified Chironomidae larvae *Cricotopus* sp. (Chironomidae) *Eukiefferiella* sp. (Chironomidae)
W26, Wind Cr. at inlet to Wind Lake	16,002	10,397	63	*Simulium* sp. (Simulidae) unidentified Chironomidae larvae *Rheotanytarsus* sp. (Chironomidae) *Eukiefferiella* sp. (Chironomidae)

Source: Westmin (1996)

Table 7.7-5 1996 Benthic Program - Water Quality and Artificial Substrate Data

Site	Date	Temp (°C)	D.O. (mg/L)	D.O. (% Sat.)	Cond (µS/cm)	pH	Depth at Basket (m)	Velocity at Basket (m/s)
W1	July 16	11.9	10.2	109	134.4	9.02		
	Aug 22	10.5	11.5	120	140.7	8.73	0.3 - 0.4	0.8
W21	July 16	9.8	10.3	103	174.9	8.53		
	Aug 22	9.7	10.9	109	188.6	8.16	0.2 - 0.3	1.1
W12	July 15	5.9	11.3	102	128.6	8.44		
	Aug 21	5.4	12.0	112	139.4	8.27	0.4	0.4
W14	July 15	6.1	11.2	106	124.3	7.76		
	Aug 21	5.7	12.9	121	136.3	7.95	0.5 - 0.6	0.6
W23	July 15	8.3	10.1	100	95.5	7.73		
	Aug 21	8.1	11.9	117	104.6	8.02	0.5	0.2
W26	July 16	15.6	18.8	218	294.0	8.73		
	Aug 22	10.0	10.1	105	299.0	7.98	0.2	0.1

Source: Westmin (1996)

Notes: D.O.: dissolved oxygen
Cond: conductivity

Ecological indicators are summarized in Table 7.7-6. Abundance, number of taxa, proportions of sensitive and tolerant taxa, and other ecological indicators were relatively consistent for the four stream sites on Go, Money and Nougha Creeks (W12, W14, W21, W23) away from the lakes. Total abundance at these four sites was notably lower than for W1 and W26. Abundance was lowest at W12 (Go Creek) and W21 (Nougha Creek at the highway). Although chironomids were predominant at all six stations, the relative abundance of mayfly, caddisfly and stonefly species (sensitive taxa) was higher at these four sites than W1 and W26.

Table 7.7-6 1996 Benthic Invertebrate Program - Ecological Indicators

Site	Tolerance Category[1]			Shannon Wiener Diversity	Domin -ance	Equitability	Richness	TU Diversity	Variance
	Sens.	Fac.	Tol.						
W1	7%	92%	1%	3.07	0.21	0.56	4.75	0.79	0.12
W21	33%	66%	1%	3.92	0.10	0.69	6.76	0.90	0.02
W12	22%	75%	3%	3.35	0.19	0.61	6.10	0.81	0.11
W14	45%	53%	2%	3.03	0.22	0.54	6.05	0.78	0.08
W23	21%	78%	1%	3.02	0.24	0.54	6.02	0.76	0.14
W26	2%	98%	0%	2.83	0.22	0.47	6.40	0.78	0.08

Source: Westmin (1996)

Notes: 1. Tolerance Category: Sens = Sensitive, Fac = Facultative, Tol = Tolerant

Higher proportions of sensitive taxa and even distribution among taxa contribute to higher diversity and richness indices, suggesting higher habitat complexity. Station W21 had the highest richness and diversity indices and lowest variance of the six sites, indicating even distribution of the population across the identified taxa.

Site W26 (Wind Creek at inlet to Wind Lake) had higher abundance and lower diversity (Shannon Wiener Index) than the other five sites. The most common taxa were members of the Chironomidae and Simulidae (midges and blackflies), considered facultative species. Taxon richness was among the highest at W26, suggesting higher habitat complexity. This station also had the highest *in situ* conductivity and water temperature and lowest water depth and velocity of the six sites. Water quality and habitat differences likely contributed to high benthic productivity and dominance of a few facultative taxa at Site W26, given that water temperature and conductivity were highest at this site.

Site W1 (Nougha Creek at Wolverine Lake outlet) also had high abundance, but with a higher proportion of sensitive taxa and higher diversity (Shannon Weiner Index) than at Wind Creek. Number of taxa and taxon richness index were lower at Site W1 than the other five sites, suggesting lower habitat complexity. Taxonomic composition differed from the other sites in predominance of Hydra sp. (Cnidaria, freshwater sponge), a common organism in lakes, ponds and streams. Blackfly and chironomid larvae were also common at W1. Differences in water temperature (higher than at the other sites), flow regime and water quality, all related to influence of the lake immediately upstream, would contribute to the relatively unique community at Site W1.

1997 Stream Benthos

The 1997 program was designed to monitor changes in the benthic community over the growing season at one site, W9 on Little Wolverine Creek (Table 7.7-7 and Appendix

7.7-2). Samples were collected from natural substrates using a Hess sampler (three replicates per site) in May, July and September. It was not relevant to compare results for W9 with those for sites sampled in 1996, which were collected using artificial substrates.

Table 7.7-7 1997 Benthic Invertebrate Program at Site W9 - Ecological Indicators

Date	# per m^2	# Taxa	Tolerance Category[1]			Shannon Wiener Diversity	Dominance	Equitability	Richness	TU Diversity	Variance
			Sens.	Fac	Tol.						
May	280	18	9%	86%	5%	2.88	0.22	0.69	5.10	0.8	0.08
July	1367	20	11%	88%	1%	2.20	0.36	0.51	3.86	0.64	0.22
Sept.	4103	39	19%	79%	2%	2.92	0.22	0.55	6.31	0.78	0.10

Source: Westmin (1997), three replicates per date

Notes: 1. Tolerance Category: Sens = Sensitive, Fac = Facultative, Tol = Tolerant

Total abundance, diversity, and proportion of sensitive taxa increased over the season to a maximum in September. In July, diversity, richness, and equitability indices were lowest and dominance and variance indices were highest, indicating an increase in abundance of a few taxa. This may result from seasonal differences in growth rates among species, given that small organisms (typically <300 μm) are not retained in the sampling net (likely for samples collected in May) and that most organisms grow to maximum size by the end of the summer. Diversity was substantially greater in September with more Plecoptera and Diptera species present.

Among the major taxonomic groups, Diptera (*Eukiefferiella* sp., *Diamesa* sp., unidentified chironomid larvae) was predominant on all three occasions, forming over 70% of the communities. Plecoptera (unidentified nymphs) was subdominant in September. Generally, composition was similar throughout the summer. Ephemeroptera, Plecoptera and Trichoptera were present in all three samples, and are generally considered pollution sensitive taxa (Lehmkuhl 1979; Winner el al.1977).

Several insect species with a low tolerance to metals (Lehmkuhl 1977) were present at W9 (ephemeropteran *Paraleptophlebia* sp., plecopterans *Despazia* sp., *Sweltsa* sp., *Zapada* sp., *Perlomyia* sp.). Plectoptera were common (>10% abundance) in September.

The diverse community at Wolverine Creek was unexpected, given the background water and sediment quality. Zinc concentrations in water were four to five times greater than the guideline of 0.03 mg/L total zinc for protection of freshwater aquatic life (CCME 2004). Most of the zinc was in the dissolved form, which is more readily available than the particulate form. Zinc levels in stream sediments were also high, and concentrated in the smaller size fraction. This could have an effect on the benthic community, given that organisms are in direct contact with stream sediments and that they may assimilate metals (e.g., the trichopteran *Imania* sp., found in May and July, ingests mineral particles by scraping the upper surfaces of rocks; Wiggins 1977).

1996 Lake Benthos

Lake benthos were sampled at three locations in Wolverine Lake and one location in each of Little Wolverine and Little Jimmy Lakes. Detailed results are contained in Appendix 7.7-3. Results are summarized for Wolverine and Little Wolverine Lake data in Table

7.7-8. The 1996 data provide information suitable for long-term monitoring of benthic communities in the three lakes.

Table 7.7-8 1996 Benthic Invertebrate Program in Wolverine and Little Wolverine Lakes - Data Summary and Ecological Indicators

Parameter		Wolverine Lake			Little Wolverine Lake
		W3a, west of island	W5a, bay near mouth of Wolf Ck	W7a, 1 km east of Viking Ck	W10a, near outlet
Total organisms/sample		652	3428	2272	2099
# of taxa		48	43	36	54
Tolerance Category	Sensitive	2%	0%	0%	0.3%
	Facultative	79%	79%	81%	75%
	Tolerant	19%	21%	19%	25%
Shannon Wiener Diversity		3.92	3.26	3.21	3.89
Dominance		0.11	0.18	0.18	0.11
Equitability		0.70	0.60	0.62	0.68
Richness		7.25	5.16	4.53	6.93
TU diversity		0.89	0.83	0.82	0.89
Variance		0.03	0.07	0.07	0.02
Temp (°C)		11.0	11.2	11.3	11.7
D.O. (mg/L)		10.2	9.9	10.2	12.5
D.O. (% Sat.)		107	107	108	135
Conductivity (µS/cm)		116.9	116.9	116.6	114.9
pH		8.16	8.16	8.31	7.90
Average Sampling Depth (m)		3.0	1.2	2.5	0.5

Source: Westmin (1997)

Notes: Sediment sampled August 20-23, 1996, mean of three samples per site
Water sampled July 15-16, 1996

Diversity (Shannon Weiner Index, number of taxa) in lake samples was similar to that of creek samples, although composition differed considerably between stream and lake habitat. Lake samples had much higher proportions of tolerant organisms and lower populations of sensitive organisms than stream samples, as would be expected for depositional habitat. Community indices showed a similar range to stream samples.

The benthic communities consisted of a variety of worms (Nematoda, Oligochaeta), crustaceans (Cladocera, Copepoda, Ostracoda) and chironomids (Chironomidae, e.g., *Rheotanytarsus* sp.) typical of lake benthic habitat. Their inclusion in facultative or tolerant categories is based on tolerance of sediment and organic matter, and illustrates the different types of communities in erosional (stream) and depositional (lake, wetland, slow flowing stream) habitat. Diversity indices were similar at all lake stations, indicating a similar degree of population distribution across taxonomic categories.

Community richness, diversity and number of taxa were high for Little Wolverine Lake, indicating high habitat diversity. This site had the shallowest depth sampled (0.5 m), and samples contained a higher proportion of bivalves (*Sphaerium* sp.) than did those from Wolverine Lake.

In Wolverine Lake, the highest richness, number of taxa and diversity index was measured at W3a, west of the island, where abundance was lowest and population distribution most even. The higher taxon number and richness indicates higher habitat complexity at W3a, which was also the deepest site sampled (3.0 m).

At Little Jimmy Lake, samples had a lower number of taxa and higher proportion of tolerant species compared to the other lake sites. Given that sediments of Little Jimmy Lake had the lowest concentrations of metals, other habitat parameters appear to play a more important role in regulating benthic communities.

1996 Lake Zooplankton

Zooplankton were collected from Little Jimmy, Little Wolverine and Wolverine Lakes using plankton tows (five replicates per lake). Results for Wolverine and Little Wolverine Lakes are summarized in Table 7.7-9. Detailed data (abundance and size of adult copepods for the three lakes, measurements and reproductive condition of plankton in Wolverine and Little Wolverine Lakes) are contained in Appendix 7.7-4.

Table 7.7-9 1996 Lake Zooplankton Program - Data Summary

Parameter	Taxon	Wolverine Lake	Little Wolverine Lake
Abundance	Cladocerans	12 per m^3	192 per m^3
	Copepods	3177 per m^3	3591 per m^3
	Rotifers	1412 per m^3	7322 per m^3
	Total	4601 per m^3	11,105 per m^3
Cladocera average size	*Daphnia pulex*	2128 µm	-
	Bosmina longispina	615 µm	654
Copepoda average size	*Heterocope septentrionalis*	3073 µm (female)	2436 µm (female)
		2998 µm (male)	2339 µm (male)
	Diaptomus pribilofensis	1438 µm (female)	1547 µm (female)
		1288 µm (male)	1413 µm (male)
	Diaptomus ashlandi	801 µm (female)	-
		781 µm (male)	-

Source: Westmin (1997)

Total abundance ranged from 4,600 organisms per m^3 (Wolverine Lake) to 16,000 organisms per m^3 (Little Jimmy Lake). Copepods were the most common organisms, with other Crustacea (cladocerans) and Rotifera also present. Wolverine Lake had the highest number of species, including *Daphnia pulex* and *Diaptomus ashlandi*, which were not collected in samples from Little Wolverine or Little Jimmy Lakes.

Periphyton

Periphyton were not collected during previous YZC investigations, but are included in the 2005 field program. Results will be reported separately in an addendum report, to be submitted in early 2006. Species common in the Yukon are described in the Biomonitoring Information System for the Yukon. This database describes many species reported in streams of British Columbia and elsewhere in North America. Commonly reported and abundant species for the Yukon are listed in Table 7.7-10.

Table 7.7-10 Common and Abundant Periphyton Species of Yukon Streams

Bacillariophyceae (Diatoms)		Cyanophyta (Blue-green Algae)	Others
• *Achnanthes* spp. • *Achnanthes minutissima* • *Cocconeis placentula* • *Cymbella* spp. • *Diatoma heimale* var. *mesodon* • *Diatoma tenue* • *Didymosphenia geminata* • *Eunotia elegans* • *Fragilaria capucina* • *Gomphonema* spp.	• *Gomphonema angustatum* • *Hannaea arcus* • *Melosira varians* • *Meridion circulare* • *Navicula* spp. • *Nitzschia* spp. • Synedra sp. • *Synedra incisa* • *Synedra rumpens* • *Synedra ulna*	• *Chamaesiphon incrustans* • *Leptolyngbya* sp. • *Lyngbya* sp. • *Lyngbya diguetii* • *Lyngbya aeruginosa-caerula* • *Nostoc* sp. • *Oscillatoria aghardii* • *Phormidium* spp. • *Phormidium tenue* • *Plectonema notatum* • *Rivularia* sp.	• Tetrasporales (Chlorophyta, Green Algae) • *Hydrurus foetidus* (Chrysophyta, Golden Algae) • *Audouinella violacea* (Rhodophyta, Red Algae)

Source: Biomonitoring Information System for the Yukon

7.7.3 Effects Assessment Methodology

Project effects on periphyton and benthos VECCs have been assessed based on predicted residual effects on water and sediment quality (Section 7.5: Surface Water and Sediment Quality) and streamflows (Section 7.6: Groundwater; Section 7.4: Surface Water Hydrology) and direct habitat disturbance due to construction of stream crossings (Section 2.10: Site Facilities and Infrastructure). Potential effects on community composition and productivity are characterized based on the likelihood of toxic effects, nutrient enrichment and metals bioaccumulation, which are based on projected instream flow and water quality conditions at the effluent discharge and at the identified compliance point on Go Creek, 2.5 km upstream of W12 (Section 7.5.3: Water and Sediment Quality, Effects Assessment Methodology).

Project and cumulative effects on periphyton and benthic invertebrates are characterized in accordance with the EA Report Guidelines using effects attributes defined in Table 7.7-11. The ecological and social contexts of effects are integrated in the attributes for effect magnitude and discussed in detail for each VECC in the assessment text.

Determination of Effects Significance

A residual effect on periphyton or benthic invertebrates is considered significant for the project or cumulatively, based on the defined attributes (Table 7.7-11), if it is:

- a moderate magnitude adverse effect that is long term or far future in duration
- a high magnitude adverse effect, unless it is site specific in geographic extent

Otherwise, effects will be rated as not significant.

In addition, as required by the EA Report Guidelines, the likelihood of occurrence of any significant adverse residual effects is stated with a supporting rationale.

Table 7.7-11 Effect Attributes for Periphyton and Benthos

Attribute	Definition
Direction	
Positive	Condition of VECC is improving
Adverse	Condition of VECC is worsening or is not acceptable
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends
Magnitude	
Low	Effect occurs that might or might not be detectable, but is within the range of natural variability, does not pose a serious risk to VECC, and does not compromise other environmental values
Moderate	Clearly an effect but unlikely to pose a serious risk to the VECC or represent a management challenge from an ecological, economic or social/cultural standpoint
High	Effect is likely to pose a serious risk to the VECC and represents a management challenge from an ecological, economic or social/cultural standpoint
Geographic Extent	
Site-specific	Effect on VECC confined to a reach of a stream in the LSA (*e.g.*, <500 m)
Local	Effect on VECC extends throughout the LSA
Regional	Effect on VECC extends into the RSA
Duration	
Short term	Effect on VECC is limited to 1 year
Medium term	Effect on VECC occurs between 1 and 5 years (parallels the age to maturity for bull trout)
Long term	Effect on VECC lasts longer than 5 years but does not extend more than 10 years after decommissioning and final reclamation.
Far future	Effect on VECC extends >10 years after decommissioning and abandonment
Frequency (Short term duration effects that occur more than once)	
Low	Frequency within range of annual variability and does not pose a serious risk to the VECC
Moderate	Frequency exceeds range of annual variability but is unlikely to pose a serious risk to the VECC
High	Frequency exceeds range of annual variability and is likely to pose a serious risk to the VECC
Reversibility	
Reversible	Effects on VECC will cease during or after the project is complete
Irreversible	Effects on VECC will persist during and/or after the project is complete
Likelihood of Occurrence	
Unknown	Effect on VECC is not well understood and, based on potential risk to the VECC or its economic or social/cultural values, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted

7.7.4 Project Effects

Potential project-VECC interactions, during routine activities associated with construction, operations, decommissioning, and closure are identified in the following sections, based on assessments described in Section 7.4: Surface Water Hydrology and Section 7.5: Surface Water and Sediment Quality. Interactions related to accidents and malfunctions are described in Section 8. Most interactions are anticipated to be with stream rather than lake habitat. The following sections describe project actions and mitigation measures by phase and by affected stream basins.

7.7.4.1 Construction

Wolverine Creek

Minesite facilities to be constructed in the Wolverine Creek drainage and potential effects on water quality are described in Section 7.5: Surface Water and Sediment Quality. Wolverine Creek is a short, high gradient stream, flowing subsurface in some areas, with fish resources concentrated at the mouth where it discharges to Little Wolverine Lake. The Wolverine Creek basin has already been affected by access road construction, mine portal construction and pre-production mine development. To date, mine dewatering rates have been very low, with no measurable effects on base flows in Wolverine Creek (Section 7.6: Groundwater), and site water management in the portal and stockpile areas has adequately protected water quality. As a result, there have been no adverse effects on water quality in Wolverine Creek. Potential effects on Wolverine Creek during project construction include:

- ***Further pre-production mining with gradually increasing groundwater interception and mine dewatering.*** Mine dewatering will likely result in decreased baseflows to Wolverine Creek. Up to 50% reduction in late summer and winter low flows have been predicted, with effects as discussed below (Section 7.4: Surface Water Hydrology; Section 7.6; Groundwater).
- ***Increased suspended sediment in runoff from construction sites for various facilities in the basin***. Effects of sediment release on water quality, associated with ground disturbance during construction, have been rated as not significant (low magnitude, site specific, short term, moderate frequency and reversible), as they will be mitigated through the YZC erosion and sediment control plan (Section 9: Environmental Management Plan). Accordingly, no effects on benthic communities in Wolverine Creek are expected during construction.
- ***Runoff from temporary development rock storage area and ore stockpiles with potentially elevated metals, nitrogen and suspended sediments.*** Introduction of metals or nitrogen from the development rock storage area to Wolverine Creek is not expected, given the observed effectiveness of the current system used to collect and treat water prior to discharge to Go Creek. To date, there have been no adverse effects of such discharges on water quality in Wolverine Creek, and no changes in the system are expected during the construction phase. As a result, no adverse effects on benthic communities are predicted during construction.

The main effect of construction in the Wolverine Creek basin is expected be decreased flows due to mine dewatering and site water management, which may have an effect on benthic periphyton and invertebrate communities through a reduction in wetted benthic habitat area in Wolverine Creek and a corresponding reduction in benthic productive capacity. This would be most apparent in the lower reaches used by fish during the summer, when benthic production is at its peak, given that habitat is fragmented in the upper portion of the stream. Decreases in groundwater flow contributions in the lower reach could be significant at maximum underground development (up to 50% during summer); however mean summer flows and peak flows will not be significantly affected by the reduction in baseflow, as these flows are primarily derived from snowmelt and rainfall runoff (Section 7:4: Surface Water Hydrology). Accordingly, during the construction phase, stream flow reductions due to mine dewatering, and related effects on benthic habitat and productivity, are expected to be adverse, low magnitude, site specific, short term, low frequency and reversible. Accordingly, effects are rated as not significant, with a high likelihood of occurrence.

Go Creek

Minesite facilities to be constructed in the Go Creek drainage and potential effects on water quality are described in Section 7.5. Go Creek is a 12 km long stream with areas of high gradient cascade and riffle habitat and low-gradient wetland and pond habitat. Fish are known to be present in the lower 2 km, upstream of the confluence with Money Creek. Access road construction and the existing airstrip have already affected the Go Creek basin; however, these activities have not had a noticeable effect on water quality in Go Creek to date (Section 7.5).

Potential effects on benthic communities in Go Creek during construction include:

- ***Flow diversion from upper Go Creek to the tailings facility.*** An intake will be located on upper Go Creek in the vicinity of the camp to allow diversion of water to the tailings pond. During construction, this diversion will operate between April and mid July (freshet) to provide water to the tailings facility at a rate of 200 m^3/hour. Go Creek flows will be maintained at higher than summer low flow levels at W31 during that period, an amount not predicted to result in notable reductions in flow, wetted habitat or benthic productivity in Go Creek. Flows at W12 will be reduced by less than 5% during the diversion period.
- ***Increased suspended sediment in runoff from construction sites for various facilities in the basin.*** The YZC erosion and sediment control plan (Section 9: Environmental Management Plan) will be implemented to minimize the risk of introducing suspended sediments to surface waters. In addition, all site drainage in the minesite construction zone will be collected by site water management facilities (Section 2.9: Site Water Management) and contained in sediment ponds for treatment before discharge to Go Creek. Accordingly, no adverse effects on water quality or benthic communities in Go Creek are expected during construction.

Site water management to collect and treat potentially contaminated runoff in the construction area is expected to minimize potential impacts on water quality in the Go Creek basin. Accordingly, effects on benthic communities, and related effects on fish, are expected to be adverse, low magnitude, site-specific, short term, low frequency and reversible. The likelihood of occurrence as predicted is high, based on the short duration of the construction phase, observed effectiveness of site water management in preventing impacts during pre-development construction, monitoring of sediment pond waters to ensure acceptable quality before release, and contingency measures for settling pond treatment if required to ensure acceptable quality before release.

Money Creek

No project related effects are anticipated for benthic communities in Money Creek, given that construction effects will be specific to Go and Wolverine Creeks and that effects of access road crossings will be confined to tributary reaches where culverts are built.

Tributaries along the Access Road

The 20 km long access road to the Robert Campbell Highway will cross the headwaters of several streams. The road has been aligned to avoid fish-bearing waters to the greatest extent possible, by traversing the higher elevations. Several small permanent and ephemeral streams will be crossed, including upper Pup and Hawkowl Creeks (Go Creek tributaries), tributaries of Chip and Bunker Creeks (Money Creek tributaries), Light Creek and Putt Creek (Light Creek tributary).

Construction activities for stream crossings and road right-of-way access that occur within the riparian management area (RMA, defined as a 20-70 m buffer on each side of the stream) may remove streamside vegetation and introduce sediment to streams through erosion. The main effect of sedimentation on benthic invertebrates and periphyton is as described for Wolverine Creek. The effects of vegetation removal include increased light exposure and temperature, loss of leaf litter (a significant source of organic matter for benthic invertebrates), burial of organisms and damage to sensitive gill structures of certain insect nymphs. The erosion and sediment control plan (Section 9: Environmental Management Plan) and other mitigation described in Table 7.7-12 will help minimize potential effects.

Small amounts of benthic habitat (approximately 10 m culvert lengths) will be lost through culvert installation. Mitigation through use of countersunk or inset culverts on smaller streams will minimize effects on benthic invertebrate communities which can re-establish; however, periphyton productivity will be affected.

7.7.4.2 Operations

Wolverine Creek

Potential effects on water, sediment and benthic communities in Wolverine Creek that were identified for the construction phase will continue during operations. Site management to collect and treat mine water and potentially contaminated runoff will continue to minimize potential impacts on water quality and benthic communities in Wolverine Creek. Effects of underground mining on groundwater discharge to Wolverine Creek will continue during operations. Potential adverse effects of project operations on periphyton and benthic invertebrates in Wolverine Creek are characterized as low magnitude, site specific, long term and reversible, therefore, not significant.

Go Creek

Potential effects on benthic communities in Go Creek that were identified for the construction phase will continue during operations. Site management to collect treat and mine water and potentially contaminated runoff will continue to minimize potential impacts on biota in the Go Creek basin during the operations phase. The main incremental effects on water and sediment quality in Go Creek during operations, described in Section 7.5.4.2 will have the following effects on benthic communities:

- ***Upper Go Creek diversion.*** The diversion channel from upper Go Creek to the tailings facility will be decommissioned early in the operations phase (Section 2.8: Tailings Disposal), and treated effluent discharge will contribute a low proportion of flows to Go Creek downstream of Hawkowl. As a result, there will be no net effect on the amount of wetted habitat and potential benthic productivity in Go Creek. Flows will be monitored during low flow periods (Section 7.4: Surface Water Hydrology).
- ***Discharge of water treatment plant effluent to Go Creek downstream of the Hawkowl Creek confluence.*** The water treatment plant will discharge effluent to Go

Creek downstream of the Hawkowl Creek confluence from May through October of each year, with effects on water quality as described in Section 7.5. Ammonia, cadmium and selenium are predicted to be elevated above site specific water quality objectives for protection of aquatic life (to be developed in consultation with YTG and Environment Canada) in the 7 km reach between the discharge point at Site W12. Cadmium levels may continue to be elevated downstream of the compliance point, given that baseline levels currently exceed the guideline at times during the summer, but are expected to be within the range of natural variability. Nitrate levels are predicted to be elevated throughout this region. There may also be effects related to deposition and transport of particulate metals, resulting in increased metal levels in stream sediments. Further discussion of predicted receiving water quality on benthic communities in Go Creek is provided below.

Discharge of mine effluent in the upper watershed, downstream of the Hawkowl Creek confluence, has the potential to have a significant adverse effect on benthic communities through toxicity of metals, nutrient enrichment (elevated nitrate or ammonia from blasting residues), changes in pH and release of suspended sediments. Predicted effluent and receiving environment water quality are described in Sections 2.9 and 7.5.4, respectively. The receiving environment and effluent will be subject to Environmental Effects Monitoring under Metal Mining Effluent Regulations.

As discussed in Section 7.5.4.2, the elevated nitrate and ammonia levels in the 7 km long reach between the discharge point and W12 may result in nutrient enrichment and increased periphyton growth, which can lead to increased benthic invertebrate abundance and shifts in species composition of both periphyton and benthos. This increased productivity may be a positive effect, given that area streams support very small fish populations (Section 7.8: Fish Resources), although excessive enrichment could lead to heavier accumulations of algae in slow-flowing areas. Shifts in the benthic invertebrate community (e.g., toward herbivorous species of mayflies and chironomids) in response to changes in periphyton abundance and composition continue to provide suitable food for fish, and might result in greater food availability. Fish spawning in late summer would be unlikely to be affected by a moderate increase in periphyton growth in riffle habitat.

Project effects on benthic communities in Go Creek related to nitrate and ammonia discharge are rated as potentially positive or adverse, depending on extent of enrichment, moderate in magnitude, local, long term in duration, moderate in frequency and reversible, with an unknown likelihood. Potential effects are rated as not significant, but will be monitored in MMER EEM programs. If moderate adverse effects are identified during monitoring, YZC may be able to instigate adaptive management strategies such as increasing nitrate treatment in the water treatment facility.

Potential effects of metals discharge on benthic communities in Go Creek will be greatest in the upper watershed, immediately downstream of the discharge, given that cadmium and selenium levels will exceed site specific water quality objectives. The effect will decrease progressively downstream, given that dilution will enable these metals to meet their respective guideline or baseline level by W12, and will be close to those levels in the lower 2 km of fish-bearing habitat upstream of W12. Other metals will meet site specific water quality objectives soon after the discharge point.

Given that most historic reports of effects on benthic communities are for streams with markedly elevated levels, for example, selenium in the range of 0.005-0.029 mg/L (Hamilton and Buhl 2003) and cadmium in the range of 0.00001-0.050 mg/L (Goodyear and McNeill 1999), the are less relevant when assessing metal levels in the lower part of the range, as would be expected in Go Creek, where cadmium levels are typically less than 0.00005 mg/L and selenium levels range from 0.0005 to 0.0012 mg/L .

Specific information about bioaccumulation of cadmium in benthic invertebrates is lacking, because much of the historic cadmium data in water reflect concentrations close to analytical detection limits. However, significant relationships have been noted between sediment cadmium levels and collector-gatherers including various mayflies, caddisflies, blackflies and chironomids (Goodyear and McNeill 1999); lead, copper and zinc levels in these organisms correlate with their levels in sediment and water. Many of the species listed by Goodyear and McNeill have been reported for Wolverine and Go Creeks.

Selenium concentrations in benthic invertebrates have paralleled levels in water (<0.005-0.024 mg/L) and sediment (1-39 mg/kg dry weight), although they tend to be more closely correlated with levels in sediment than water (Hamilton and Buhl 2003). As noted in Section 7.5, accumulation of selenium and other metals in depositional areas has become an issue of concern for mines (McDonald and Strosher 2000; Chapman 2004), with research ongoing into the relationship between ambient levels and organism responses. Selenium has been noted to bio-accumulate in fish tissue, probably through consumption of benthic invertebrates that dwell in close contact with the metal-containing sediment. Current recommendations are for a maximum of 2 mg/kg in sediment (BC Ministry of Environment 2005). Selenium levels in Go Creek sediment have been below that level (Table 7.5-9), but will be monitored during mine operations.

If selenium levels in sediment show an increasing trend and are approaching guideline levels, additional sampling of benthic invertebrates and fish (sculpin) for tissue metals analysis will be conducted in downstream fish-bearing areas. In the event of an increasing trend in sediment and tissue concentrations, adaptive management, such as enhanced treatment to reduce bio-available selenium levels, will be implemented.

Project effects on Go Creek benthic communities related to metals discharged in effluent are predicted to be adverse, low magnitude, local in extent, long term in duration, moderate in frequency and reversible, but with an unknown likelihood in terms of extent (which will be monitored through MMER). As a result, effects are rated as not significant.

Money Creek

No significant project related effects are anticipated for Money Creek, given that effluent discharges to Go Creek will meet site specific water quality objectives at Site W12 and that there is a further four-fold dilution of Go Creek water at the Go – Money confluence (Section 7.4: Surface Water Hydrology). The potential for accumulation of transported metal-bearing particulate matter from effluent discharges into the fish-bearing Money Creek is considered low, given the levels discharged, the distance to be covered (more than 7 km) and the number of potential depositional areas in Go Creek (behind beaver dams). However, monitoring of sediment metal levels will be recommended and should follow methods used in 2005.

Tributaries along the Access Road

There is potential for road runoff carrying metals, hydrocarbons and sediment to enter the tributaries along the access road during operation of the mine. Potential effects on benthic communities have been minimized by situating the road in headwater areas and by implementing the YZC erosion and sediment control plan (Section 9.2) to minimize the risk of introducing suspended sediments to surface waters.

7.7.4.3 Decommissioning

The potential effects of mine closure will be more limited than during the construction phase because the access road will be retained at the request of the Kaska First Nation. The mine closure plan is described in Section 3.4. Effects on hydrology and water quality are described in Sections 7.4 and 7.5, respectively

Wolverine Creek

Groundwater will recharge underground areas of the mine over a period of 2.5 years, then groundwater contributions to surface flows will return to baseline conditions over a 13.5-year period. Any effects of reduced wetted habitat resulting from earlier mine dewatering will then be reversed. Metals may be transported to Wolverine Creek in the groundwater over a long period of time (see Closure section). Potential adverse effects on benthic organisms in Wolverine Creek related to sediment release in runoff during removal of facilities will be mitigated by following the erosion and sediment control plan (Section 9.2), so no significant adverse effect on periphyton and benthic invertebrate communities are expected.

Go Creek

The tailings facility will remain in place to provide permanent storage of mine tailings, which will be covered by at least 0.5 m depth of water. As described in Sections 2.8 and 7.5.4, it is predicted that levels of most metals (antimony, arsenic, copper, lead, molybdenum, silver, thallium, zinc, nitrate) in supernatant water will be reduced to site specific water quality objectives within five years of closure and that levels of selenium and cadmium will reach those objectives within eight and nine years, respectively. Supernatant water will be monitored following the end of operations and the water treatment plant will remain operational for at least five years to provide treatment of tailings supernatant if required. In combination with the relatively small flows over the tailings pond spillway (up to 2.6% of summer flows), this should result in no adverse effects on water quality or benthic communities.

Potential adverse project effects on Go Creek during decommissioning include increased suspended sediment in runoff from deconstruction sites for various facilities, as noted for Wolverine Creek, which will be mitigated by the erosion and sediment control plan (Section 9.2) and site revegetation included in the mine closure plan (Section 3.4). Accordingly, no adverse effects on water quality or benthic periphyton and invertebrate communities in Go Creek are anticipated during closure.

Tributaries along the Access Road

The access road to the Robert Campbell Highway will be maintained at the request of the Kaska First Nation, so there will be no new effects associated with road closure on Pup, Pitch and Putt Creeks and tributaries of Chip and Bunker Creeks.

7.7.4.4 Closure

The mine closure plan is described in Section 3.4 and project effects on surface water and sediment quality are described in Section 7.5.

Wolverine Creek

Groundwater recharge after closure of the mine may eventually have an effect on metal levels, and hence on periphyton and benthic invertebrates in Wolverine Creek (Section 7.6: Groundwater). After groundwater fills the underground areas (up to five years), it may seep into Wolverine Creek and lead to elevated levels of zinc in the creek and possibly in Little Wolverine Lake, over an indefinite period of time (Section 2.4: Rock Characterization). Based on humidity cell tests conducted in 1996, levels of other metals of concern were reported at less than analytical detection limits; however these detection limits were 10-100 times higher than CCME guidelines for protection of aquatic life, so cannot be assumed to be adequately characterized in terms of effects on aquatic life. Humidity cell tests currently being conducted for characterization of ARD and metal leaching effects will be analyzed using detection limits appropriate to comparison with CCME guidelines and will be reported in an addendum report in early 2006 (Section 2.4). This information can be used to re-assess potential effects on benthic communities.

Benthic organisms in Wolverine are already adapted to high levels of cadmium, selenium and zinc, which currently exceed CCME guidelines. The likelihood of a measurable adverse effect on surface water quality and benthic communities in Wolverine Creek is unknown and can be assessed, in part, during monitoring of groundwater quality when portions of the mine are decommissioned during operations. Post-closure monitoring is recommended for Wolverine Creek to assess effectiveness of adaptive management measures to control groundwater quality. As a result, the effect of discharge of potentially contaminated groundwater on receiving water or sediment of Wolverine Creek or Little Wolverine Lake has been rated as not significant, based on characterization as adverse, low to moderate magnitude, local extent, far future in duration and ultimately reversible (Section 7.6: Groundwater).

Go Creek

At closure the quality of tailings pond supernatant will not cause a change in the quality of Go Creek beyond the natural variability established over the period of baseline monitoring, as discussed above for the decommissioning phase. Accordingly there will be no further effects of the project on Go Creek at closure.

The tailings pond itself is unlikely to form suitable habitat for benthic organisms, given the lack of organic matter in the tailings to provide food for invertebrates. Although metal levels in the supernatant will stabilize at levels below site specific water quality objectives, it is likely that levels in the tailings will remain elevated enough to discourage growth of algae and benthic organisms. As a result, the likelihood for bio-accumulation of metals by aquatic plants and invertebrates in the tailings pond and their eventual consumption by birds and other wildlife would be small, and are not considered to be a potential adverse effect of the project. Additional design considerations, such as steep banks and shorelines unsuitable for plant growth in littoral areas, will also discourage bird populations from using the pond as habitat. A monitoring program for phytoplankton, benthic invertebrates and vegetation can be conducted during closure (i.e., five years after operations cease) to assess colonization potential of the tailings, with additional management strategies put in place to discourage bird usage, if needed.

7.7.4.5 Residual Project Effects and Significance

Culvert Installation on Access Road

Disturbance of streambeds during the growing season will have unavoidable residual effects on benthic habitat and productivity of periphyton and invertebrates, essentially removing them from the affected reaches. This effect will be noticeable primarily in headwaters of tributaries to Go, Money and Light Creeks. From an ecological perspective, the main concern is reduction in productive capacity of streams and food supply for fish using the affected stream basins in a maximum 100 m length of each stream and considering a 10 m wide road allowance. With the exception of Bunker and Light Creeks, stream crossings will be in areas where fish have not been reported, so the main concern relates to contributions to downstream fish habitat and food supply (see Section 7.8). The 1996 benthic invertebrate survey indicates that Go and Money Creeks contain typical insect taxa that provide fish food. Benthic productivity will be further characterized in the addendum report to be submitted in early 2006.

Accordingly, effects of culvert installation on benthic invertebrate and periphyton communities during construction are predicted to be moderate magnitude, site specific, short-term, low frequency, reversible and highly likely to occur. During operations, benthic communities will re-establish in restored substrates of the countersunk or inset culverts, so the reduction in benthic productivity in general and downstream fish habitat is predicted to be low magnitude, site specific and long term. It is expected that the road will remain, at the request of the Kaska; therefore, no incremental effects on benthic communities are predicted during decommissioning or closure. As a result, the effects of reduced benthic productivity will persist for as long as the culverts remain in place, and are predicted to be of low magnitude, site specific and far future.

The adverse effects of access road construction on benthic habitat and communities are expected to be not significant, throughout all phases of the project and at closure, with a high likelihood of effects occurring as predicted.

Effluent Discharge to Go Creek

During operations, residual effects on benthic communities are expected to be limited to those related to metals in stream water and sediments in Go Creek between the water treatment plant discharge and the compliance point for site specific water quality objectives at Site W12. Section 7.5 discusses effects of discharged effluent on water quality. Dilution in Go Creek will be adequate for most metals, which reduces the magnitude of most potential effects to a low level in that section of stream. A water treatment system will be used to reduce levels of ammonia, cadmium and selenium to meet site specific water quality objectives in Go Creek downstream of W12; however, elevated levels of these substances may have an adverse effect in the 7 km section between the discharge and W12. No adverse effects on benthic communities are anticipated downstream of W12, given that metal levels will remain below site specific water quality objectives.

Treated effluent can also contain nitrogenous compounds (from blasting residues), which stimulate periphyton growth, and suspended solids, which reduce benthic habitat quality (smothering, reduced oxygen transport) or damage organisms (e.g., abrasion of gills). There is a high likelihood that nitrate and ammonia levels in discharged effluent will result in increased periphyton growth throughout Go Creek, with attendant changes to benthic invertebrate populations. Given the current low productivity in Go Creek, nutrient enrichment may be a positive rather than adverse effect.

There may be potential for localized accumulation of metals in erosional or depositional sediment within the affected reach, with potential for uptake in periphyton and benthos, although this is considered unlikely due to the annual freshet, which will mobilize and disperse stream sediments. From an ecological perspective, elevated metals in benthic invertebrates that drift downstream into fish-bearing reaches could contribute to bioaccumulation of metals in fish, although the likelihood of this is low, given the intervening areas of beaver pond and riffle habitat. Follow-up monitoring of metals in sediment and fish tissue are recommended to check predictions and improve mitigation, if necessary.

Baseline water chemistry in Go Creek and other area streams is described in Section 7.5.2. Go and Money Creeks are low in hardness, slightly alkaline in pH, and generally low in nutrients. Metal levels are within CCME guidelines, with few, relatively small exceptions for copper and iron. There is less confidence in cadmium levels, given historic difficulties achieving the low detection limits needed for comparison with the CCME guideline. Lower detection limits (<0.000017 to <0.00005 mg/L) used in the 2005 studies showed cadmium exceeding the CCME guideline in some samples, with levels of up to 0.000047 mg/L, suggesting there may be difficulties determining whether future effects are related to background or mine-related releases of cadmium.

Given that the likelihood of potential effects is unknown, YZC will be required to monitor effluent and the receiving environment using an EEM program, under MMER. Benthic invertebrate and fish communities will be monitored on a multi-year cycle to provide data about effectiveness of the water management plan and environmental effects of discharges on the benthic community of Go Creek, and will guide decisions on mine practices and monitoring requirements.

At mine closure, the tailings facility will be maintained with a water layer over the tailings. Supernatant water will be monitored and treated before discharge, if needed, during at least the first five years. As a result, the likelihood of adverse effects of metals discharge on benthic communities is considered to be low.

The adverse effects of effluent discharge on benthic habitat, community composition and productivity are expected to be not significant, throughout all phases of the project and at closure, although the likelihood of these effects is not clear and will be subject to monitoring.

Flow Regime Changes in Go Creek

Small changes to flow regimes of Go Creek are anticipated (Section 7.4: Surface Water Hydrology) as a result of diversion of surface runoff and discharge of treated effluent to Go Creek. The largest diversion will occur during the construction phase, when flows from Go Creek are diverted to fill the tailings facility during freshet (May through mid-July). Although changes may be localized, they will be long term in duration. No fish have been reported for either Wolverine or upper Go Creek (Section 7.8), so the broader ecological effect of changes to flow regimes is considered not significant.

The adverse effects of effluent discharge on benthic habitat, community composition and productivity are expected to be not significant, throughout all phases of the project and at closure. The likelihood of effects occurring as predicted is high.

7.7.5 Cumulative Effects

The only other development in the RSA that could affect benthic communities is the Robert Campbell Highway. The highway crosses Money Creek more than 25 km downstream of the project area and 15 km downstream of the closest project access road crossing, and crosses Light Creek at least 4 km downstream of the closest access road crossing. Cumulative effects could potentially arise from introduction of pollutants to these streams from road accidents, spills and maintenance (sediment or salt introductions from road drainage).

As noted above, residual project effects on benthic habitat and communities in the Money and Light Creek basins are all expected to be site specific or local in extent with no likelihood of overlap with effects from the Robert Campbell Highway. Localized residual effects of the project on benthic communities are expected to be not significant, and will not affect the overall ecological health of the streams or the fish that use them. Effects of contaminants from the Robert Campbell Highway could potentially influence the lower 1 km of these streams. Effects on benthic communities would vary depending on the nature and volume of contaminants introduced, the season of occurrence and ecological importance of these reaches to fish production at the time. Effects could vary from not significant to significant. Any contribution of project related effects to cumulative effects arising from the Robert Campbell Highway are expected to be not significant.

Potential effects of metals inputs from groundwater recharge into Wolverine Creek and Little Wolverine Lake following mine closure are a regional concern, given the valued fish populations in Wolverine and Little Wolverine Lakes. These effects are addressed above in Section 7.5.5, and rated as not significant

There is potential for unanticipated effects on algae and invertebrate communities of Wolverine Lake or Little Wolverine Lake, should metals be accidentally discharged into Wolverine Creek. Wolverine Lake is considered a valuable fish-bearing lake. The likelihood of this is considered low, given the emphasis in the Water Management Plan on protecting that watershed.

Plans for regional, government-based plans to monitor locations for cumulative effects have not been identified. Zooplankton and lake benthos data collected for Wolverine and Little Wolverine Lakes and benthic invertebrate data collected at sites along the access road will provide baseline information should such a program be developed.

7.7.6 Mitigation Measures

Mitigation measures are described in Table 7.7-12.

7.7.7 Monitoring and Follow-up

Follow-up Studies

Recommendations for follow-up baseline studies to improve predictive confidence or the database for effects monitoring purposes will be made when all data for the 2005 field program are reviewed (addendum report to be submitted in early 2006). At this point, it is felt that the 2005 baseline study will provide relevant data for benthic invertebrates and periphyton, as samples were collected from natural substrates at an ecologically relevant time of year (September) and at suitable locations within the Regional Study Area.

Table 7.7-12 Mitigation Measures for Effects on Periphyton and Benthos

Potential Project Effect	Mitigation Measures
Construction	
Changes in water and sediment quality in Wolverine and Go Creeks from contaminated construction site runoff, waste rock storage, ore stockpiles	• Implement erosion and sediment control plan (Section 9: Environmental Management Plan) and water management plan (Section 2.9: Site Water Management) to ensure no contaminated drainage water enters Wolverine Creek and all drainage is treated prior to discharge to Go Creeks
Minesite and road right-of-way clearing causing loss of riparian vegetation and increased sediment input to Go and Wolverine Creeks	• Locate buildings, tanks & facilities outside Riparian Management Area (RMA, 20-70 m buffer along affected streams) • Minimize vegetation removal and soil disturbance within RMA • Implement erosion and sediment control plan and water management plan (Section 9.2) to ensure no sediment laden water enters Wolverine or Go Creeks • Revegetate disturbed areas as soon as possible
Sediment inputs during construction of stream crossings (culvert installations) on access road in Upper Go, Hawkowl, Pup, Chip, Bunker, Putt and Light Creeks	• Observe instream construction windows • Implement erosion and sediment control plan (Section 9.2) • Restore streambed to pre-construction status • Adhere to appropriate guidance documents for work around watercourses such as the British Columbia Standards and Best Practices for Instream Works: Stream Crossings (MWLAP 2004) • Revegetate cleared stream banks with native flora
Loss of benthic habitat during and after culvert installation	• Use countersunk or inset culverts wherever possible
Operations	
Changes in Go Creek flow regime related to mine dewatering and diversions, affecting dilution capacity in affected stream reaches	• Implement Approved Water Management Plan, based on approvals from federal and territorial government regarding flow conditions in Go Creek
Changes in water and sediment quality from tailings facility seepage to Go Creek (metals TSS, nutrients, SO_4)	• Intercept seepage in collection pond, and recycle back to tailings and process water balance. Ultimate discharge to Go Creek will be via water treatment plant • Monitor effluent and receiving water quality and initiate adaptive management as required
Changes in water and sediment quality in Go Creek from treatment plant effluent discharges (metals, TSS, nutrients, SO_4)	• Ensure adequate treatment and effluent quality to meet site specific water quality objectives for protection of aquatic life 2.5 km upstream of W12 • Discharge wastewater in accordance with Yukon and Federal regulations • Monitor effluent and receiving water quality and initiate adaptive management as required
Accumulation of metals (Se) in sediment of Go Creek with increased potential for bioaccumulation	• Monitor water and sediment concentrations in Go Creek. If results indicate increasing trend initiate collection of benthic invertebrates and fish (sculpin) for tissue metals analysis • Apply adaptive management measures if necessary (enhanced effluent treatment)
Introduction of sediment and other road runoff contaminants into Upper Go, Hawkowl, Pup, Chip, Bunker, Putt and Light Creeks	• Reclaim/revegetate disturbed areas in riparian zones • Implement sediment and erosion control plan (Section 9.2)
Decommissioning	
Changes in water and sediment quality in Wolverine and Go Creeks from site runoff where facilities have been removed and/or the ground recontoured	• Implement erosion and sediment control plan (Section 9.2) and water management plan (Section 2.9) to ensure no contaminated drainage water enters Wolverine Creek and all drainage is treated prior to discharge to Go Creek • Reseeding of recontoured areas as soon as possible

Table 7.7-12 Mitigation Measures for Effects on Periphyton and Benthos (cont'd)

Potential Project Effect	Mitigation Measures
Changes in water and sediment quality in Go Creek from tailings water treatment and effluent discharges (metals, TSS, nutrients, SO_4)	• Ensure adequate treatment and effluent quality to meet CCME guidelines for protection of aquatic life 2.5 km upstream of W12 • Discharge wastewater in accordance with Yukon and Federal regulations • Monitor effluent and receiving water quality and initiate adaptive management as required
Closure	
Changes in water and sediment quality of Go Creek from ongoing tailings storage	• Adhere to the mine closure plan • Testing and treatment during decommissioning will confirm effectiveness of management • Maintain water cover over the disposed tailings as designed
Changes in water quality (Cd, Se, Zn) of Wolverine Creek related to groundwater discharge affected by underground mine backfill	• Follow the mine closure plan • Monitor groundwater in backfilled areas during operation, refine hydrogeological model and apply adaptive management if required
Potential Cumulative Effect	**Mitigation Measures**
All Phases	
Introduction of sediment at multiple road crossings, long-distance transport of metals from effluent discharge, and potential introduction of sediment or contaminants from Robert Campbell Highway affecting Money and Light Creeks.	• Mitigation measures for project-related effects will ensure effects on water and sediment quality are localized and minimize the potential for cumulative effects

Monitoring Programs

Monitoring programs are summarized in Table 7.7-13 and will be implemented by YZC. The main monitoring program identified to determine project effects on benthic communities from construction, operation and closure phases or cumulative effects will be the EEM program required under MMER. Periphyton monitoring should be conducted concurrent with the EEM program, to provide further description of ecological health.

Construction monitoring for release of sediment (TSS) to streams will be conducted as part of the sediment and erosion control program (Section 9: Environmental Management Plan) during facility and access road construction, to monitor effectiveness of mitigation measures.

Go Creek flows will be monitored to assess predicted effects of hydrologic changes. Monitoring of metal levels, particularly selenium, in sediment (depositional areas) and, perhaps, in benthic invertebrate tissue is also recommended.

Table 7.7-13 Monitoring and Follow-up Programs for Periphyton and Benthos

Potential Project Effect	Program Objectives	General Methods	Reporting	Implement-ation
Follow-up Programs				
None				
Monitoring Programs				
Construction monitoring for sediments	• To confirm effectiveness of mitigation measures, and to address compliance issues immediately	• Monitor TSS at settling basins and in receiving waters according to EPP schedule	• YTG as required	• Proponent
Effects of treatment plant effluent discharge on benthic invertebrates	• To identify effects of metals and nutrients	• EEM program conducted on 3-year cycle following EEM methods	• Reporting schedule according to MMER	• Proponent
Effects of effluent discharges on periphyton	• To provide supporting environmental information for EEM studies and ecological health indicator	• Concurrent with EEM program, periphyton collection from natural substrates (same methods as baseline study)	• Reporting schedule according to MMER	• Proponent
Accumulation of selenium and other metals in depositional habitat	• To check potential for bioaccumulation. As needed, initiate contingency plans to address unexpected effects	• Concurrent with EEM program on three-year cycle • Initiate benthic invertebrate or fish tissue sampling based on results of sediment analysis	• YTG as required • Reporting schedule according to MMER	• Proponent
Ability of tailings pond to support aquatic life	• To identify potential for bioaccumulation of metals in birds and wildlife	• Assess phytoplankton, invertebrates and plants in tailings pond at closure	• YTG as required	• Proponent

7.7.8 Summary of Effects

Project and cumulative effects are summarized in Table 7.7-14.

Table 7.7-14 Summary of Effects on Periphyton and Benthic Invertebrates

Potential Effect	Level of Effect[1]						Effect Rating[2]	
	Direc-tion	Magni-tude	Extent	Duration/ Frequency	Reversi-bility	Likeli-hood	Project Effect	Cumulative Effect
Construction								
Altered benthic communities resulting from changes in water and sediment quality in Wolverine and Go Creeks from contaminated construction site runoff, waste rock storage, ore stockpiles, culvert installations	Adverse	Low	Site-specific	Short term, Moderate frequency	Reversible	Unknown	Not significant	N/A
Reduced wetted habitat and benthic productivity in Wolverine Creek resulting from flow changes related to mine dewatering	Adverse	Low	Site-specific	Long term, Moderate frequency	Reversible	High	Not significant	N/A
Reduced wetted habitat and benthic productivity in Go Creek resulting from flow diversion to tailings facility	Adverse	Low	Site-specific	Short term, Moderate frequency	Reversible	High	Not significant	N/A
Reduced benthic productivity resulting from minesite and road right-of-way clearing loss of riparian vegetation and increased sediment input to Go and Wolverine Creeks	Adverse	Low	Site-specific	Long term, Moderate frequency	Reversible	High	Not significant	N/A
Loss of benthic habitat from installation of culverts on access road in Upper Go, Hawkowl, Pup, Chip, Bunker, Pitch and Light Creeks	Adverse	Low	Site-specific (less than 20 m per culvert)	Far future, Moderate frequency	Reversible	High	Not significant	N/A
Operations								
Reduced wetted habitat and benthic productivity in Go Creek resulting from flow diversion to tailings facility	Adverse	Low	Site-specific	Short term, Moderate frequency	Reversible	High	Not significant	N/A
Altered benthic communities in Go Creek from treatment plant effluent discharges (metals, TSS)	Adverse	Low	Local	Long term, Moderate frequency	Reversible	Unknown	Not significant	N/A
Increased benthic productivity in Go Creek from nitrate and ammonia in effluent discharges	Positive or Adverse	Low to Moderat e	Local	Medium term, moderate frequency	Reversible	Unknown	Not significant	N/A
Accumulation of Se in Go Creek sediment with increased potential for bioaccumulation in benthic communities and higher trophic levels	Adverse	Low	Site-specific	Long term	Reversible	Unknown	Not significant	N/A

Table 7.7-14 Summary of Effects on Periphyton and Benthic Invertebrates (cont'd)

Potential Effect	Level of Effect[1]						Effect Rating[2]	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Reduced benthic productivity resulting from introduction of sediment and other road runoff contaminants into Upper Go, Hawkowl, Pup, Chip, Bunker and Light Creeks	Adverse	Low	Site-specific	Long term	Reversible	High	Not significant	N/A
Decommissioning								
Reduced benthic productivity in Wolverine and Go Creeks resulting from changes in water quality from site runoff where facilities have been removed and/or the ground recontoured	Adverse	Low	Site-specific	Short term	Reversible	High	Not significant	N/A
Reduced benthic productivity in Go Creek resulting from changes in water quality related to tailings water treatment and discharges (metals, nutrients)	Adverse	Low	Site-specific	Medium term	Reversible	High	Not significant	N/A
Closure								
Reduced benthic productivity in Go Creek resulting from changes in water and quality related to ongoing tailings pond supernatant discharge	Adverse	Low	Site-specific	Far future	Reversible	Unknown	Not significant	N/A
Uptake of metals by invertebrates in the tailings pond, and their consumption by birds and other wildlife	Adverse	Low	Site-specific	Far future	Reversible	Unknown	Not significant	N/A
Reduced benthic productivity in Wolverine Creek resulting from elevated cadmium, selenium or zinc levels related to recharge of groundwater	Adverse	Low	Site-specific	Far future	Reversible	Unknown	Not significant	N/A

Notes:
1. Based on criteria in Table 7.5-11
2. Based on criteria in Section 7.5.7
N/A = not applicable