7.7 Benthos, Periphyton and Sediment Quality

As part of the environmental baseline studies, natural background metal concentrations in sediments and benthic communities were determined as high metal concentrations are common in mineralized areas. Analysis of benthic invertebrates is typically conducted to determine longer term, sub-lethal impacts that may not be apparent using standard water quality monitoring programs. Establishing background concentrations is essential to ensure that the impact of mine development will be assessed properly.

Sediment quality and benthic communities were assessed in 2006, 2007 and 2008 at the Minago Property according to Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring (Environment Canada, 2002b). In 2006, Wardrop collected five (5) replicate sediment samples from Oakley Creek (at OCW-1, OCW-2, OCW-3) and Minago River (at MRW-1), identified all organisms in each sample to family, and calculated the Simpson's Index of Diversity, Evenness,Taxon Richness, and the Bray-Curtis distance (Table 7.7-1 and Figure 7.7-1) (Wardrop, 2007). URS conducted a stream sediment and benthic invertebrate sampling program at nine locations in the vicinity of the Minago Project in 2007 (URS, 2008h). The analysis of benthic invertebrate communities was conducted using a variety of biological indices and statistics to evaluate the difference between sampling sites and between populations as well as the general quality of the aquatic habitat. In 2008, Roche collected sediment samples from six (6) stations (Cross Lake (CLF1), Hill Lake (HLF1), Limestone Bay (LBF1), Minago River (MRF3), William River (WRF3) and Oakley Creek (OCF1)) (Table 7.7-1 and Figure 7.7-1) (Roche, 2008a). They collected benthic samples from the same locations, except from HLF1 and measured key parameters related to invertebrate habitats.

7.7.1 Relevant Guidelines

Relevant sediment guidelines for the Minago Project include the *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life* (CCME, 2002). The intent and application of these guidelines are summarized below, but detailed guideline concentration limits are presented as part of the discussion of sediment quality results.

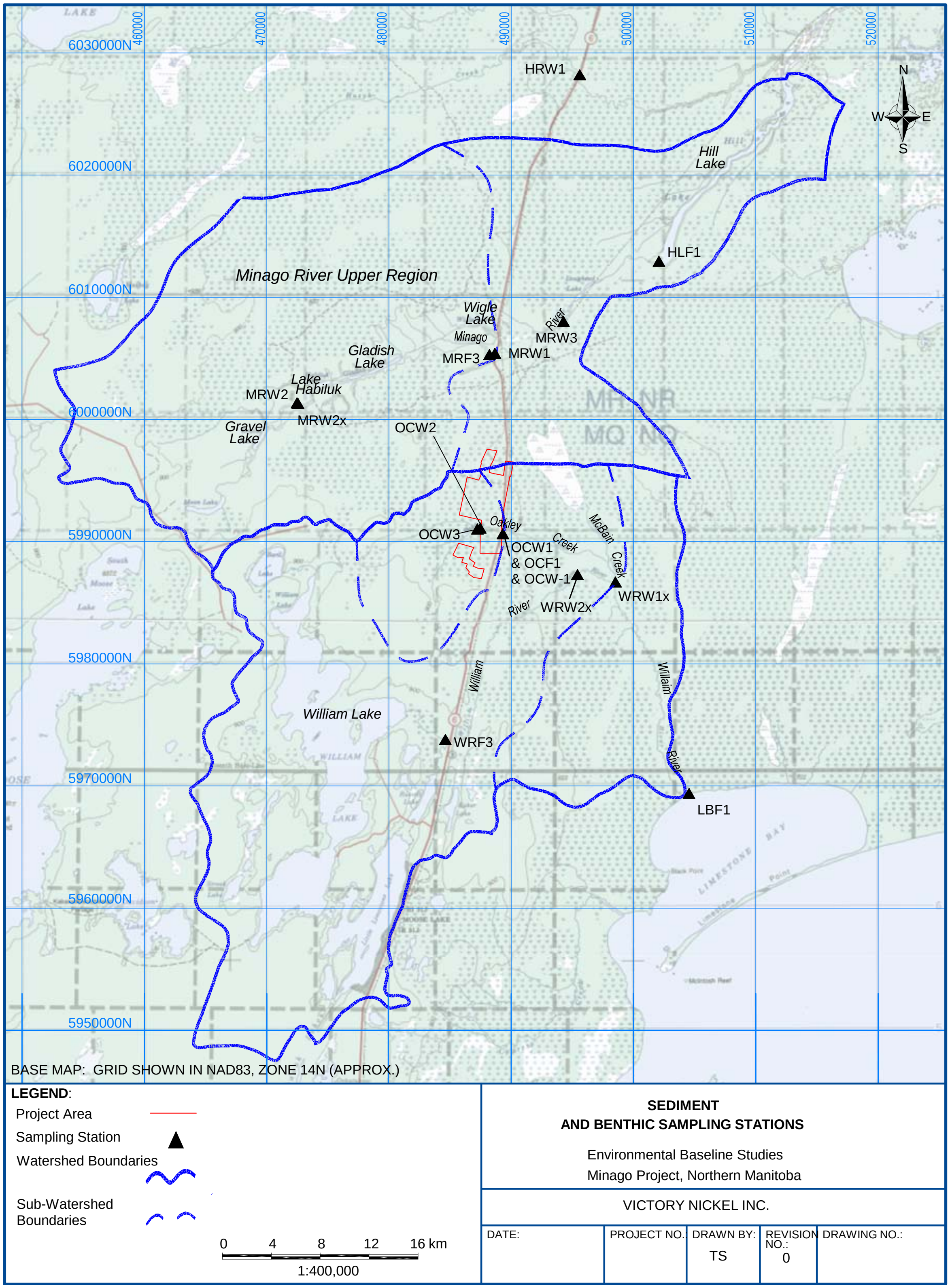
7.7.1.1 Canadian Sediment Quality Guidelines for the Protection of Aquatic Life

The *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life*, which includes the Interim Freshwater Quality Guidelines (ISQGs) and the Probable Effect Levels (PELs), provide a flexible interpretive tool for evaluating the toxicological significance of sediment chemistry data, as well as for prioritizing actions and management decisions (CCME, 2002). Sediment chemical concentrations below the Sediment Quality Guidelines are not expected to be associated with any adverse biological effects; however, concentrations above the probable effect levels are expected to be frequently associated with adverse biological effects. Chemical concentrations between the Sediment Quality Guidelines and probable effect levels represent the range in which effects are

Table 7.7-1 Nomenclature and Coordinates of Sediment and Benthic Invertebrates Monitoring Stations

Sample Location	UTM Northing	UTM Easting	Description	Sampled by:		
				Wardrop (2007)	URS (2008h)	Roche (2008a)
OCW-1	5990528	489238	Oakley Creek immediately east of HW6	X		
OCW1, OCF1	5990510	489322	Oakley Creek east of HW6		X	X
OCW-2 & OCW2	5990974	487559	Approx. 2.2 km upstream of OCW-1	X	X	
OCW-3	5990931	487048	Oakley Creek upstream of confluence of tributary	X		
OCW3	5990892	487230	Oakley Creek upstream of confluence of north tributary		X	
MRW-1 & MRW1	6005275	488684	Minago River at the Highway 6 crossing, approximately 15 km north of Oakley Creek.	X	X	
MRW2	6001212	472476	Minago River near Habiluk Lake		X	
MRW3	6007895	494274	Minago River downstream of Highway 6 near powerline cut		X	
MRF3	6005308	488362	Minago River location upstream of Highway 6			X
HRW1	6028072	495606	Hargrave River immediately west of Highway 6		X	
WRW1x (formerly WRW2)	5986554	498523	William River approx. 100 m downstream of the Oakley Creek confluence		X	
WRW2x (formerly WRW1)	5987162	495416	William River approx. 6 km upstream of the Oakley Creek confluence		X	
WRF3	5973598	484762	William River immediately downstream of Little Limestone Lake outlet stream.			X
CLF1	6046198	555324	Cross Lake			X
HLF1	6012816	502060	Hill Lake			X
LBF1	5969136	503911	Limestone Bay			X

Source: Wardrop, 2007; URS, 2008h; Roche, 2008a



Source: adapted from URS, 2008h

Figure 7.7-1 Monitoring Locations for Sediments and Benthic Communities

occasionally observed. These two values provide practical means to characterize sites as of minimal, potential, or significant toxicological concern in order to focus further investigations.

The guidelines should not be regarded as blanket values for national sediment quality. Variations in environmental conditions across Canada will affect sediment quality in different ways and many of the guidelines may need to be modified according to local conditions such as assimilative capacity, sensitivity of endangered species and habitat (CCME, 2002).

7.7.2 Scope of Assessment

7.7.2.1 Scope and Methodology of 2006 Sediment and Benthic Invertebrates Assessments

In 2006, Wardrop collected bulk sediment samples at stations OCW-1, OCW-2, and OCW-3 using a stainless steel Ekman dredge (15.2 cm x 15.2 cm mouth size, 22.9 cm tall) (Table 7.7-1) (Wardrop, 2007). Samples for chemical analysis were taken from the bulk sediment samples using a 5 cm diameter cellulose-acetate-butyrate (CAB) core tube pressed 5 cm into the sediment in the dredge. Up to three core sub-samples were taken from each bulk dredge sample, with a total of eight core sub-samples taken and pooled to comprise a replicate sample for analysis. Five of these replicate samples were collected per station. The samples were kept refrigerated or on ice from the time of collection until delivery to Maxxam Analytics (Calgary, AB). Sediments were analyzed for total metals, moisture content, organic matter, total organic carbon, and hot water soluble boron.

Wardrop also collected five replicate sediment samples for benthic assessments at stations OCW-1, OCW-2, OCW-3 and MRW-1 using a stainless steel Ekman dredge (Table 7.7-1) (Wardrop, 2007). Samples were field-sieved using a 500-µm mesh-size screen to remove sediment. The retained organisms were transferred to a polyethylene zipper lock bag and preserved in 10% buffered formalin. Samples were sent to the ALS Laboratory Group in Winnipeg for analysis. All organisms in each sample were identified and counted. Organisms were typically identified to family, with the following exceptions:

- Hydracarina, Copepoda and Araneae were identified to order; and,
- Nematoda were identified to phylum.

Specimens damaged during sampling were identified to the nearest possible taxonomic level. The Simpson's Index of Diversity, Evenness, Taxon Richness, and the Bray-Curtis distance were calculated according to methods detailed in Environment Canada (2002b).

7.7.2.2 Scope and Methodology of 2007 Sediment and Benthic Invertebrates Assessments

In 2007, URS conducted a stream sediment and benthic invertebrate sampling program at nine locations in the vicinity of the Minago Project from August 13 to 16, 2007 (URS, 2008h). The overall scope of work for that program involved the following tasks:

- establishing pre-mining disturbance baseline conditions of existing stream sediment quality and benthic communities;
- establishing sediment quality and benthic invertebrate baseline condition for monitoring in future years during mine development and operation to assess potential impacts on the aquatic environment.

The analysis of benthic invertebrate communities was conducted using a variety of biological indices and statistics to evaluate the difference between sampling sites and between populations as well as the general quality of the aquatic habitat.

Field Methods:

From August 13 to 16, 2007, URS collected one sediment and three replicate benthic invertebrate samples at each of the nine sampling locations using a Ponar sediment sampler that had a sampling area of 0.02 m^2. To distinguish natural versus human influence, invertebrate samples were also collected at a reference site (HRW1 on Hargrave River) north of the project area (Table 7.7-1). Sampling methodology was based on the 'Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring' (Environment Canada, 2002b) and the field manual, entitled 'Field Guidelines - Benthic Sampling Protocol, Integrated Resources Consultants (IRC)', dated July 2007 and given in Appendix 7.7.

The monitoring sites are given below and more details are provided in Table 7.7-1:

- William River: WRW1X (downstream site), WRW2X (upstream site);
- Oakley Creek: OCW1 (downstream site), OCW2 (upstream site), OCW3 (upstream site);
- Minago River: MRW1 (downstream site), MRW2 (upstream site) and MRW3 (downstream site); and
- Hargrave River (Reference Site): HRW1.

Each sample was delicately transferred into 1 litre sampling containers provided by Integrated Resource Consultants Inc. (IRC) of Richmond, BC and preserved using 10% formaldehyde prior to shipping to IRC's laboratory for analysis. IRC analyzed the samples using their internal standard methods for preservation and identification. IRC tabulated benthic communities into the following taxons and their associated families: Insecta, Arachnida, Acarina, Crustacea, Annelida, Mollusca, Nematoda, and Cnidaria. Sediment samples collected during August 2007 in the Minago Project Area were submitted to ALS Laboratories in Vancouver, BC, for analysis of moisture content, pH, total metals, organic carbon and particle size.

7.7.2.3 Scope and Methodology of 2008 Sediment and Benthic Invertebrates Assessments

The main objective of Roche's 2008 sediment and benthic invertebrates assessment program was to determine the actual specific composition of the sediments and benthic community living in the freshwater system (i.e., document the presence/absence of benthic families in water bodies that will likely be affected by the Minago Project) and to determine the basic biological characteristics of the benthic community (total invertebrate density, taxonomic richness, Simpson's diversity index, Bray-Curtis distance). Moreover, the basic biological characteristics of the major taxa were documented. The objectives, methodology and results of the program are detailed in Roche (2008a).

Roche collected sediment samples with a Ponar grab and a 500 µm strainer from an area of approximately 0.05 m^2 (Roche, 2008a). Their sampling methodology was based on the 'Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring' (Environment Canada, 2002b). Collected sediment samples were stored and preserved in bottles provided by Bodycote Laboratories. Sediment samples were tested for the following parameters: total organic carbon, particle size distribution and metal content (arsenic, cadmium, chromium, cobalt, copper, iron, manganese, magnesium, mercury, molybdenum, selenium, zinc, nickel and lead).

Roche collected sediment samples from the following six (6) locations: Cross Lake (CLF1), Hill Lake (HLF1), Limestone Bay (LBF1), Minago River (MRF3), William River (WRF3) and Oakley Creek (OCF1). Roche also collected samples for benthic assessments from all of these locations with exception of Hill Lake (HLF1) (Table 7.7-1 and Figure 7.7-1).

The benthic organisms, with exception of nematodes, were fixed for at least 72 hours in a 10% formaldehyde solution and then transferred in a 70% ethanol solution for preservation until their identification was done up to the family level, at an accredited laboratory. Laboratoires SAB Inc. was in charge of the analysis of all collected benthic samples. Methods and results, including for the quality control test, are detailed in Appendix 7.7 and laboratory certified reports are given in Appendix L7.7. A reference collection was built up for consistency in taxonomic identifications between benthic assessments.

For each replicate station sampled, key parameters related to invertebrate habitats were measured according to Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring. These parameters included:

- water depth.
- water temperature;
- pH;
- type of substratum (clay, silt, sand) gravel,
- conductivity;
- dissolved oxygen;

- alkalinity;
- nutrients;
- riparian vegetation;
- turbidity;
- fine sediment particle size and total organic carbon;
- canopy cover (%).

In 2008, Roche implemented some specific measures to assess the biological characteristics of the benthic invertebrate communities. Nematodes were considered to be a distinct category as it is the case for the other families and an abundance of 1 was attributed to Spongillidae colonies.

7.7.2.4 Sediment Quality Results

7.7.2.4.1 Sediment Quality for the 2006 and 2007 Field Programs

The average sediment quality results for samples collected from watercourses surrounding the Minago Project in 2006 and 2007 are listed in Table 7.7-2. Detailed results, summarized in spreadsheet format, are given in Appendix 7.7 and detailed laboratory certified reports and quality control results are presented in Appendix L7.7.

Sediment pH levels ranged from 6.88 to 8.45 and the average pH was 7.8 (alkaline) (Wardrop, 2007). The only sediment that had a pH value less than 7 was located at OCW-3 (Table 7.7-2). In all rivers and creeks (Minago River, Oakley Creek and William River) in the Minago Project Area, the sediment pH was lowest at the upstream site and increased to the highest at the downstream site.

Average moisture content in tested sediment samples ranged from 42.4% to 82.6% (Table 7.7-2).

The organic matter content ranged from a minimum of 7.72% at OCW-1 to a maximum of 30.5% at OCW-3. The average total organic carbon (TOC) content ranged from a minimum of 4.5% at OCW-1 to a maximum of 17.7% at OCW-3 in 2006 (Table 7.7-2, Figure 7.7-2). Based on 2006 results, the ratio of organic matter to total organic carbon ranged from 1.69 to 1.8 (Wardrop, 2007).

Only total chromium exceeded the CCME (2002) Interim Freshwater Sediment Quality Guidelines (ISQGs). Average chromium levels, based on 5 replicate samples, were higher than the ISQGs level of 37.3 mg/kg at OCW-1, OCW-2, OCW-3 and MRW-1 in 2006 (Table 7.7-2 and Figure 7.7-3). In 2006, average chromium concentrations were 38.4 mg/kg at OCW-2, 39.8 mg/kg at OCW-3, 69.2 mg/kg at MRW-1, and 71 mg/kg at OCW-1 (Wardrop, 2007). In 2007, the chromium level, based on one sample per monitoring station, exceeded the ISQG at MRW2. In 2007, the chromium concentration ranged from a minimum of 9.9 mg/kg at MRW3 to a maximum of 39.2 mg/kg at MRW2 (Appendix 7.7) (URS, 2008h). It is important to note that chromium did not exceed CCME (2007) criteria for surface water quality (Section 7.5).

Table 7.7-2 Average Sediment Quality in Watercourses surrounding the Minago Project

		OCW-1		OCW-2		OCW-3		MRW-1		All 2007 Stations		REGULATIONS	
Sample ID		Average [1]	Coefficient of Variation	Average [1]	Coefficient of Variation	Average [1]	Coefficient of Variation	Average [1]	Coefficient of Variation	Average [1]	Coefficient of Variation %	Canadian Sediment Quality of Aquatic Life (CCME, 2002)	
Sampling Date		19-20 Sept 2006	19-20 Sept 2006	19-20 Sept 2006	19-20 Sept 2006	19-20 Sept 2006	19-20 Sept 2006	19-20 Sept 2006	19-20 Sept 2006	16-Aug-07	16-Aug-07		
COC Number / Lab ID			%		%		%		%			**ISQG**	**PEL**
Depth	**Units**									0-0.2 m			
Moisture	%	47.8	38%	77.5	5%	81.4	4%	82.6	7%	42.4	56%		
pH										7.8	8%		
Organic Matter	%	7.72	99%	25.3	28%	30.5	18%	21.5	25%				
Total Organic Carbon (C)	%	4.48	99%	14.7	27%	17.7	18%	12.5	25%	7.2	113%		
Soluble (Hot water) Boron (B)	mg/kg	0.4	47%	0.8	17%	1.0	13%	1.9	26%				
Elements													
Total Aluminum (Al)	mg/kg	15,498	31%	3,970	14%	4,252	22%	12,050	32%				
Total Antimony (Sb)	mg/kg	0.5	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0%		
Total Arsenic (As)	mg/kg	2.8	53%	0.7	39%	1.4	39%	2.8	39%	2.5	0%	**5.9**	**17**
Total Barium (Ba)	mg/kg	131	21%	61	9%	94	21%	112	34%	74.5	60%		
Total Beryllium (Be)	mg/kg	0.78	36%	0.2	0%	0.2	0%	0.58	49%	0.4	50%		
Total Boron (B)	mg/kg	9.4	19%	5.8	8%	9	24%	12.4	19%				
Total Cadmium (Cd)	mg/kg	0.68	32%	0.34	16%	0.4	31%	0.54	43%	0.25	0%	**0.6**	**3.5**
Total Chromium (Cr)	mg/kg	**71**	17%	**38.4**	9%	**39.8**	7%	**69.2**	17%	21.6	55%	**37.3**	**90**
Total Cobalt (Co)	mg/kg	13	30%	4	18%	5	12%	11	33%	6	62%		
Total Copper (Cu)	mg/kg	18	40%	3	0%	3	37%	14	39%	10	56%		
Total Iron (Fe)	mg/kg	17,140	25%	6,036	7%	7,954	13%	14,640	27%				
Total Lead (Pb)	mg/kg	10	32%	3	0%	4	22%	10	32%	15	0%	**35**	**91.3**
Total Lithium (Li)	mg/kg	22	31%	1	0%	1	0%	17	36%				
Total Manganese (Mn)	mg/kg	381	24%	244	30%	319	35%	294	49%				
Total Mercury (Hg)	mg/kg	0.025	0%	0.025	0%	0.13	34%	0.032	49%	0.026	74%	**0.17**	**0.486**
Total Molybdenum (Mo)	mg/kg	0.2	0%	0.2	0%	0.2	0%	0.32	51%	2	0%		
Total Nickel (Ni)	mg/kg	34	32%	8	14%	11	17%	28	32%	15	61%		
Total Phosphorus (P)	mg/kg	404	15%	313	9%	459	11%	567	27%				
Total Selenium (Se)	mg/kg	0.25	0%	0.54	50%	0.96	42%	0.25	0%	1.4	47%		
Total Silver (Ag)	mg/kg	0.5	0%	0.5	0%	0.5	0%	0.5	0%	1	0%		
Total Strontium (Sr)	mg/kg	30	33%	17	5%	23	17%	24	22%				
Total Thallium (Tl)	mg/kg	0.18	37%	0.15	0%	0.15	0%	0.15	0%	0.5	0%		
Total Tin (Sn)	mg/kg	1.2	130%	0.5	0%	0.5	0%	1.1	50%	2.5	0%		
Total Uranium (U)	mg/kg	0.8	34%	0.7	39%	2	0%	2	35%				
Total Vanadium (V)	mg/kg	45	34%	10	15%	10	20%	37	33%	23	54%		
Total Zinc (Zn)	mg/kg	67	18%	23	16%	35	22%	76	31%	32	56%	**123**	**315**

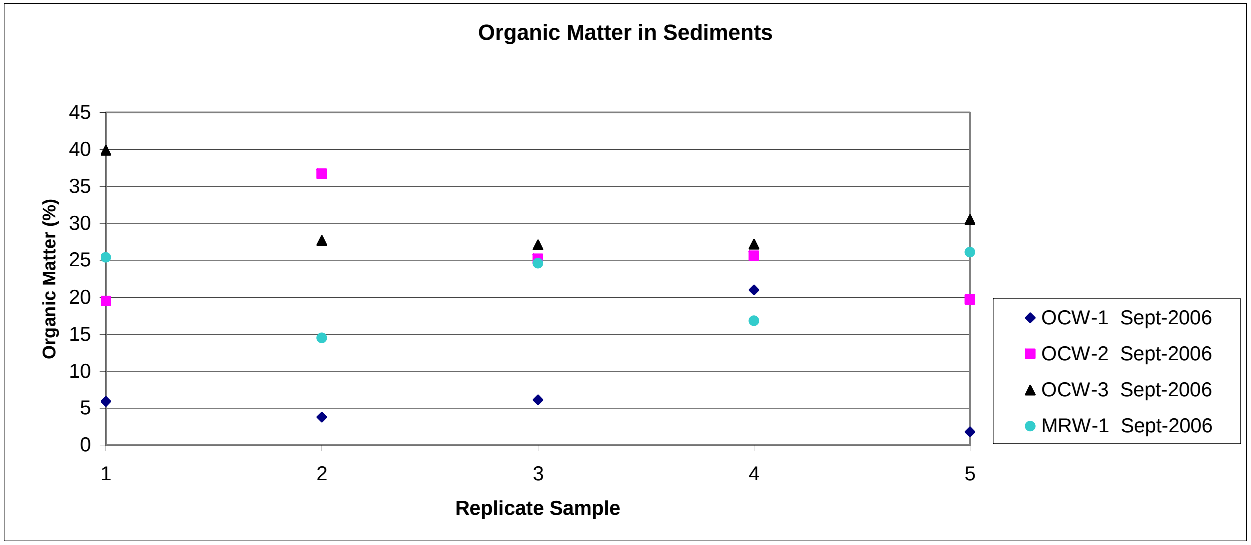
NOTES:

1 — If the sample concentration was less than the detection limit, half the detection limit was used to compute the average.

ISQG — Interim freshwater sediment quality guidelines

PEL — Probable effects levels

0.0056 — Bold and underlined number is exceeding guideline value.



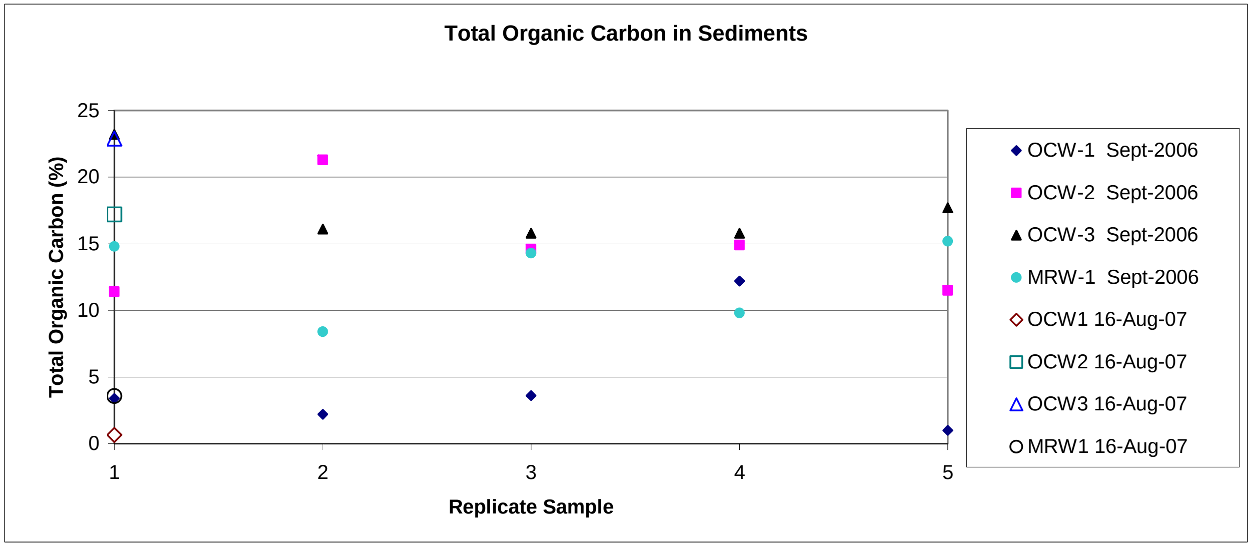


Figure 7.7-2 Organic Matter and Total Oganic Carbon in Watercourse Sediments

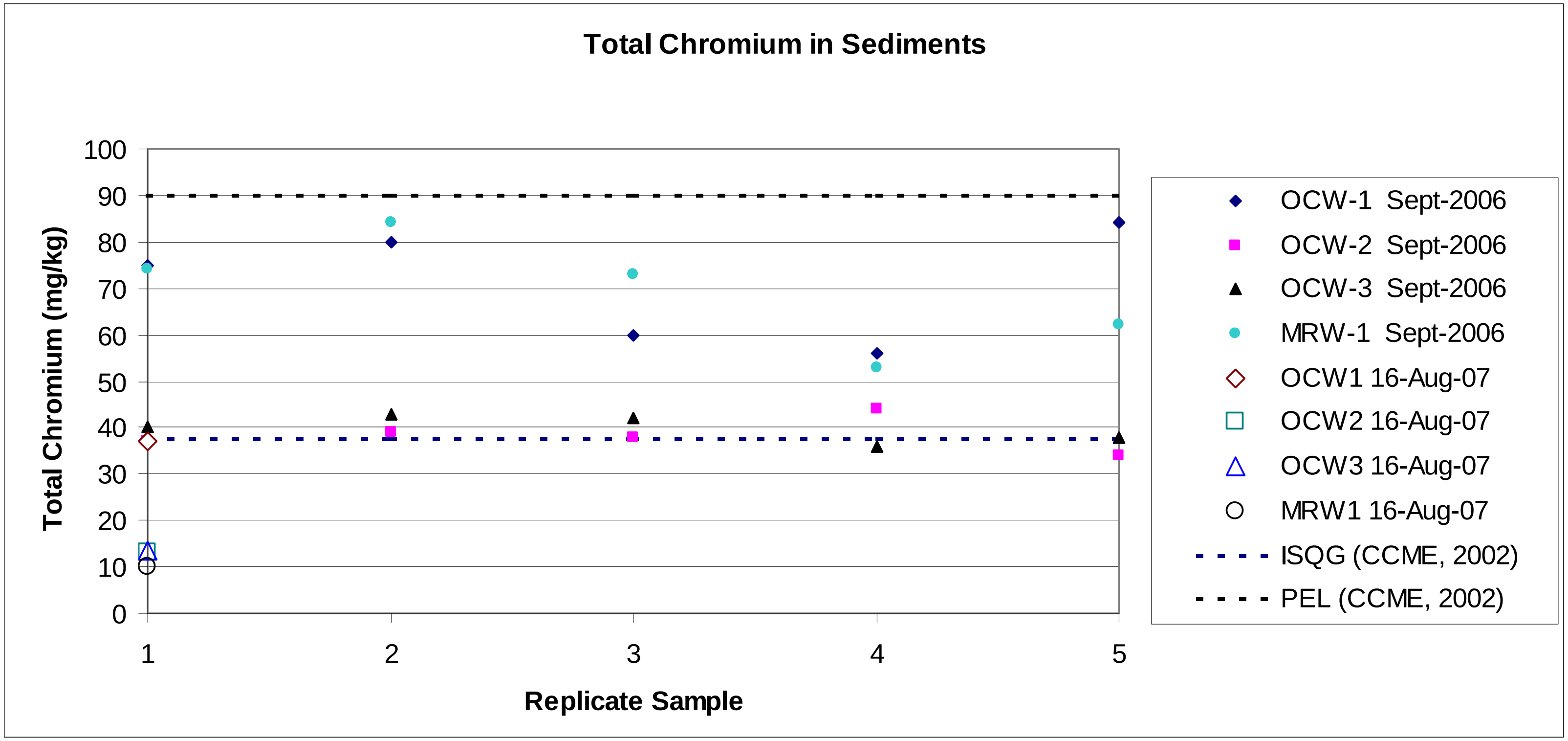


Figure 7.7-3 Total Chromium in Watercourse Sediments (mg/kg)

Chromium (Cr) is an essential trace element that can be toxic to aquatic biota at elevated concentrations. Chromium exists in two oxidation states in aquatic systems: hexavalent Cr (i.e., Cr^{6+}) and trivalent Cr (i.e., Cr^{3+}). Independent assessments of the potential for toxicity of Cr^{6+} and Cr^{3+} in the Canadian environment were carried out according to the *Canadian Environmental Protection Act* (CEPA). The CEPA assessment reported that dissolved and soluble forms of Cr^{6+} may have, a harmful effect on the environment (Government of Canada, 1994). However, for Cr^{3+}, the CEPA assessment reported that it was not possible to determine whether dissolved and soluble forms were entering the Canadian environment according to the above conditions (Government of Canada, 1994).

The majority of the data used to derive ISQGs and probable effects levels (PELs) for Cr are from studies on field-collected sediments that measured concentrations of Cr, along with concentrations of other chemicals, and associated biological effects, as compiled in the Biological Effects Database for Sediments (BEDS) (Environment Canada, 1998). In most studies that evaluated the distribution of Cr in the environment, only total Cr was measured; little information was provided on the species of Cr present in the sediment. However, results of recent studies in Canada and other countries, indicate that Cr^{6+} is the dominant form in the dissolved phase, whereas nearly all of the Cr in sediments (excluding that immediately below the sediment–water interface with overlying aerobic waters) is likely present in the form of Cr^{3+} (Government of Canada, 1994).

Concentrations of Cr in marine and freshwater sediments vary substantially across Canada (Environment Canada, 1998). In the National Geochemical Reconnaissance (NGR) program database by the Geological Survey of Canada (GSC) (Friske and Hornbrook, 1991), the mean background concentrations in lake and stream sediments are 47 mg/kg and 81 mg/kg, respectively (CCME, 1999). When compared with concentrations in the combined lake and stream NGR database (n = 51,311), the freshwater ISQG and PEL for Cr fall at percentiles 38.6 and 83, respectively, of background concentrations (CCME, 1999). Background concentrations of Cr across most of Canada are higher than the ISQG of 37.3 mg/kg. This situation may be explained in part by the different digestion methods used in deriving ISQGs and PELs versus those used in determining concentrations of metals for the NGR database.

Currently, the degree to which Cr will be bioavailable at particular sites cannot be predicted conclusively from the physicochemical characteristics of the sediments or the attributes of endemic organisms (Environment Canada, 1998).

The average aluminum concentrations in Minago sediments were 15.5 mg/kg at OCW-1, 12.1 mg/kg at MRW-1, 4 mg/kg at OCW-2, and 4.3 mg/kg at OCW-3 in 2006 (Table 7.7-2). The average iron concentrations in the sediments were 17.1 mg/kg at OCW-1, 14.6 mg/kg at MRW-1, 8 mg/kg at OCW-3 and 6 mg/kg at OCW-2.

More than 95% of the mineral fractions of examined sediments were finer than 2 mm. Only two locations, OCW1 (downstream) on Oakley Creek and MRW1 (downstream) on the Minago River, contained substrate coarser than sand (> 2 mm) (Figure 7.7-4).

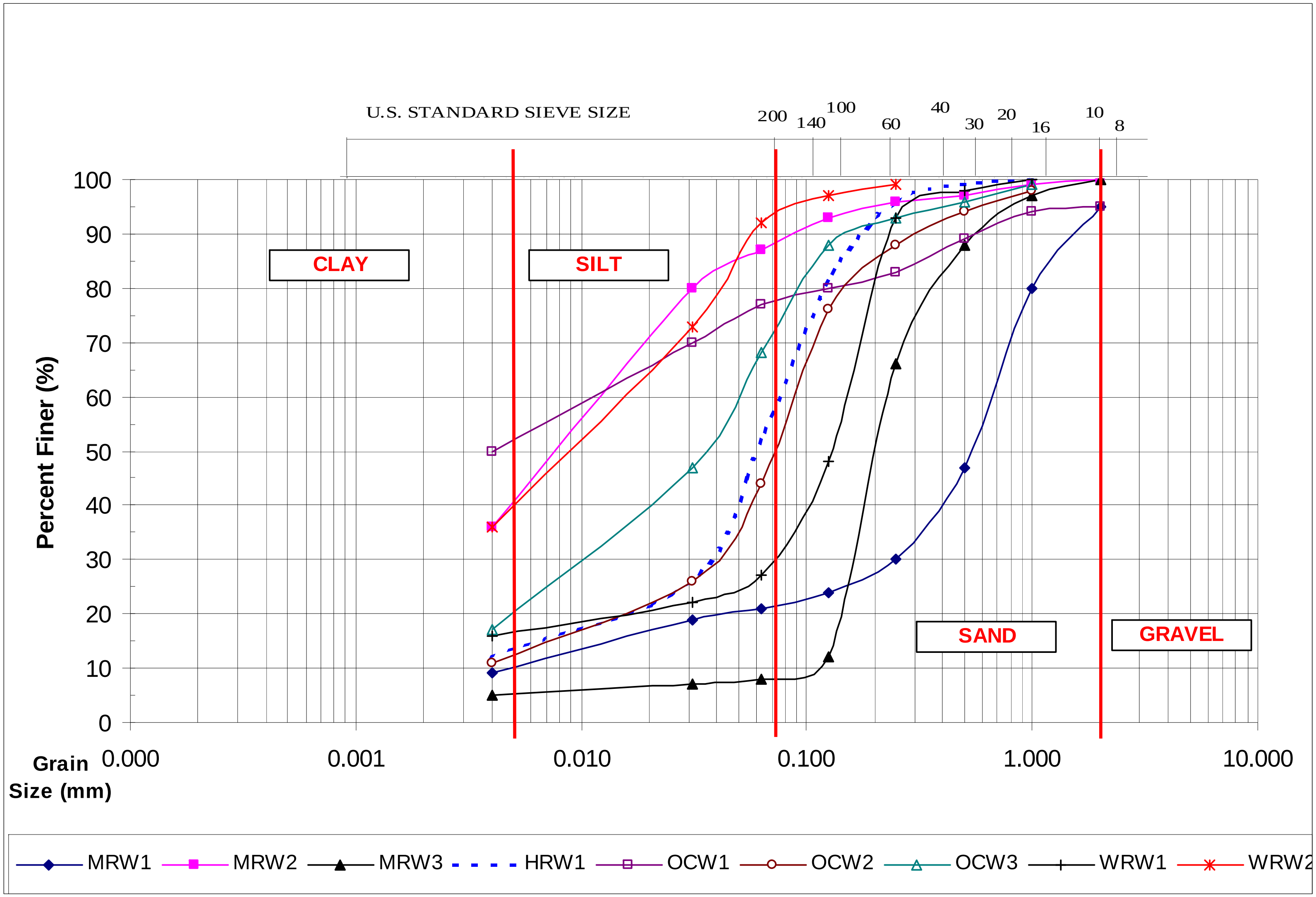


Figure 7.7-4 Particle Size Distribution of Watercourse Sediments in the Vicinity of the Minago Project

(using AASHTO classification for clay, silt, sand and gravel)

7.7.2.4.2 Sediment Quality for the 2008 Field Program

Table 7.7-3 shows key parameters of the 2008 sediment and benthic monitoring locations (Figure 7.7-1). None of the measured water quality parameters for surface water exceeded CCME (2007) criteria for the protection of aquatic life. However, at the Minago River sampling station, arsenic and chromium contents in sediments exceeded Interim Freshwater Sediments Quality Guidelines (ISQGs). In both cases, concentrations were lower than the probable effect level (PEL). At MRF3, other metals concentrations were also higher.

Total organic carbon (TOC) has a major influence on both the chemical and biological processes that take place in sediments. The amount of organic carbon influences the redox potential in sediments, thus regulating the behaviour of other chemical species such as metals. Since organic matter is a primary source of food for benthic organisms, it is important in maintaining a viable ecosystem. However, too much organic matter can lead to the depletion of oxygen in the sediments and overlying water, which can have a deleterious effect on benthic and fish communities (Hyland et al., 2000).

At Minago, TOC values were in most cases under 4% and sediment quality did not appear to be a limiting factor for the viability of benthic communities. However, in Limestone Bay and Oakley Creek, TOC concentrations ranged from 19.4 to 23.3%, indicating a possible deleterious effect on benthic invertebrates (Roche, 2008a).

7.7.3 Baseline Conditions - Benthic Invertebrates and Periphytons

The benthic invertebrate communities collected in samples for the Minago Project were enumerated using a variety of statistics and indices, detailed below, in order to assess the aquatic habitat quality, as well as to identify differences between sampling sites, and populations. The analysis of benthic invertebrate communities permits an assessment of long-term, sub-lethal effects that cannot be determined using standard water quality sampling as the sole indicator.

7.7.3.1 Biological Indices and Data Interpretation

A benthic community may be analyzed and interpreted in terms of general health using indicators of abundance and metrics of richness.

Dominance - Natural biological communities include groups of organisms that are not equally successful. This variability is a function of competition for biotic/abiotic resources in the environment. A few organisms may dominate a community with the spectrum extending to groups of intermediate abundance and, finally, to rare organisms. In order to measure the relevant abundance of biological samples a Dominance Index was proposed by Simpson in 1949. The output of the Simpson Index is used to evaluate the dominance of one taxonomic group over the rest of the population data.

Table 7.7-3 Surface Water and Sediments Quality Results for the 2008 Program

Parameters	Units	Method detection limit	Canada: Surface water quality criteria for the protection of aquatic life (CCME) [1]	Canada - CCME [2]: Sediment Quality Guidelines for the protection of aquatic life: Interim freshwater sediment quality guidelines (ISQGs)	Canada - CCME [2]: Sediment Quality Guidelines for the protection of aquatic life: Probable Effect Level (PEL)	Stations: LBF-1	Stations: OCF-1	Stations: MRF-3	Stations: WRF-3	Stations: CLF-1
Station characteristics										
Sampling site						Limestone Bay	Oakley Creek	Minago River	William River	Cross Lake
Certificate of analysis number						08-259707	08-259707	08-259707	08-259707	08-261093
Sample number			-			1184152	1184154	1184155	1184156	1188980
Sampling Date						2008-05-08	2008-05-08	2008-05-08	2008-05-08	2008-05-09
UTM (NAD 83) East						503911	489238	488362	484762	555324
UTM (NAD 83) North						5969136	5990528	6005308	5973598	6046198
***In situ* measurements (Surface water)**										
Depth of the station	meters	-	-	-	-	0.74	0.64	0.61	0.61	4.20
Sample collection depth	meters	-	-	-	-	0.74	0.64	0.61	0.61	4.20
Dissolved oxygen	mg/L	-	<5.5-9.5	-	-	12.10	10.83	10.27	10.35	11.91
Dissolved oxygen	%	-	narrative	-	-	94.8	81.1	83.2	84.8	91.7
Water temperature	°C	-	narrative	-	-	5.0	3.1	6.8	6.6	4.2
Conductivity	µS/cm	-	-	-	-	240.0	230.0	134.0	290.0	178.3
pH	pH units	-	6.5 - 9	-	-	7.98	7.65	7.53	8.27	7.85
Particle size distribution (Sediments)										
< 4 µm clay	%	-	-	-	-	2.2	14.4	24.6	2.0	25.5
4 to 60 µm silt	%	-	-	-	-	28.4	31.8	33.5	6.6	38.7
60 to 200 µm fine sand	%	-	-	-	-	58.2	23.1	16.2	13.0	24.6
200 to 2000 µm coarse sand	%	-	-	-	-	11.2	23.3	11.7	27.4	10.2
> 2000 µm gravel	%	-	-	-	-	0.0	7.4	14.0	51.0	1.0
Organic compounds (Sediments)										
Total organic carbon	%C	0.01	-	-	-	23.30	19.40	3.82	0.74	1.61
Metals and metalloids (Sediments)										
Arsenic	mg/kg	0.5	-	5.9	17	1.9	2.1	**5.9**	1.3	4.4
Cadmium	mg/kg	0.4	-	0.6	3.5	0.09	0.12	0.20	0.04	0.05
Chromium	mg/kg	2	-	37.3	90	12	27	**51**	14	37
Cobalt	mg/kg	2	-	-	-	4	9	15	5	13
Copper	mg/kg	1	-	35.7	197	5	11	23	6	16
Iron	mg/kg	10	-	-	-	6800	17000	32000	7800	24000
Lead	mg/kg	5	-	35.0	91.3	< 5	9	34	<5	11
Magnesium	mg/kg	5	-			7400	9700	24000	12000	14000
Manganese	mg/kg	1	-	-	-	200	710	830	170	560
Mercury	mg/kg	0.01	-	0.17	0.486	0.03	0.05	0.04	0.02	0.04
Molybdenum	mg/kg	2	-	-	-	< 1	< 1	< 1	< 1	< 1
Nickel	mg/kg	2	-	-	-	8	17	35	9	25
Selenium	mg/kg	0.1	-	-	-	0.3	0.5	0.3	0.1	0.1
Zinc	mg/kg	5	-	123	315	21	59	110	23	58
Total volatile solids (wet weight)	mg/kg	1000	-	-	-	87000	96000	59000	16000	-
Total volatile solids (wet weight)	%	0.1	-	-	-	8.7	9.6	5.9	1.6	-
Total volatile solids (dry weight)	mg/kg	1000	-	-	-	210000	350000	110000	19000	-
Total volatile solids (dry weight)	%	0.1	-	-	-	21.0	35.0	11.0	1.9	-

(grey box) Value does not respect the canadian guideline for the protection of aquatic life - surface water

Bold Value exceeding criteria for the protection of aquatic life - Sediments (ISQGs)

[1] Canadian Council of the Ministers of Environment. 2007. Canadian Guidelines for the Protection of Environment.

[2] Canadian Council of the Ministers of Environment. 2002. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life.

Source: adapted from Roche, 2008a

Simpson's Index – The Simpson's index depends on both the abundance and the taxonomic richness. It is calculated using the following formula:

$$D = 1 - \sum_{i=1}^{S} (p_i)^2$$

with D corresponding to Simpson's index, S being the total amount of taxa at the station and p_i being the relative abundance of the i^{th} taxa at the station.

The Simpson's index ranges from 0 to 1. A community with only one taxa would score 0 while a community showing an infinite number of taxa all being equally abundant would score 1. The maximal value which can be obtain is proportional to the amount of taxa (for example, 4 taxa with a relative abundance of 25%, D = 0.75 and 5 taxa with a relative abundance of 20%, D = 0.8). The advantage of employing this index is that it provides a single objective value describing proportionate relationships of various categories of invertebrates being considered in the analysis.

Density and Relative Abundance - For each taxa, the density was calculated using the average amount of invertebrates and the sampled area. The total density (all taxa) was also calculated for each sampling station. Taxa's relative abundance at each station may be calculated by dividing one taxa's density by the total density.

Shannon-Weaver Diversity Index - The Shannon-Weaver diversity index provides a valuable tool to evaluate community complexity, which can be expressed as equitability, evenness, or diversity of a population (URS, 2008h). The Shannon-Weaver Diversity Index is an adaptation of the communication engineering theories created by Shannon-Weaver (1949), Margalef (1958) and MacArthur (1955), which is applied to biological systems such as benthic invertebrate communities. The Shannon-Weaver function is based on the theory that the greater the source of information is, the greater the resulting variability will be.

Equitability Index – The measures of community complexity (equitability, evenness, or diversity of a population) are calculated based on how the individuals in a population are distributed between the sampled taxa and how many different taxa are found in each sample. Pielou (1966) found that increasingly equitable distribution of individuals in the taxa sampled indicates a community that is not dominated by one specific taxon and therefore indicates community stability. In general, population stability is important because complex communities can be expected to respond favourably to changes in environmental conditions over time.

Taxonomic Richness Index - The richness of a population is a measure of the variety of taxa encountered regardless of the total individuals found. The Richness Index indicates the relative wealth of a taxa or species found in a community (Peet, 1974). The Richness Index created by Margalef (1958) is considered the most appropriate measure of Richness because it includes the effect of numerical abundance in a population on its output.

Bray-Curtis Distance – The similarity of a population is a measure of how a population compares on a species by species basis with another population or a reference population. The Bray-Curtis distance has a maximum value of 1 and a minimum value of 0. A pair of communities that are mathematically identical has a Bray-Curtis distance of 0. The advantage of the Bray-Curtis distance is that it provides a single numerical evaluator that describes the similarity of two populations (URS, 2008h).

Bray-Curtis distance is calculated using the following formula (Roche, 2008a):

$$B - C = \frac{\sum_{i=1}^{n} |y_{i1} - y_{i2}|}{\sum_{i=1}^{n} (y_{i1} + y_{i2})}$$

with *B – C* representing the Bray-Curtis distance between two stations, y_{i1} being the density of the i^{th} taxa at station 1, y_{i2} being the density of the i^{th} taxa at station 2 and *n* being the total number of taxa observed at both stations.

EPT/EPT+Chironomid Ratio biometric - This biometric may be used to provide a general indicator of the health of each site. The ratio of EPT (Ephemeroptera, Plecoptera and Trichoptera taxa) to chironomids is a common biometric that measures the abundance ratio of the two groupings and indicates the balance of the benthic community diversity. A healthy community should have a high proportion of EPT individuals relative to chironomids. The proportions of chironomids generally rise with increasing pollution, replacing the more sensitive EPT species. Therefore, since EPT taxa are known to be mostly intolerant and the family Chironomidae (at least as a whole) is generally considered tolerant to contaminants, the ratio of EPT taxa to the total of EPT + Chironomidae becomes lower as the environment becomes more polluted.

In this report, the biological indices were calculated using the methods outlined in Environment Canada (2002b).

7.7.3.2 Benthic Invertebrates Results for the 2006 Assessment Program

Table 7.7-4 presents a summary of zoobenthos encountered at Oakley Creek stations OCW-1, OCW-2, and OCW-3 in September 2006. Detailed results for these stations are presented in Appendix 7.7 and detailed laboratory certified reports are given in Appendix L7.7.

The highest density of benthic organisms occurred at OCW-2 (9,555 ind/m^2) with community densities at OCW-3 (3,775 ind/m^2) and OCW-1 (2,451 ind/m^2) approximately 30% of that at OCW-2. Taxon richness was also highest at OCW-2, with a mean of 16 taxa/sample with similarly lower values of 10 taxa/sample at OCW-1 and 11 taxa/sample at OCW-3 (Table 7.7-4).

The numerically dominant (i.e., most abundant) organisms at all stations were midge larvae (Chironomidae), which represented 31% to 64% of the community (Table 7.7-4). The Ceratopogonidae was the only sub-dominant (>5% of community density) taxon common to all three stations (Wardrop, 2007). The Tubificidae were sub-dominants at OCW-2 and OCW-3 and the Sphaeriidae were sub-dominants at both OCW-1 and OCW-3. Other sub-dominant taxa included the Elmidae and Caenidae at OCW-1 and the Hydroptilidae at OCW-2 (Table 7.7-4).

The mean value of Simpson's Index of Diversity was highest at OCW-1 (0.801) and lowest at OCW-2 (0.610) (Table 7.7-4). Evenness was low at all stations, with the mean value ranging

Table 7.7-4 Summary of Zoobenthos Community Composition and Abundance at Oakley Creek Stations in September 2006

				OCW-1			OCW-2			OCW-3		
Phylum	**Class**	**Order**	**Family**	**Mean**	**SD**	**% of Community**	**Mean**	**SD**	**% of Community**	**Mean**	**SD**	**% of Community**
Annelida	Hirudinea	Acanthobdellida	Glossiphonidae	0.6	0.9	1.1	3	2.4	1.4	1.2	1.6	1.4
		Arhynchobdellida	Erpobdellidae	0.4	0.5	0.7	1.2	1.3	0.5	0	-	0
	Oligochaeta	Lumbriculida	Lumbriculidae	1	1.7	1.8	4	1.9	1.8	3	2.4	3.4
		Tubificida	Naididae	1.4	1.9	2.5	4.2	3.9	1.9	0.2	0.4	0.2
			Tubificidae	1.4	1.9	2.5	12.2	13	5.5	8	10.4	9.1
Arthropoda	Arachnida	Araneae		0	-	0	0.4	0.9	0.2	0	-	0
	Hydracarina			0	-	0	0.4	0.9	0.2	0	-	0
Crustacea	Amphipoda	Gammaridae		0	-	0	0.4	0.5	0.2	1.2	1.8	1.4
		Hyalellidae		0	-	0	0.2	0.4	0.1	0.4	0.9	0.5
	Copepoda			0	-	0	1.6	2.1	0.7	1.4	1.5	1.6
Insecta	Coleoptera	Elmidae		9	4.5	15.8	0	-	0	0	-	0
		Haliplidae		0	-	0	0.4	0.5	0.2	0.2	0.4	0.2
		Hydraenidae		0	-	0	0	-	0	0.2	0.4	0.2
		Staphylinidae		0.2	0.4	0.4	0	-	0	0	-	0
	Diptera	Ceratopogonidae		6.2	2.2	10.9	18.6	12.8	8.4	15.2	6.4	17.3
		Chironomidae		**17.8**	**15.9**	**31.2**	**142.8**	**99.8**	**64.3**	**32.8**	**36.9**	**37.4**
		Empididae		0.2	0.4	0.4	0.4	0.5	0.2	0	-	0
		Tabanidae		0.2	0.4	0.4	0.2	0.4	0.1	0.4	0.5	0.5
		Tipulidae		0	-	0	0.4	0.5	0.2	0	-	0
	Ephemeroptera	Damaged		0.2	0.4	0.4	2	2.3	0.9	1	1.7	1.1
		Caenidae		5.4	5.2	9.5	1	1.2	0.5	0	-	0
		Ephemerellidae		0	-	0	2	3.9	0.9	1.4	1.5	1.6
		Ephemeridae		4.6	4.6	8.1	0	-	0	0	-	0
		Heptageniidae		0	-	0	0.2	0.4	0.1	0	-	0
		Leptophlebiidae		0	-	0	1	1.7	0.5	2.2	3.2	2.5
	Hemiptera	Corixidae		0	-	0	0	-	0	2.6	5.3	3
	Lepidoptera	Pyralidae		0.2	0.4	0.4	0	-	0	0	-	0
	Odonata-Anisoptera	Corduliidae		0	-	0	0.4	0.5	0.2	0.2	0.4	0.2
	Plecoptera	Capniidae		0	-	0	0	-	0	0.2	0.4	0.2
		Chloroperlidae		0	-	0	0.8	1.1	0.4	0	-	0
	Trichoptera	Damaged		0	-	0	0.2	0.4	0.1	0	-	0
		Hydroptilidae		1.6	3	2.8	11.4	14.4	5.1	0.6	0.9	0.7
		Lepidostomatidae		0	-	0	0	-	0	0.4	0.9	0.5
		Leptoceridae		0	-	0	0.4	0.9	0.2	0	-	0
		Limnephilidae		0.6	0.9	1.1	0.2	0.4	0.1	0	-	0
		Molannidae		0	-	0	0	-	0	0.2	0.4	0.2
		Phryganeidae		0.2	0.4	0.4	0.4	0.9	0.2	0	-	0
		Polycentopodidae		0.2	0.4	0.4	0	-	0	0	-	0
Mollusca	Bivalvia	Veneroida	Sphaeriidae	5	6.4	8.8	5.2	4.2	2.3	12.4	12.6	14.1
	Gastropoda	Ctenobranchiata	Valvatidae	0	-	0	0.2	0.4	0.1	0	-	0
		Pulmonata	Ancylidae	0	-	0	0.4	0.9	0.2	0.2	0.4	0.2
			Lymnaeidae	0	-	0	0.2	0.4	0.1	0	-	0
Nematoda				0.6	0.9	1.1	5.8	10.3	2.6	2.2	4.9	2.5
	Total Number of Organisms			57			222	128		88	50	
	Density (ind/m^2)			2451			9,555	5,491		3,775	2,153	
	Taxon Richness			10			16	5		11	5	
	Evenness			0.118			0.036	0.060		0.067	0.048	
	Simpson's Index of Diversity			0.801			0.610	0.139		0.722	0.110	
	Bray-Curtis Index			0.539			0.622	0.190		0.453	0.171	

Source: Wardrop, 2007

from 0.036 at OCW-2 to 0.118 at OCW-1 (Table 7.7-4). This is the result of the strong dominance of the Chironimidae at each station (Wardrop, 2007).

The reference median for the Bray Curtis distance calculation was based on the pooled data from all three Oakley Creek stations. The resulting Bray Curtis distances ranged from 0.453 to 0.622 (Table 7.7-4) and provide a numerical demonstration of the moderate similarity in the composition and structure of the three communities on Oakley Creek.

7.7.3.3 Benthic Invertebrates Results for the 2007 Assessment Program

Following is a summary of the 2007 invertebrate results. Detailed results are presented in Appendix 7.7 and detailed laboratory certified reports are given in Appendix L7.7.

Table 7.7-5 lists the number of invertebrates collected in August 2007 (URS, 2008h). The average total numbers of organisms/m^2 ranged from 1,400 at MRW1 to 27,550 at MRW3 (URS, 2008h). The average number of taxonomic groups ranged from 6 at OCW2 to 12.3 at MRW3. Results from the reference site HRW1 had an average of 3,700 total numbers of organisms/m^2 and 7 taxonomic groups.

William River

The average number of organisms found in replicates collected from sites WRW1 and WRW2 was 2,858 ind/m^2 consisting of an average number of 8.33 taxa. The dominant taxon at this site was the *Hexagenia* sp. comprising 33% of the population sampled. The other species found in significant numbers were Tubificidae comprising 19% of the population sampled.

Oakley Creek

The average number of organisms found in replicates collected from sites OCW1, OCW2 and OCW3 was 7,856 ind/m^2 consisting of an average number of 8 taxa. The dominant taxon at these sites were the *Rheotanytarsus* sp., comprising 20 and 33% of the population sampled for OCW1 and OCW2, and chironomids, representing 29% at OCW3. Other species found in significant numbers were Tubificidae, *Ephemeroptera caenis*, *Phaenospectra* sp., *Pisidium* sp., *Cricotopus* sp. and the *Trichoptera hydroptila*.

Minago River

The average number of organisms per m^2 increased from 1,400 at MRW1 to 6,850 at MRW2 and 27,550 at MRW3 in Minago River. The average number of taxa also increased from 7 at MRW1 to 8.67 at MRW2 and 12.33 at MRW3. The dominant taxa at these sites were the *Pisidium* sp. (MRW1), Tubificidae (MRW2) and *Ceriodaphnia* sp. (MRW3). Other species found in significant numbers were *Hyalella azteca*, *Thienemannimyia* sp., and *Rheotanytarsus* sp.

Table 7.7-5 Summary of Invertebrates Collected at the Minago Project, Manitoba - August 2007

	OCW1 R1	OCW1 R2	OCW1 R3	OCW2 R1	OCW2 R2	OCW2 R3	OCW3 R1	OCW3 R2	OCW3 R3	WRW1 R1	WRW1 R2	WRW1 R3	WRW2 R1	WRW2 R2	WRW2 R3	MRW1 R1	MRW1 R2	MRW1 R3	MRW2 R1	MRW2 R2	MRW2 R3	MRW3 R1	MRW3 R2	MRW3 R3	HRW1 R1	HRW1 R2	HRW1 R3
INSECTA																											
Insecta Larva dam														1									1				
Ephemeroptera - mayflies	10	3		2			17	3	10	30	10	17	25	20	21	4	1	3	20	4	2	3	33	37	3	3	
Odonata - dragonflies								1		1		1												1			
Plecoptera - stoneflies																											
Trichoptera - caddisflies	16	1	2			1	2	4	9		1		3	5	2		1	1	3	1			2		4	3	
Diptera - true flies	27	4	15	86	77	228	245	98	219	10	23	21	2	12	13	11	1	24	11	27	8	4	74	42	23	4	13
Coleoptera - beetles	2	1	1				2						1	1		1	1					2	2	1			
Collembola - springtails Unid											1																
Hemiptera		1					3	1			1						1			5				1			
Lepidoptera - butterflies & moths Larva									1		1		1		1												
ARACHNIDA - spiders			1										1							1					1	1	
ACARINA - mites and ticks			1				2	1	3						1							1	5	1			
CRUSTACEA - crustaceans																2		7	92	3	5	6	61	43		1	
Amphipoda, sideswimmers, or scuds	2		3		1		1							2													
Cladocera - water fleas								1						1						6		221	772	6			
Copepoda - microcrustaceans	1		2	1			8	4	2	1	1				1				6	13	1	18	76	36		1	2
ANNELIDA - segmented worms																											
Oligochaeta - segmented worms	13	2	9	8	10	11	16	8	9	4	13	8	13	27	4	2	5		46	83	12	12	48	44	106	33	11
Hirudinea - leeches Unid Juv		1				2	2	2							1		2					2					
MOLLUSCA - clams, snails, etc.																											
Bivalvia - clams	2			13	19	23	14	29	29					3	1	9	4		22	21	8	3	11	12		1	3
Gastropoda - snails			4			2	1		6					1	2	2	1			8		4	37	15	2		
NEMATODA - roundworms		1	1	1	2	3	22	15	8	4	4	5	3	8	8	1			2	1		2	13		1	2	4
CNIDARIA - hydroids, jellies, etc.													1										1				
Total Number per 0.02 m^2	73	14	39	111	109	270	335	167	296	50	55	52	50	81	55	32	17	35	202	173	36	278	1,136	239	140	49	33
Average Number per Location per 0.02 m^2	42			163			266			52			62			28			137			551			74		
Average Number per Location per m^2	2,100			8,167			13,300			2,617			3,100			1,400			6,850			27,550			3,700		
Number of Taxa	8	8	10	6	5	7	13	12	10	6	9	5	9	10	11	8	9	4	8	12	6	12	13	12	7	9	5
Average Taxa Per Location	8.67			6.00			11.67			6.67			10.00			7.00			8.67			12.33			7.00		

Source: adapted from URS, 2008h

Hargrave River (Reference Site)

The average number of organisms found in the three replicates collected from Reference Site HRW1 was 3,700 ind/m^2 consisting of an average number of 7 taxa. The dominant taxon at this site was Tubificidae comprising 66% of the population sampled.

7.7.3.3.1 Community Indices for the 2007 Program

Following is a summary of community indices that were calculated for the invertebrates collected in August 2007 (Table 7.7-6). The highest benthic invertebrate densities were found in Minago River at MRW3 (27,550 ind/m^2) and the lowest invertebrate density in 2007 was also encountered in Minago River at MRW1 (1,400 ind/m^2) (Table 7.7-5). Benthic invertebrate densities in Oakley Creek showed similar variability with the highest numbers found at OCW3 (13,300 ind/m^2) and much lower numbers at OCW2 (8,716 ind/m^2) and OCW1 (2,100 ind/m^2). Results for the William River were similar for both locations WRW1 (2,617 ind/m^2) and WRW2 (3,100 ind/m^2).

Dominance and Equitability

Dominance values generated in the August 2007 samples were low to moderate for all sites ranging from 0.06 to 0.45 (URS, 2008h) (Table 7.7-6). Lower dominance values were determined for sites MRW1 (0.06) and OCW1 (0.09) while moderate values were determined for sites MRW3 (0.37) and HRW1 (0.45). These values were much lower than those determined from the 2006 data, which showed Simpson's Index values between 0.61 at OCW-2 and 0.80 at OCW-1.

Equitability is a measure of evenness in the distribution of taxa and is inversely related to dominance. Equitability is related to the dominance values indicated above but is compared to a standard of 1, which represents an equal distribution. If a given taxonomic group dominates samples, this condition tends to decrease the equitability factor. All of the August 2007 sediment samples indicated high evenness values ranging from 0.55 to 0.94 (URS, 2008h).

Richness

Richness compares the number of taxa present at a particular site to population density. Richness values ranged from 13.3 at MRW1 to 142 at MRW3 in 2007 benthic samples (Table 7.7-6).

Diversity

Species diversity was measured using the Shannon-Weaver and Margalef equations. The Shannon-Weaver Diversity index values were lowest for samples collected at HRW1 (1.57) and highest at MRW1 (3.05). The Margalef index values were lowest for samples collected at site OCW2 (0.75) and highest at site WRW2 (1.66).

Similarity

The reference site used for the Bray-Curtis distance calculations in the 2007 assessment program was based on pooled data from the location HRW1 on Hargrave River. This location was

Table 7.7-6 Summary of Invertebrates Indices for the 2007 Benthic Survey

Location		Simpson's Dominance	Richness	Shannon Weaver	Margalef's	EPT/EPT+Chironomid Ratio
HARGRAVE RIVER	**HRW1**	0.45	32	1.57	1.11	0.68
MINAGO RIVER	**MRW1**	0.06	13	3.05	1.20	0.77
	MRW2	0.17	49	2.38	1.22	0.79
	MRW3	0.37	142	1.94	1.44	0.83
WILLIAM RIVER	**WRW1**	0.17	24	2.23	1.12	0.78
	WRW2	0.18	19	2.31	1.66	1.00
OAKLEY CREEK	**OCW1**	0.09	16	2.83	1.45	0.84
	OCW2	0.18	86	2.15	0.75	0.03
	OCW3	0.14	77	2.50	1.40	0.16

Source: adapted from URS, 2008h

chosen because it is outside of the watershed connected to the future mining operations. The Bray-Curtis distance provides a numerical assessment of the similarity of the structure and composition of the nine locations sampled in 2007. Bray-Curtis distances ranged from 0.24 to 0.90, indicative of low to moderate similarity between populations (Table 7.7-7).

Table 7.7-7 Bray Curtis Distances for Benthic Invertebrates for the 2007 Survey

STATIONS	OCW1	OCW2	OCW3	WRW1	WRW2	MRW1	MRW2	MRW3	HRW1
OCW1		0.74	0.75	0.38	0.44	0.41	0.60	0.89	0.49
OCW2			0.24	0.73	0.78	0.78	0.70	0.82	0.76
OCW3				0.73	0.73	0.83	0.68	0.79	0.80
WRW1					0.27	0.55	0.64	0.83	0.56
WRW2						0.60	0.61	0.82	0.50
MRW1							0.68	0.90	0.60
MRW2								0.67	0.35
MRW3									0.82
HRW1									

STREAMS	OC	WR	MR	HR
OC (Oakley Creek)		0.64	0.71	0.71
WR (William River)			0.70	0.49
MR (Minago River)				0.67
HR (Hargrave River)				

Source: Roche Ltd. recalculated all Bray Curtis Distances originally given in URS, 2008h in March 2010.

EPT/EPT+Chironomid Ratio biometric

The general health of encountered benthic communities was evaluated using the EPT/EPT+Chironomid Ratio biometric. The EPT/EPT+Chironomid Ratio values were lowest for the samples collected at sites OCW2 (0.03) and OCW3 (0.16). The highest values were determined for the samples collected from site WRW2 (1.0). Overall the sampling sites had low numbers of chironomids, which is a general indicator of community health and little or no pollution levels.

The low ratios calculated for the two locations upstream of Highway #6 on Oakley Creek were the result of high chironomid numbers and may represent a natural characteristic of Oakley Creek in this area due to the high percentage of organic carbon found in the sediment at these locations compared to other sites in the area. Sites OCW2 and OCW3 also had low results for dominance and diversity (Table 7.7-6).

7.7.3.4 Benthic Invertebrates Results for the 2008 Assessment Program

In 2008, a total of 25 taxa (24 families and one phylum) of benthic invertebrates were identified among the 5 samples collected within the study area (Table 7.7-8; Roche, 2008a). Five phyla were identified: Porifera (sponges), Nematoda (roundworms), Mollusca,

Table 7.7-8 Densities and Relative Abundances per Taxa (2008 Assessment Program)

TAXA				DENSITY (individuals/m^2)					RELATIVE ABUNDANCE (%)				
				CLF-1	LBF-1	MRF-3	OCF-1	WRF-3	CLF-1	LBF-1	MRF-3	OCF-1	WRF-3
PORIFERA													
	Demospongiae												
			Spongillidae	19	19				1.1	0.8			
NEMATODA				57	858		76	38	3.3	34.6		5.7	0.9
MOLLUSCA													
	Prosobranchia												
			Hydrobiidae	191		38		839	10.9		4.3		19.5
	Pulmonata												
			Ancylidae					57					1.3
	Bivalvia												
			Sphaeriidae	76	744	153	477		4.3	30.0	17.4	35.7	
ANNELIDA													
	Oligochaeta												
			Lumbriculidae		38	19		782		1.5	2.2		18.1
			Tubificidae	19	114	210		782	1.1	4.6	23.9		18.1
	Hirudinea												
			Glossiphoniidae			19					2.2		
ARTHROPODA													
Chelicerata													
	Arachnida												
		Acari											
			Unionicolidae	19					1.1				
Crustacea													
	Copepoda												
		Cyclopoida											
			Cyclopidae	19					1.1				
	Ostracoda												
		Podocopida											
			Candonidae			19					2.2		
	Malacostraca												
		Amphipoda											
			Hyalellidae	38		19		19	2.2		2.2		0.4
Uniramia													
	Insecta												
		Anisoptera											
			Corduliidae				57					4.3	
		Ephemeroptera											
			Ephemeridae	1030	19		19	381	58.7	0.8		1.4	8.8
			Leptophlebiidae				76					5.7	
		Megaloptera											
			Sialidae	76				19	4.3				0.4
		Hemiptera											
			Corixidae				19					1.4	
		Trichoptera											
			Hydroptilidae				76	19				5.7	0.4
			Leptoceridae		19	19		19		0.8	2.2		0.4
			Limnephilidae			38	38	57			4.3	2.9	1.3
		Coleoptera											
			Chrysomelidae			38		153			4.3		3.5
			Elmidae				153					11.4	0.0
			Haliplidae				19					1.4	0.0
		Nematocera											
			Ceratopogonidae	19	114	19	172	744	1.1	4.6	2.2	12.9	17.3
			Chironomidae (pupes)					38					0.9
			Chironomidae (larves)	191	553	286	153	362	10.9	22.3	32.6	11.4	8.4
			TOTAL	**1754**	**2479**	**877**	**1335**	**4310**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Roche, 2008a

Annelida (segmented worms) and Arthropoda (including arachnids, insects and crustaceans).

Table 7.7-8 shows the abundance of benthic invertebrates at each of the sampling stations. Only Nematocera (Ceratopogonidae and Chironomidae) were observed at every station while the other 10 benthic invertebrates were only observed at one station: Ancylidae (WRF3), Glossiphoniidae (MRF3), Unionicolidae (CLF1), Cyclopidae (CLF1), Candonidae (MRF3), Corduliidae (OCF1), Leptophlebiidae (OCF1) Corixidae (OCF1), Elmidae (OCF1) and Haliplidae (OCF1). Out of 25 taxa, 16 were observed less than ten times and 14 at two or less sampling stations. William River station WRF3 had the highest total number of benthic invertebrates (4,310), followed by Limestone Bay station LBF1 (2,479) and Cross Lake station CLF1 (1,754) (Table 7.7-8 and Figure 7.7-5).

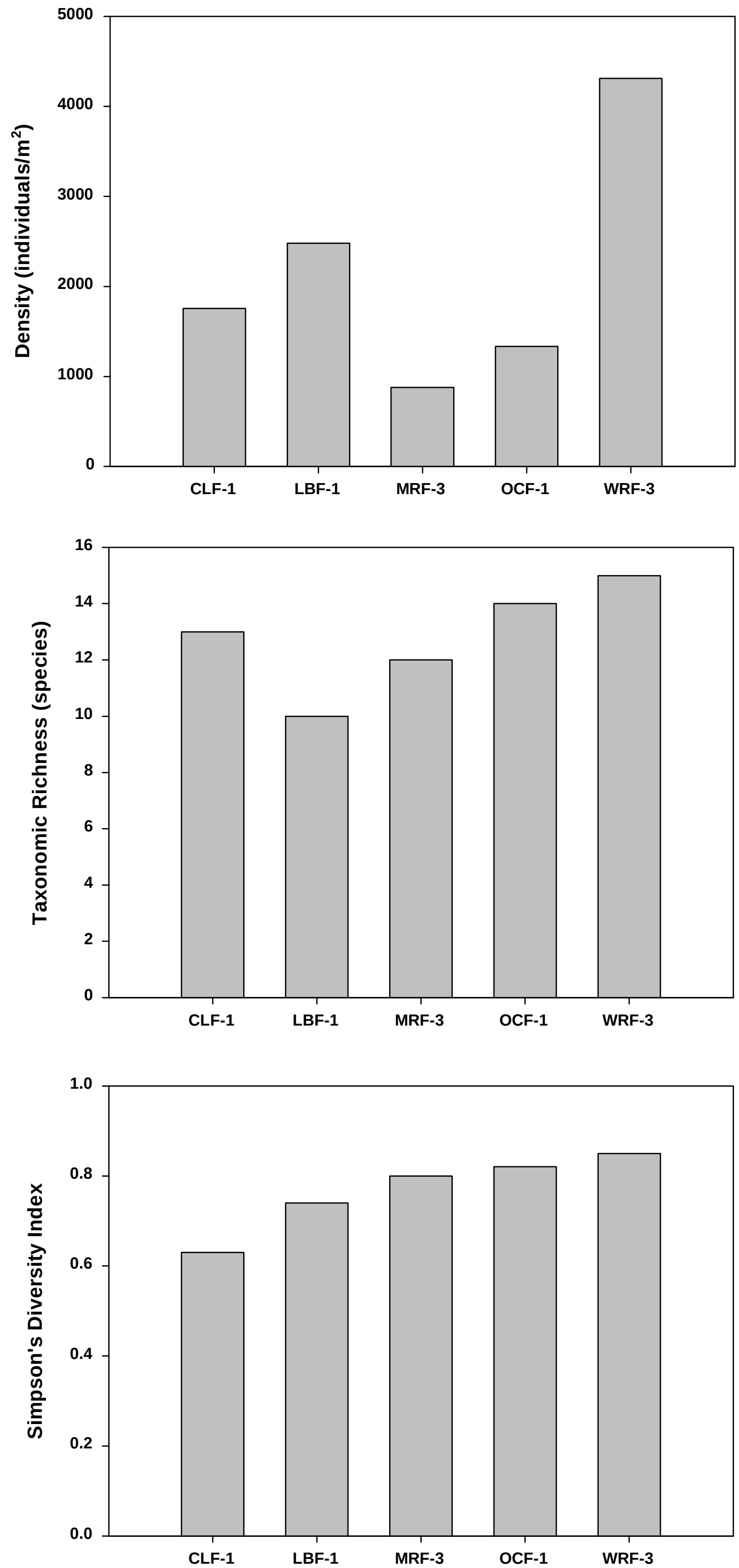
Taxonomic richness ranged from 10 to 15 species per stations (Table 7.7-8 and Figure 7.7-5). The lowest value was observed within Limestone Bay on Lake Winnipeg. Five taxa were denser than 100 individuals/m^2 for at least two stations, namely Sphaeriidae, Tubificidae, Ephemeridae, Ceratopogonidae and Chironomidae. The most abundant taxa (relative abundance higher than 20% for at least one station) were Chironomidae, Ephemeridae, Tubificidae, Sphaeriidae and Nematoda.

The Simpson's diversity index takes into account both the relative abundance and the taxonomic richness of a community. The Simpson's diversity index was highest in William River, where a maximum amount of species were observed and where four different taxa had a relative abundance higher than 15% (Figure 7.7-5). The Simpson's diversity index was lowest in Cross Lake, where one taxa represented almost 60% of all the benthic invertebrates collected.

Even though the Bray-Curtis distance is usually used to compare one site to a reference site, it was used by Roche to evaluate how benthic communities differed from each other in their composition. The investigated communities were quite different as no two stations had a Bray-Curtis distance lower than 0.56 (Tables 7.7-8 and 7.7-9) (Roche, 2008a).

The EPT/EPT+Chironomid Ratios were 0.06 at LBF1, 0.19 at MRF3, 0.58 at WRF3, 0.65 at OCF1, and 0.84 at CLF1. No Plecoptera species were identified. This indicates that Limestone Bay and Minago River experience deleterious impacts caused by pollution of some kind (Roche, 2008a). These two stations (LBF1 and MRF3) also showed the lowest values in terms of taxonomic richness, being both dominated by chironomids with relative abundances higher than 20%. In contrast, almost 60% of all species collected at Cross Lake station CLF1 were Ephemeridae, which indicates a low level of pollution.

A weak relation between the EPT/EPT+Chironomid Ratio and the total organic carbon (TOC) content was observed since the highest TOC value was observed in the Limestone Bay (Roche, 2008a). However, the second highest value was measured at MRF3 where the ratio was quite low. Total organic carbon content is known to have possible deleterious impacts on benthic invertebrate communities (Hyland et al., 2000).



Source: Roche, 2008a

Figure 7.7-5 2008 Benthic Invertebrate Communities

Table 7.7-9 Bray-Curtis Distance between 2008 Benthic Monitoring Sites

STATIONS	CLF1	LBF1	MRF3	OCF1	WRF3
CLF1		0.81	0.72	0.79	0.71
LBF1	0.81		0.64	0.56	0.79
MRF3	0.72	0.64		0.67	0.74
OCF1	0.79	0.56	0.67		0.84
WRF3	0.71	0.79	0.74	0.84	

Source: Roche, 2008

Even if the highest metal content values were measured for Minago River, which had a low EPT/EPT+Chironomid Ratio (0.19), metal content within sediments did likely not have any negative impacts on benthic invertebrates since the lowest EPT Ratio was measured for Limestone Bay where metal concentrations were among the lowest (Roche, 2008a).

7.7.3.5 Characteristics of the Dominant Taxa

Following is a description of taxa that had the highest relative abundance values in all environmental baseline studies, or a particularly high value in one of them.

Chironomidae

Chironomidae is the most important dipterans (flies, mosquitoes, deer flies) aquatic family. Even if adults are not aquatic, Chironomidae spend most of their life in freshwater at intermediate development stages (Wetzel, 2001). This family is considered as pollution resistant (Moisan, 2006). Most of its species can resist to lower dissolved oxygen level and some can even survive where oxygen content cannot be detected (Thorp and Covich, 1991). In fact, the blood of some Chironomidae contains a specific type of haemoglobin, which is efficient at low oxygen content (Thorp and Covich, 1991; Wetzel, 2001).

Chironomidae are a very important link in the aquatic food chain, acting as preys for many other insects and most of the fishes (Thorp and Covich, 1991). Chironomid larvae vary in their feeding habits with herbivorous-scavengers and carnivorous being well represented (Thorp and Covich, 1991).

Sphaeriidae

The Sphaeriidae, commonly known as “pea,” “pill,” “nut,” and “fingernail clams,” are an exclusively freshwater bivalve family. As their common names imply, sphaeriid clams are small: the adult shells length rarely exceed 25 mm. Yet, they play important roles in freshwater ecosystems. Sphaeriids often constitute a large proportion of the benthic biomass of freshwater habitats and play a key role in energy and nutrient cycling (Lee, 2001). Sphaeriid clams are important components in the diets of some fish, aquatic insects and waterfowl (Lee, 2001).

Sphaeriids display great intra- and interspecific variation in life-history characteristics. They are characterized by short life spans, early maturity, small adult size and increased energetic input to unstable habitats, as well as slow growth, low fecundity and release of extremely large, fully developed young associated with adaptation to highly stable habitats (Thorp and Covich, 1991).

Ephemeridae

Ephemeridae is a family of mayflies with about 150 described species. These are generally quite large mayflies (up to 35 mm) with either two or three very long tails. Many species have distinctively patterned wings.

Ephemerides breed in a wide range of waters, usually requiring a layer of silt as the nymphs have strong legs which are adapted for burrowing (the group is sometimes known as burrowing mayflies). It is considered a pollution-intolerant taxon. Larvae burrow into sand or eddies in riffle areas of small- to medium-sized streams or inhabit bottoms of medium to large streams. They also inhabit sandy or silt substrata in relatively clean lakes (Thorp and Covich, 1991). The nymphs are largely carnivorous and collect their food either through predation or scavenging.

Tubificidae

The Tubificidae are a family of clitellate oligochaete worms. They are key components of the benthic communities of many freshwater and marine ecosystems. These aquatic oligochaetes are resistant to pollution (Moisan, 2006). In fresh water, they are usually benthic inhabiting nearby bottoms or within the substratum (Hickman et al., 1997). Most of them are well adapted to substrata ranging from mud to sand (Thorp and Covich, 1991) and are important components in the diets of fishes (Hickman et al., 1997).

Tubificidae feed from surface sediments which contain organic matter colonized by bacteria and other microorganisms. Moreover, food availability seems to be the most important factor influencing their distribution and abundance (Wetzel, 2001).

Tubificidae are particularly abundant where organic pollution helps lowering the oxygen content (Wetzel, 2001). While many benthic invertebrates are quite sensible to low oxygen levels, many Tubificidae can tolerate anaerobic conditions for more than a month if they are periodically exposed to oxygen (Wetzel, 2001). Therefore, in these conditions and if toxic metabolites do not accumulate, the abundance of the food and the diminution of the interspecific competition enable a rapid growth of these oligochaete (Wetzel, 2001).

Daphniidae (Ceriodaphnia sp.)

This family is part of the Cladocera phylum, which is also known as the water flea group. Cladocera or cladocerans are small crustaceans commonly called water fleas, part of the class Branchiopoda. The most commonly known genus is *Daphnia* (freshwater water fleas), which is the most researched in this group. *Ceriodaphnia* is commonly used to test the toxicity of chemicals in solution or for water pollution, especially *Ceriodaphnia dubia*.

Daphniids are common inhabitants of the plankton and littoral zones of standing waters of all kinds. They function as grazers of bacteria and zooplankton, and provide a major food resource for young fishes.

7.7.4 Effects Assessment

This section examines potential effects of the Minago Project on benthos and periphyton. Existing conditions in the project area are characterized and effects of project activities predicted based on effects on water quality described in Section 7.5: Surface Water Quality and stream flows described in Section 7.4: Surface Water Hydrology. The findings of this section provide the basis for assessment of potential 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.

7.7.4.1 Scope of Assessment

Periphyton and benthic invertebrate communities have been 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 low tolerances and respond to metals, nutrients and sediment quality, 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 their known sensitivity to changes in nutrients, sediments (TSS) and metal levels. They are used in government biomonitoring programs in Canada (Environment Canada, 2002b) and the United States (Barbour et al., 1999). The benthic index of biotic integrity - a multi-metric assessment method - 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 as well as change in stream flows, temperature, and water quality. In addition, they provide an important link to fish resources. Changes in periphyton and benthos productivity can have effects on fish (abundance, size, bioaccumulation of metals in tissue), which can in turn affect birds and wildlife that consume fish.

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

- **Polishing Pond Discharge to Oakley Creek and Minago River** – Discharge of mine effluent can have potentially positive and/or adverse effects on periphyton and invertebrates through toxicity of metals, nutrient enrichment, 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. VNI will discharge water from the Polishing Pond that meets MMER discharge criteria.

- **Changes to Oakley Creek and Minago River Flow Regimes** – Minago River will not be affected by any project related diversions as the project area is located in the Oakley Creek watershed. Streamflow in Oakley Creek will not be affected by site diversions as the diverted water will be returned to Oakley 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 Baseline Studies presented to regulators and stakeholders by VNI. The VECCs and rationale for their selection are described in Table 7.7-10.

Temporal Boundaries

The temporal boundaries applicable to periphyton and benthic invertebrates include the period of record for the baseline data collection (2006-2008 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 nitrate/ammonia to 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. 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 originating 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. The current plans are for discharge of water to Minago River and Oakley Creek.

The local study area (LSA) includes all streams that may be influenced by the mine facilities. The LSA includes:

- the Oakley Creek watershed, which will be affected by diversions from the Tailings and Ultramafic Waste Rock Facility (TWRMF) and the Overburden Disposal Facility (ODF);
- the Minago River watershed, which will be affected by the Polishing Pond discharges; and
- the industrial area, which has no streams/creeks.

Table 7.7-10 Periphyton and Benthic Invertebrate VECCs, Selection Rationale and Data Sources

VECC	Rationale for Selection	Linkage to EAP Report Regulatory Drivers	Baseline Data for EAP
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,* can influence benthic invertebrate abundance and composition.	• Environmental Baseline Studies (EBS)	• 2007-2008 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.	• Environmental Baseline Studies (EBS) • Environmental Impact Assessement guidelines	• 2007-2008 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.	• Environmental Baseline Studies (EBS) • Will be required for *Metal Mining Effluent Regulations* (MMER) environmental effects monitoring (EEM). [1]	• 2007-2008 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.	• Environmental Baseline Studies (EBS) • Will be required for MMER EEM. [1]	• 2007-2008 field data

Note:

1 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 the administration of MMER.

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. Water bodies in the RSA include:

- Hargrave River, which flows to the Minago River; and
- William Lake and William River upstream of the William River / Oakley Creek confluence.

7.7.4.2 Effects Assessment Methodology

Project effects on periphyton and benthos VECCs have been assessed based on predicted residual effects on water and sediment quality, also discussed in Section 7.5: Surface Water Quality; Section 7.6: Hydrogeology and Groundwater Quality; and Section 7.4: Surface Water Hydrology. Potential effects on sediment quality are assessed in Section 7.5: Surface Water Quality. Potential effects on community composition and productivity were 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 locations and at the identified compliance points on the Minago River and Oakley Creek.

Project and cumulative effects on periphyton and benthic invertebrates were characterized on the based on effects attributes defined in Table 7.7-11. The ecological and social context of effects were integrated in the attributes for effect magnitude and are discussed in detail for each VECC in this report.

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, detailed in Table 7.7-11, if it is:

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

Otherwise, a residual effect will be rated as not significant.

The likelihood of occurrence of any significant adverse residual effects is stated with a supporting rationale in this document.

7.7.4.3 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 Quality. Interactions related to accidents and malfunctions are described in Section 8.

Table 7.7-11 Effect Atributes 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 extents 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.
Long-term	Effects on VECC lasts longer than 5 years, but does not extend more than 10 years after decommissioning and the 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	Effects on VECC are 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.

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.

7.7.4.3.1 Construction

Oakley Creek

Minesite facilities to be constructed in the Oakley Creek drainage and potential effects on water quality are described in Chapter 2. Oakley Creek is a short, low gradient stream, which has fish resources and drains to William River. The Oakley Creek basin has already been affected by periodic PTH6 road repairs. Potential effects on the Oakley Creek watershed during project construction include:

- increased suspended sediment in runoff from construction sites for various facilities in the basin;
- runoff from the Dolomite Waste Rock Dump (WRD) with potentially elevated metals, nitrate/ammonia and suspended sediments; and
- changes of flow regimes in Oakley Creek due to open pit dewatering.

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 in frequency and reversible), as they will be mitigated through the VNI Erosion and Sediment Control Plan (Section 9: Environmental Management Plan). In addition, the muskegs will filter discharges by removing TSS and metals. Accordingly, no effects on benthic communities in Oakley Creek are expected during construction.

Introduction of metals or nitrate/ammonia from the Dolomite WRD to the Oakley Creek may be mitigated by wetlands (bogs). It is projected that there will be no adverse effects of such discharges on water quality in Oakley 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.

Nitrate levels may become elevated relative to baseline conditions throughout Oakley Creek downstream of the Oakley Creek discharge point. The 2007 CCME nitrate guideline level of 13 mg/L was established in relation to nitrate toxicity, rather than eutrophication potential and will not be exceeded in Oakley Creek. Nitrogen inputs from blasting will decrease over the operational phase and denitrification will reduce nitrate levels in the effluent and stream water. Aquatic plants in the creek will also take up and store nitrate during the growing season, and release it later during decomposition, resulting in lower nitrate levels. Nitrate levels are likely to stimulate periphyton growth in Oakley Creek. Nitrate levels tend to be very low in Oakley Creek rendering the stream sensitive to enrichment effects from nitrate. The magnitude and direction of the periphyton response to enrichment will depend on flows, light, temperature, and available phosphorus, as well as inorganic nitrogen. In oligotrophic systems, some nutrient enrichment can be considered beneficial to benthic communities.

The pumping test results (Section 7.6: Hydrogeology and Groundwater Quality) conducted in 2008 showed that the open pit dewatering program will not decrease flows in Oakley Creek. Therefore, there will be no adverse effect on periphyton and benthic invertebrate communities. There will be no stream flow reduction due to mine dewatering, and related effects on benthic habitat and productivity are expected to be low magnitude, site-specific, short-term, low frequency and reversible. Overall effects are rated as not significant, with a high likelihood of occurrence.

Minago River

No project related effects are anticipated for benthic communities in the Minago River, given that construction effects will be specific to the Oakley Creek watershed.

7.7.4.3.2 Operations

Discharges to Oakley Creek

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

Discharges to Minago River

Discharge of Polishing Pond effluent in the upper watershed of the Minago River has the potential to have significant adverse effect on benthic communities through toxicity of metals, changes in pH and release of suspended sediments. Predicted effluent and receiving environment water quality are described in the Water Management Section. VNI will discharge effluent that meets MMER discharge criteria. The receiving environment and effluent will be subject to Environmental Effects Monitoring (EEM) under *Metal Mining Effluent Regulations* (MMER).

Project effects on benthic communities in the Minago River related to nitrate and ammonia (from blasting operations) discharge are rated as potentially positive (since it will meet MMER discharge criteria), moderate in magnitude, local, long-term in duration, moderate in frequency and reversible, with an unknown likelihood. VNI will ensure through the explosive contract that explosives spillage is controlled and minimized and that emulsion explosives will be used, where applicable. Potential effects are rated as not significant, but will be monitored in MMER EEM programs. If moderate adverse effects were to be identified during monitoring, VNI will be able to implement adaptive management strategies.

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) - these reports are less relevant when assessing metal levels in the lower part of the range, as would be expected in the Minago River.

The accumulation of selenium and other metals in despositional 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 are in close contact with the metal-containing sediment. Current recommendations are for a maximum of 2 mg/kg in sediment (Engberg et al., 1998; Lemly, 2002). Selenium levels in the Minago River and Oakley sediment have been below that level (Table 7.7-2 and Table 7.7-3), 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 to reduce bio-available selenium levels will be implemented, when necessary.

Project effects on the Minago River and Oakley 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. The effects will be monitored through MMER. As a result, effects are rated as not significant.

7.7.4.3.3 Decommissioning

The potential effects of mine closure will be more limited than during the construction phase. The Mine Closure Plan is described in Chapter 3. Effects on hydrology and water quality are described in other sections, Sections 7.4 and 7.5, respectively.

Oakley Creek

Potential adverse effects on benthic organisms in Oakley Creek related to sediment release in runoff during removal of facilities will be mitigated by implementing an Erosion and Sediment Control Plan, so that no significant adverse effect on periphyton and benthic invertebrate communities will occur.

The TWRMF will remain in place to provide permanent storage of tailings and ultramafic waste rock, which will be covered by at least 1.5 m of water. It is predicted that levels of most metals in supernatant water will be reduced within the time of closure. Supernatant water will be monitored following the end of operations. In combination with relatively small flows over the TWRMF spillway, this should result in no adverse effects on water quality or benthic communities in Oakley Creek.

Potential adverse effects in Oakley Creek during decommissioning include increased suspended sediment in runoff from the deconstruction of various facilities. These will be mitigated by the Erosion and Sediment Control Plan (Section 9.2) and site revegetation included in the Mine Closure Plan. Accordingly, no adverse effects on water quality or periphyton and benthic invertebrate communities in Oakley Creek are anticipated during decommissioning.

7.7.4.3.4 Closure

The Mine Closure Plan is described in Chapter 3 and in a separate report and project effects on surface water quality are described in Section 7.5.

Oakley Creek

Post-closure monitoring is proposed for Oakley Creek to assess the effects of pit discharges on Oakley Creek. The effect of discharges on receiving water or sediment quality in Oakley Creek has been rated as not significant, based on the characterization as being adverse, low to moderate magnitude, local extent, far future in duration and ultimately reversible.

At closure, the quality of TWRMF pond supernatant will not cause a change in the quality of Oakley Creek beyond the natural variability established over the period of baseline monitoring. Accordingly, there will be no further effects of the project on Oakley Creek at closure.

The TWRMF 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 well below MMER, it is likely that levels in the tailings will remain elevated enough to discourage growth of algae and benthic organism. As a result, the likelihood for bio-accumulation of metals by aquatic plants and invertebrates in the TWRMF and their eventual consumption by birds and other wildlife would be small, and were 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 the end of the operations) to assess the colonization potential around the TWRMF, with additional management strategies to be put in place to discourage bird usage, if needed. Observations will be made during the operational phase to determine if birds usage will be an issue at closure.

7.7.4.4 Residual Project Effect and Significance

Effluent Discharge to Minago River

During operations, residual effects on benthic communities are expected to be related to metals in stream water and sediments deposited between the Polishing Pond discharge point and the compliance point in Minago River. Dilution in Minago River will be adequate for Contaminants of Concern (COC), which will reduce the magnitude of most potential effects to a low level in the Minago River. No adverse effects on benthic communities are anticipated downstream of the Minago River mixing zone, given that metal levels will remain below Manitoba Tier II and CCME water quality objectives for the protection of aquatic life.

Discharged effluent may also contain nitrogenous compounds (from blasting residues), which may 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 Minago River, with potential changes to benthic invertebrate populations. However, nutrient enrichment may be a positive rather than an 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. 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 ponds and riffle habitat. Follow-up monitoring of metals in sediment and fish tissue will be undertaken to check predictions and improve mitigation, if necessary.

Baseline water chemistry in the Minago River and other streams is described in Section 7.5. Given that the likelihood of potential effects is unknown, VNI will be required to monitor effluent and the receiving environment using an EEM program. Benthic invertebrate and fish communities will be monitored on a multi-year cycle to provide data about the effectiveness of the Water Management Plan and the environmental effects of discharges on the benthic community of the Minago River. Results will guide decisions on mine practices and monitoring requirements.

At mine closure, the TWRMF will be maintained with a water layer over the tailings and ultramafic waste rock. TWRMF supernatant water will be discharged to the Polishing Pond (PP) and water in the PP will be monitored before it is discharged to the receiving environment, if needed, during the first six 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. The likelihood of these effects is not clear and will be subject to monitoring.

Flow Regime Changes in Minago River

Small changes to flow regimes of the Minago River are anticipated as a result of discharges from the Polishing Pond. During operations, discharges to the Minago River will be approximately 36%, 10%, and 19% of the anticipated average flows in the winter months (Nov.-Apr.), during the freshet (May), and in the summer months (Jun. – Oct.), respectively. Details are provided and discussed in Section 2.14 (Site Water Management). Higher water flow and thus water level will help maintain the existing stream habitat types and limit changes in water quality that can occur during low flow periods, therefore limiting seasonal stresses for periphyton, benthic invertebrates and other biota.

The impacts of a reduction in the water flow on stream habitats would be more significant after closure of the Nickel Processing Plant and the Frac Sand Plant, especially in winter low flow conditions. Lower water flow and thus water level reduces stream habitat types and increases the risk of changes in water quality, increasing seasonal stresses for fish and other biota.

Therefore, mitigation measures will have to be implemented in order to limit the potential impacts of such a change in water level conditions, meaning that discharge from the Polishing Pond has to be gradually reduced and not drastically as operations wind down. This would enable a comeback to pre-mining conditions. Depending on the PP capacity, a gradual reduction over one or two years is planned as the operations transition from full production in years 1 through 8 when both of the Nickel Processing Plant and the Frac Sand Plant are operating, to partial production in years 9 and 10 when the Nickel Processing Plant will be closed and the Frac Sand Plant will be operating, to finally no production starting in year 11. Details of the site water management program are given in Section 2.14.

As discussed in the previous sections, the impacts of increasing or decreasing the water flow in the Minago River will be low, or not significant after closure, in terms of hydrology since they are within the natural variation occurring in this region.

Effluent Discharge to Oakley Creek

During operations, residual effects on benthic communities are expected to be limited to those related to metals in stream water and sediments deposited between the Polishing Pond discharge point and the compliance point in Oakley Creek. Dilution in Oakley Creek will be adequate for Contaminants of Concern (COC), which reduces the magnitude of most potential effects to a low level in Oakley Creek. No adverse effects on benthic communities are anticipated downstream of the William River/Oakley Creek confluence, given that metal levels will remain below Manitoba Tier II and CCME water quality objectives for the protection of aquatic life.

Discharged effluent may also contain nitrogenous compounds (from blasting residues), which may 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 Oakley Creek, with potential changes to benthic invertebrate populations. Given the current low productivity in Oakley Creek, nutrient enrichment may be a positive rather than the 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. 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 ponds and riffle habitat. Follow-up monitoring of metals in sediment and fish tissue will be undertaken to check predictions and improve mitigation, if necessary.

Baseline water chemistry in Oakley Creek and other streams is described in Section 7.5. Given that the likelihood of potential effects is unknown, VNI will be required to monitor effluent and the receiving environment using an EEM program. Benthic invertebrate and fish communities will be monitored on a multi-year cycle to provide data about the effectiveness of the Water Management Plan and the environmental effects of discharges on the benthic community of Oakley Creek. Results will guide decisions on mine practices and monitoring requirements.

At mine closure, the TWRMF will be maintained with a water layer over the tailings and ultramafic waste rock. TWRMF supernatant water will be discharged to the Polishing Pond (PP) and water in the PP will be monitored before it is discharged, if needed, during the first six 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. The likelihood of these effects is not clear and will be subject to monitoring.

Flow Regime Changes in Oakley Creek

Small changes to flow regimes of Oakley Creek are anticipated as a result of discharges from the Polishing Pond. During operations (year 1 through 8), discharges to the Oakley Creek will be approximately 0%, 10%, and 31% of the anticipated average flows in the winter months (Nov.-Apr.), during the freshet (May), and in the summer months (Jun. – Oct.), respectively. Details, including PP discharge flows during year 1 through 8 operations, year 9 and year 10 operations, closure and post closure and are provided and discussed in Section 2.14 (Site Water Management). No water will be discharged to Oakley Creek in the winter months as it is typically frozen solid.

Higher water flow and thus water level will help maintain the existing stream habitat types and limit changes in water quality that can occur during low flow periods, therefore limiting seasonal stresses for periphyton, benthic invertebrates and other biota.

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

7.7.4.5 Cumulative Effects and Significance

It is not expected that multiple localized project impacts on periphyton and benthic invertebrate communities will result in a measurable effect on habitat quality and populations in the regional drainages (Minago River, Cross Lake, William Lake and Limestone Bay).

Other activities within the mine site that may combine with project effects to influence periphyton and benthic invertebrate communities include:

- increased traffic on the PTH6 due to the project with potential for introduction of contaminated runoff (due to potential spills, accidents, and road maintenance) to rivers and creeks such as the William River, the Oakley Creek and the Minago River;
- effects of future mining projects in the same drainages (there are currently no mining projects under review that would incur cumulative effects on periphyton and benthic invertebrate communities in the area); and
- increased risk of forest fires due to mining activity with the potential for sedimentation of instream habitat.

Such effects will be described in more detail in Section 7.8: Fish Resources.

7.7.4.6 Mitigation Measures

Mitigation measures to minimize effects on benthos and periphyton are described in Table 7.7-12.

7.7.4.7 Monitoring and Follow-up

The 2006/2007/2008 benthic and sediment quality baseline studies resulted in the compilation of relevant data for benthic invertebrates and periphyton, as samples were collected from natural substrates at an ecologically relevant time of year and a suitable location within the Local Study Area (LSA) and Regional Study Area (RSA).

Table 7.7-12 Mitigation Measures for Effects in Benthic Invertebrates and Periphyton

Potential Project Effect	Mitigation Measures
Construction	
• Changes in water and sediment quality in Oakley Creek from contaminated construction site runoff, waste rock storage, ore stockpiles	• Implement the Erosion and Sediment Control Plan (Section 9: Environmental Management Plan) and Site Water Management Plan (Section 2.14: Site Water Management) to ensure no contaminated drainage water enters Oakley Creek. Wetlands (bogs) will act as filters.
Operations	
• Changes in Minago River flow regime related to Polishing Pond discharge	• Implement Approved Water Management Plan based on approvals from federal and provincial governments regarding flow conditions in Minago River.
• Changes in water and sediment quality from potential TWRMF seepage to Minago River (metals TSS, nutrient, SO_4)	• Intercept seepage in collection ditches, and recycle back to the TWRMF. Discharge to Minago River will be via the Polishing Pond (PP). • Monitor effluent and receiving water quality and initiate adaptive management as required.
• Changes in water and sediment quality in Minago River from Polishing Pond effluent discharges (metals, TSS, nutrients, SO_4)	• Ensure effluent quality meets MMER objectives for the protection of aquatic life. • Discharge wastewater in accordance with Manitoba and Federal regulations. • Monitor effluent and receiving water quality and initiate adaptive management as required.
• Accumulation of metals in sediment of Minago River with increased potential for bioaccumulation	• Monitor water and sediment quality concentrations in Minago River. If results indicate (an) increasing trend(s), initiate collection of benthic invertebrates and fish for tissue metals analysis. • Apply adaptive management measures, if necessary.
• Changes in Oakley Creek flow regime related to Polishing Pond discharge	• Implement Approved Water Management Plan based on approvals from federal and provincial governments regarding flow conditions in Oakley Creek.
• Changes in water and sediment quality from potential TWRMF seepage to Oakley Creek (metals TSS, nutrient, SO_4)	• Intercept seepage in collection ditches, and recycle back to the TWRMF. Discharge to Oakley Creek will be via the Polishing Pond (PP). • Monitor effluent and receiving water quality and initiate adaptive management as required.
• Changes in water and sediment quality in Oakley Creek from Polishing Pond effluent discharges (metals, TSS, nutrients, SO_4)	• Ensure effluent quality meets MMER objectives for the protection of aquatic life. • Discharge wastewater in accordance with Manitoba and Federal regulations. • Monitor effluent and receiving water quality and initiate adaptive management as required.
• Accumulation of metals in sediment of Oakley Creek with increased potential for bioaccumulation	• Monitor water and sediment quality concentrations in Oakley Creek. If results indicate (an) increasing trend(s), initiate collection of benthic invertebrates and fish for tissue metals analysis. • Apply adaptive management measures, if necessary.

Table 7.7-12 (Cont.'d) Mitigation Measures for Effects on Benthic Invertebrates and Periphyton

Potential Project Effect	Mitigation Measures
Decommissioning	
• Changes in sediment quality in Minago River and Oakley Creek from site runoff where facilities have been removed and/or the ground has been recontoured.	• Implement the Erosion and Sediment Control Plan and Site Water Management Plan (Section 2.14) to ensure no contaminated drainage water enters Oakley Creek or the Minago River. • Reseed recontoured areas as soon as possible.
• Changes in water and sediment quality in Oakley Creek from Polishing Pond effluent discharges (metals, TSS, nutrients, SO_4)	• Ensure effluent quality meets MMER objectives for the protection of aquatic life. • Discharge wastewater in accordance with Manitoba and Federal regulations. • Monitor effluent and receiving water quality and initiate adaptive management as required.
Closure	
• Changes in water and sediment quality of Oakley Creek from ongoing TWRMF	• Adhere to the Mine Closure Plan requirements. • Test of water quality during decommissioning to confirm effectiveness of adaptive management. • Maintain water cover over the disposed tailings and ultramafic waste rock as designed.
All Phases	
• Long-distance transport of metals from effluent discharge, and potential introduction of sediment or contaminants from affected area streams.	• Implement mitigation measures for project-related effects to ensure effects in water and sediment quality are localized and minimize the potential for cumulative effects.

Monitoring Programs

A monitoring program for benthos and sediment quality is proposed in Table 7.7-13. The main monitoring program will be the EEM program required under MMER to determine project effects on benthic communities from the construction, operation and closure phases, and cumulative effects. Periphyton monitoring will be conducted concurrent with the EEM program to provide further description of ecological health. Additional monitoring programs will be undertaken to monitor effects outside the EEM program.

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

Oakley Creek and Minago River streamflows will be monitored to assess predicted effects of hydrologic changes. Monitoring of metal levels in benthic invertebrate tissue will also be undertaken.

7.7.4.8 Summary of Effects

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

Table 7.7-13 Monitoring and Follow-up Programs for Benthic Invertebrates and Periphyton

Potential Project Effect	Program Objectives	General Methods	Reporting	Implementation
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 the Environmental Protection Plan schedule.	• To Manitoba Gov.'t as required following environmental assessment guidelines	• Proponent
Effects of Polishing Pond effluent discharge on benthic invertebrates	• To identify effects of metals and nutrients.	• Conduct an EEM program on 3-year cycle following EEM methods.	• Following reporting schedule according to *Metal Mining Effluent Regulations* (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 (using same methods as were used during the baseline studies).	• Following reporting schedule according to MMER	• Proponent
Accumulation of selenium and other metals in depositional habitat	• To check the 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.	• To Manitoba Gov.'t as required • Following reporting schedule according to MMER	• Proponent
Ability of TWRMF pond to support aquatic life	• To identify potential for bioaccumulation of metals in birds and wildlife.	• Assess phytoplankton, invertebrates and plants in TWRMF pond at closure.	• To Manitoba Gov.'t as required	• Proponent

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

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Construction								
Altered benthic communities resulting from changes in water and sediment quality in Oakley Creek from contaminated construction site runoff, waste rock storage, and ore stockpiles.	Adverse	Low	Site-specific	Short-term, Moderate frequency	Reversible	Unknown	Not significant	N/A
Operations								
Altered benthic communities in Oakley Creek and Minago River from Polishing Pond discharges (metals, TSS).	Adverse	Low	Local	Long-term, Moderate frequency	Reversible	Unknown	Not significant	N/A
Increased benthic productivity in Oakley Creek and Minago River from nitrate and ammonia in effluent discharges.	Positive	Low to Moderate	Local	Medium term, Moderate frequency	Reversible	Unknown	Not significant	N/A

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

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Decommissioning								
Reduced benthic productivity in Oakley Creek resulting from changes in water quality from site runoff where facilities have been removed and/or the ground has been recontoured.	Adverse	Low	Site-specific	Short-term	Reversible	High	Not significant	N/A
Reduced benthic productivity in Oakley Creek resulting from changes in water quality related to Polishing Pond effluent treatment and discharges (metals, nutrients).	Adverse	Low	Site-specific	Medium term	Reversible	High	Not significant	N/A
Closure								
Uptake of metals by invertebrates in the TWRMF, and their consumption by birds and other wildlife.	Adverse	Low	Site-specific	Far future	Reversible	Unknown	Not significant	N/A
Reduced wetted habitat and benthic productivity in Oakley Creek and the Minago River resulting from flow changes related to discontinued discharge of Polishing Pond	Adverse	Low	Site-specific	Long-term, Moderate frequency	Reversible	High	Not significant	N/A

effluent at closure.								

7.8 Fish Resources

This section describes the fish resources of the project area and potential project and cumulative effects on fish. The assessment of effects on fish is based on the assessment of project effects, detailed in Section 7.5: Surface Water Quality; Section 7.7: Periphyton and Benthos; Section 2.16: Transportation; and commitments to environmental protection during construction and operation as outlined in Section 9: Environmental Protection Plan. The potential social and cultural implications of project effects on fish resources are discussed in Section 7.11: Land Use and Tenure (effects on non-traditional fishing activities) and in Section 7.12: First Nations and Traditional Use.

This section discusses the effects of routine project construction and operations on fish resources. Potential effects of accidents and malfunctions are discussed in Section 8: Accidents and Malfunctions.

Fish habitat assessment in rivers, creeks and lakes surrounding the Minago Project was undertaken to determine the presence/absence of fish populations in water bodies and streams likely to be affected by the Minago Project. Fish assessments (fish habitat and abundance) were undertaken by Wardrop (2007) in May and August 2006, by URS (2008b) in May/June 2007, and by Roche Consulting Group (Roche) in May 2008.

Wardrop undertook fisheries assessments at three stations on Oakley Creek and at one station on Minago River in 2006. URS assessed fish habitat and abundance on Oakley Creek, Minago River, and William River at three stations per watercourse. Fish samples were also collected for baseline measurements of metal concentrations in fish in 2007. Roche's work included the installation of two to three bait traps in Oakley Creek, Minago River, and William River and one bait trap and one experimental net each in Cross Lake, Hill Lake and Limestone Bay on Lake Winnipeg. Roche also collected tissue samples in order to evaluate total metal content for 20 individuals (13 predator and 7 prey fish specimens) (Roche, 2008a).

Minago River and Oakley Creek were sampled, because treated effluent from the proposed mining operation may be discharged into the Minago River and Oakley Creek. The William River was surveyed above and below its confluence with Oakley Creek to establish baseline conditions and to determine potential future impacts on William River and Limestone Bay at the north end of Lake Winnipeg.

Table 7.8-1 lists the GPS coordinates (UTM; NAD83) of all fish sampling and monitoring stations. Figure 7.8-1 illustrates the 2006-2008 fish sampling locations on an aerial map, while Figure 7.8-2 provides a close-up view of the sampling locations.

7.8.1 Scope of Fisheries Assessments

The scope of the assessments included inventorying fish habitats in water bodies around the Minago Project, including the Minago, William, and Hargrave Rivers and Oakley Creek. In

Table 7.8-1 Coordinates of Minago 2006-2008 Fish Sampling Locations

Sample Location	UTM Northing	UTM Easting	Description	Sampled by: Wardrop (2007)	URS (2008b)	Roche (2008a) Nets	Roche (2008a) Bait trap
OCF1 & OCW-1	5990528	489238	Oakley Creek immediately east of HW6	X	X		X
OCW-2	5990974	487559	2.2 km upstream of OCW-1	X			
OCF2 - 2007	5990978	487136	Oakley Creek immediately downstream of tributary stream entering from the north		X		
OCF2 - 2008	5990908	487235	approximately 125 m downstream of OCF2-2007				X
OCF3 & OCW-3	5990931	487048	Oakley Creek upstream of confluence of tributary (~ 550 m upstream of OCW-2)	X	X		
MRW2x	6001209	472465	Minago River near Habiluk Lake				X
MRF1 & MRW-1	6005275	488684	Minago River at the Highway 6 crossing, approximately 15 km north of Oakley Creek.	X	X		
MRF2 - 2007	6004902	488527	Minago River tributary immediately west of HW6		X		
MRF2 - 2008	6005007	488562	approximately 25 m downstream of MRF2-2007				X
MRF3	6005308	488362	Minago River location upstream of HW6		X		X
WRF1	5987166	495419	William River approximately one kilometre upstream of Oakley Creek		X		X
WRF2	5986330	498578	William River immediately downstream of Oakley Creek		X		X
WRF3	5973598	484762	William River immediately downstream of Little Limestone Lake outlet stream.		X		X
CLF1	6046198	555324	Cross Lake			X	X
HLF1	6012816	502060	Hill Lake			X	X
LBF1	5969136	503911	Limestone Bay			X	X

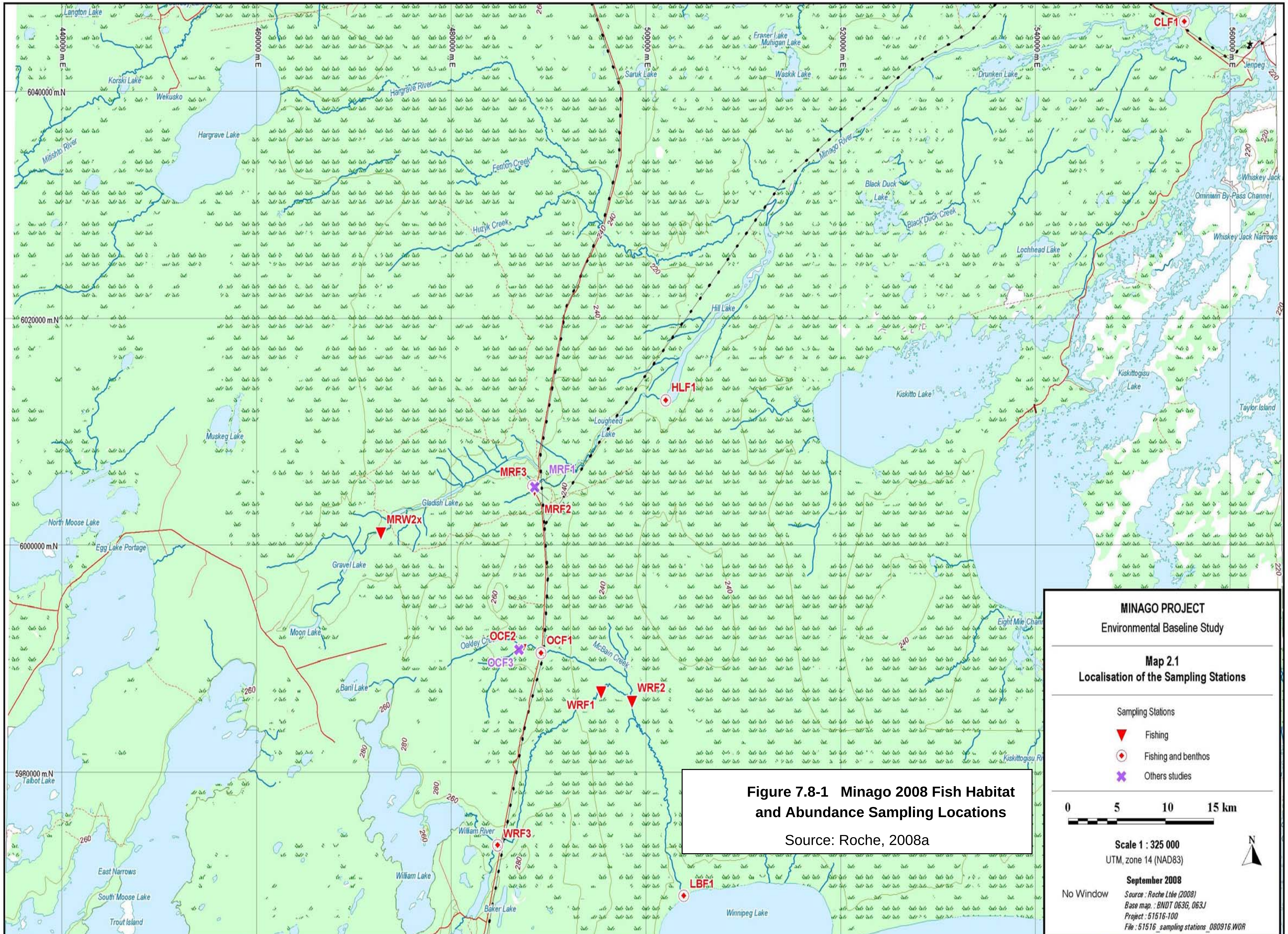
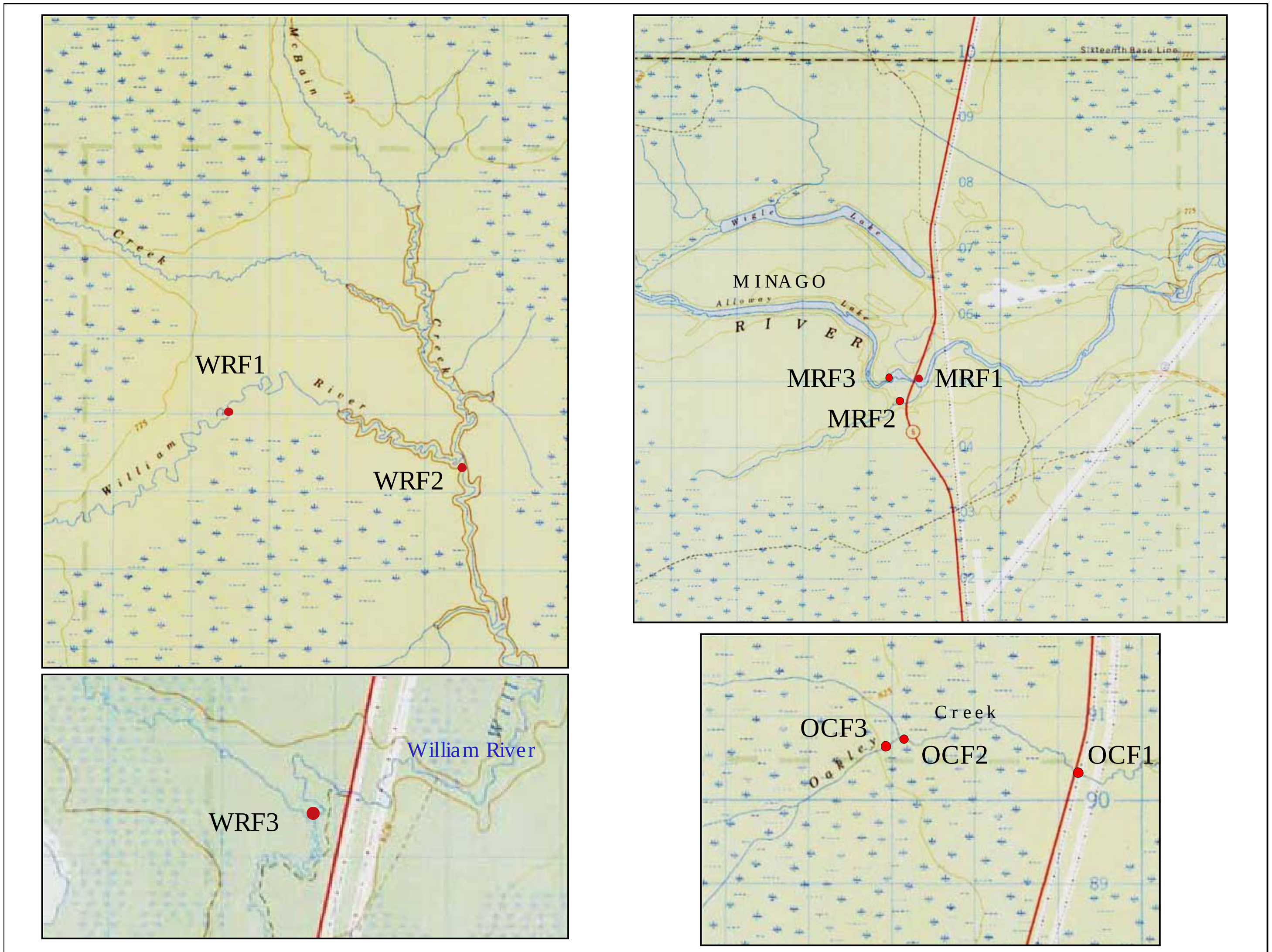


Figure 7.8-1 Minago 2008 Fish Habitat and Abundance Sampling Locations

Source: Roche, 2008a



Source: adapted from URS, 2008b

Figure 7.8-2 Close-up View of the 2007 Fish Sampling Locations

addition, Limestone Bay, Cross Lake, Hill Lake, Little Limestone Lake and William Lake were assessed.

7.8.1.1 Scope of Fisheries Assessments - 2006

Wardrop assessed fish communities at OCW-1 in May 2006 and at OCW-1, OCW-2, OCW-3, and MRW-1 in August 2006 (Table 7.8-1). Electrofishing was conducted by surveying all varieties of habitat present at each sampling station. The length of the survey section and the number of seconds of electrofishing were recorded. Habitat features for each survey length were inventoried. The Catch Per Unit Effort (CPUE) was calculated for each sampling station by dividing the number of fishes caught by the fishing time.

7.8.1.2 Scope of Fisheries Assessments -2007

URS conducted fish habitat and distribution surveys of Oakley Creek (OCF1, OCF2 and OCF3) upstream of Highway 6 and south of the Minago Project area, habitat characterization and fish distribution survey of the Minago (MRF1, MRF2 and MRF3) and William (WRF1, WRF2 and WRF3) Rivers, and an analysis of fish tissue for metals (full ICP scan) from specimens collected at selected sites on Minago River, William River, and Oakley Creek. These fish surveys were undertaken by URS in May and June 2007.

7.8.1.3 Scope of Fisheries Assessments - 2008

Roche Consulting Group assessed fish habitat and abundance by installing eleven (11) bait traps and three experimental nets in areas surrounding the Minago Project (Table 7.8-1 and Figure 7.8-1) (Roche, 2008a).

Three lakes (Cross Lake, Hill Lake and Limestone Bay of the Lake Winnipeg) were sampled in order to establish background levels of contamination for fishes collected within the study area. Fish captured were counted, sacrificed and identified to species. Tissue samples were collected in order to evaluate total metal content (As, Pb, Se and Hg) for twenty specimens. These twenty specimens were also measured, weighed, sexed and their stage of gonad development was determined based on the Nikolsky scale (Appendix 7.8).

Eleven Cuba-Franklin (45 x 20 cm) bait traps were distributed within the study area, one each in Cross Lake, Hill Lake and Limestone Bay of Lake Winnipeg and two to three in each sampled stream (Minago River, Oakley Creek and William River) (Table 7.8-1).

7.8.1.4 Fish Survey Methodologies

Fish survey methodologies are summarized in the Sections below. Details pertaining to specific methodologies are given elsewhere (Wardrop, 2007; URS, 2008b; Roche, 2008a).

7.8.1.4.1 Fisheries Survey - 2006

Wardrop (2007) surveyed fish communities at OCW-1 on May 16, 2006 and at OCW-1, OCW-2, OCW-3, and MRW-1 on August 22-23, 2006, using a Smith-Root LR-24 Electrofisher (Table 7.8-1). Electrofishing was conducted by surveying all varieties of habitat present at each sampling station. The field crew began sampling downstream and worked upstream, dipnetting any stunned fishes. The length of the survey section and the number of seconds of electrofishing were recorded. Fishes were placed in a bucket during the survey and later fixed in 10% buffered formalin. Samples were returned to the Winnipeg Wardrop office for fish identification to species, enumeration, and preservation in 60% isopropyl alcohol. Habitat features for each survey length were inventoried. The Catch Per Unit Effort (CPUE) was calculated for each sampling station by dividing the number of fishes caught by the fishing time.

7.8.1.4.2 Fisheries Survey - 2007

Existing habitat and fish distribution reports, aerial photographs, and topographic maps were used to create maps, which helped determine where field surveys should occur. Topographic maps of the area were downloaded from Topoweb Canada: Manitoba (Softmap 2007), converted to a PathAway 4.0 (Muskoka Tech 2007) file format and loaded onto a Palm Treo 680 PDA. The PathAway mapping application on the Treo 680 was used in conjunction with an EMTAC mini Bluetooth GPS unit to locate positions in the field and record their coordinates.

A Smith-Root 12-B Backpack Electrofisher was used to sample for fish presence/absence at each of the nine sample locations and along roadside ditches and small drainages flowing through the Minago Project area (URS, 2008b). A 100 m reach downstream from each sampling location was electrofished to collect fish specimens.

Fish in all drainages were relatively rare and unevenly distributed. Sample locations selected on Oakley Creek and the Minago River locations had solid substrates or were readily accessible from the bank. The William River had a mud and loose sand substrate at all sample locations, and steep banks that quickly dropped-off into turbid water. Sampling on the William River was confined to carefully sampling from the banks, particularly on side channels and near weed beds. Sampling was opportunistic, because of the uneven distribution of fish and their relative scarcity.

Fish attracted to the anode ring or stunned were dipnetted and placed in a bucket of stream water to which a few drops of clove oil were added to tranquilize the fish. This made it easier to take measurements of the fish. Fish specimens were placed on ice and frozen upon return from the field for later delivery to an accredited laboratory (URS, 2008b). Fish were collected for baseline measurements of metal concentrations in fish tissues at each of the nine sampling locations according to the EPA (2000) protocol. The sampling protocol for fish tissues is provided in Appendix 7.8.

During the 2007 fisheries survey, water temperature and stream flow data were recorded at every sample location. Temperature was recorded in centigrade with a William Joseph digital thermometer. Streamflow measurements in Oakley Creek, William River, and Minago River watersheds were recorded using a Global Water FP101 Flow Probe. Details of the streamflow measurement program are presented in Appendix 7.8.

Collection of fisheries field data began on May 16, 2007, but was interrupted on the first day by equipment failure that required leaving the field and returning on May 31, 2007 (URS, 2008b). Field data collection was completed on June 7, 2007. The fisheries field study was led by Dr. Rob Nielsen (Fish and Wildlife Scientist, URS) and assisted by Bill Kidder (Wetland and Wildlife Scientist, URS) and Ken Budd (Field Assistant from Norway House representing Victory Nickel Inc.). Photographs of the 2007 fisheries assessment are presented in Appendix 7.8.

7.8.1.4.3 Fisheries Survey - 2008

Roche's fisheries survey was completed according to a scientific collection permit (#10-08), issued on April 14, 2008 (Appendix 7.8), under the authority of the *Fisheries Act* (Manitoba) and the Fishing License Regulation and Fishing License Fee Regulation. The inventory was performed by Simon Thibault and Brigitte Dutil from Roche Ltd. for VNI (Roche, 2008a).

Roche characterized fish habitats in terms of:

- water depth;
- substrate characterization;
- Secchi disk water transparency measurements;
- water temperature and pH;
- water conductivity; and
- oxygen concentration in water.

Nine substrate classes were used to characterize the fish habitat: clay, silt, sand, gravel, pebble, cobble, boulder, large boulder, and bedrock. Every substrate size class that was present at a sampling location was noted and reported in order of importance. The distribution and presence of organic detritus, wood debris, aquatic vegetation and algae were also noted.

The shore characteristics were also recorded in May 2008. However, since shores were still covered with snow or ice, their description was not as precise as it could have been during summer months. The height of the embankment was visually estimated. Vegetation present on the shore was briefly described. Surface materials (using the above mentioned substrate classes) and dead trees present on the shore were characterized and reported in order of importance.

Experimental nets were installed at three different stations, one each in Cross Lake, Hill Lake and Limestone Bay of Lake Winnipeg (Figure 7.8-3). The experimental gill nets used were 45.7 m long, 1.8 m high, and were made of six consecutive panels of equal length (7.6 m) with stretched mesh size varying between 25 and 102 mm. The nets in Hill Lake and Limestone Bay were installed on May 6, 2008 while the net in Cross Lake was installed on May 8, 2008. All nets were left in place for one night (Roche, 2008a).

Source: Roche, 2008a

Figure 7.8-3 Bait Trap Set at MRW2x (Minago River; left) and Experimental Net Set at LBF1 (Limestone Bay; right)

Eleven Cuba-Franklin (45 x 20 cm) bait traps were distributed within the study area (Figure 7.8-3). The Cuba-Franklin bait traps had a circular aperture of 4 cm at each extremity. Bread and cat food (salmon-flavoured) were put in the traps as bait. One bait trap each was installed in Cross Lake, Hill Lake and in Limestone Bay of the Lake Winnipeg and two to three in each of the sampled streams (Minago River, Oakley Creek and William River) (Table 7.8-1). The bait traps were left in place for one night (Roche, 2008a).

Fish captured were counted, scarificed and their respective species were identified. Twenty specimens were measured, weighed, sexed and their stage of gonad development was determined based on the Nikolsky scale before their flesh was collected (Figure 7.8-4). The twenty specimens consisted of 13 predators (4 Walleyes, 7 Northern pikes, 2 Yellow perch) and seven preys (3 White suckers, 4 Longnose suckers). Tissue samples were collected from these specimens in order to evaluate total metal content (As, Pb, Se, and Hg) (Roche, 2008a).

7.8.2 Baseline Conditions

Baseline conditions for the waterbodies around the Minago Project were assessed to determine the pre-development environmental conditions and fisheries inventories in terms of population size and species distribution.

Source: Roche, 2008a

Figure 7.8-4 Fish Dimensional Measurements

7.8.2.1 Baseline Fish Habitat

Fish habitat surveys were undertaken in the waterbodies around Minago Project. The water bodies included Oakley Creek, Minago River, William River, Hargrave River, Cross Lake, Limestone Bay of Lake Winnipeg, Cross Lake, Hill Lake, Little Limestone Lake and William Lake.

7.8.2.1.1 Fish Habitat Survey - 2006

Wardrop found that fish habitat at OCW-1 was the most diverse and provided the best quality in relation to the other Oakley Creek stations OCW-2 and OCW-3 (Wardrop, 2007). The streambed at OCW-1 was dominated by cobble, gravel, and boulder substrate with smaller proportions of sand, bedrock, and fines. Habitat components, cover, and substrate at OCW-1 were diverse, providing potential spawning, rearing, migration, and adult feeding habitat for large-bodied fishes. Upstream of Highway 6, the stream gradient decreased and the stream was characterized by numerous channels and ponds. As well, intense beaver activity had resulted in 14 dams between Highway 6 and OCW-3. Habitat upstream of Highway 6 was relatively consistent, characterized by beaver ponds and deep, narrow channels predominantly underlain by a substrate of organic matter and fines. Areas of sand, gravel, and cobble occurred incidentally. Habitat quality was below that of OCW-1, with low quality habitat for adult, large-bodied fishes, particularly with respect to spawning, and adult feeding.

The Minago River at MRW-1 is characterized by a broad, deep flat streambed that discharges over a shelf of bedrock, through a short set of rapids, into a downstream flat (Wardrop, 2007; Appendix 7.8). The rapids are formed by large, angular boulders that form a riffle in high water and a boulder garden in low water. The substrate at station MRW-1 is primarily bedrock covered with large (> 100 mm) angular rocks.

Photographs of the 2006 fish monitoring locations are given in Appendix 7.8.

7.8.2.1.2 Fish Habitat Survey - 2007

Oakley Creek

The stream channel of Oakley Creek primarily exists as a deep and sinuous, steep-sided channel (glide) traversing beaver ponds and areas of floodplain that were created by former beaver ponds that have become vegetated with a shrub habitat. With the exception of a few patches of cobble at riffles, the substrate consists entirely of mud and silt. Aquatic plants, such as spatter-dock (*Nuphar luteum*) are relatively common in the channel, but aquatic weed beds are only present in the beaver ponds (URS, 2008b).

The surveyed portions of Oakley Creek were divided into 9 stream reaches, based on changes in physical characteristics, such as average channel width or depth and average floodplain width. A total of 15 beaver dams were recorded by URS (2008b). The locations of the stream reaches are presented in Figures 7.8-5 and 7.8-6. Survey data for the 9 stream reaches and the surface channel of the north tributary is given in Table 7.8-2. The locations of the beaver dams is detailed in Table 7.8-3.

With the exception of reaches 1 and 9, which have a mix of riffle and glide habitat, riffle habitat is confined to immediately below beaver dams. Beaver dams often were broad, crossing much of the floodplain and with several outlets. Although deep (up to 3.6 m deep) at the dams, the ponds quickly became shallow and filled with emergent wetland vegetation and multiple side channels (URS, 2008b).

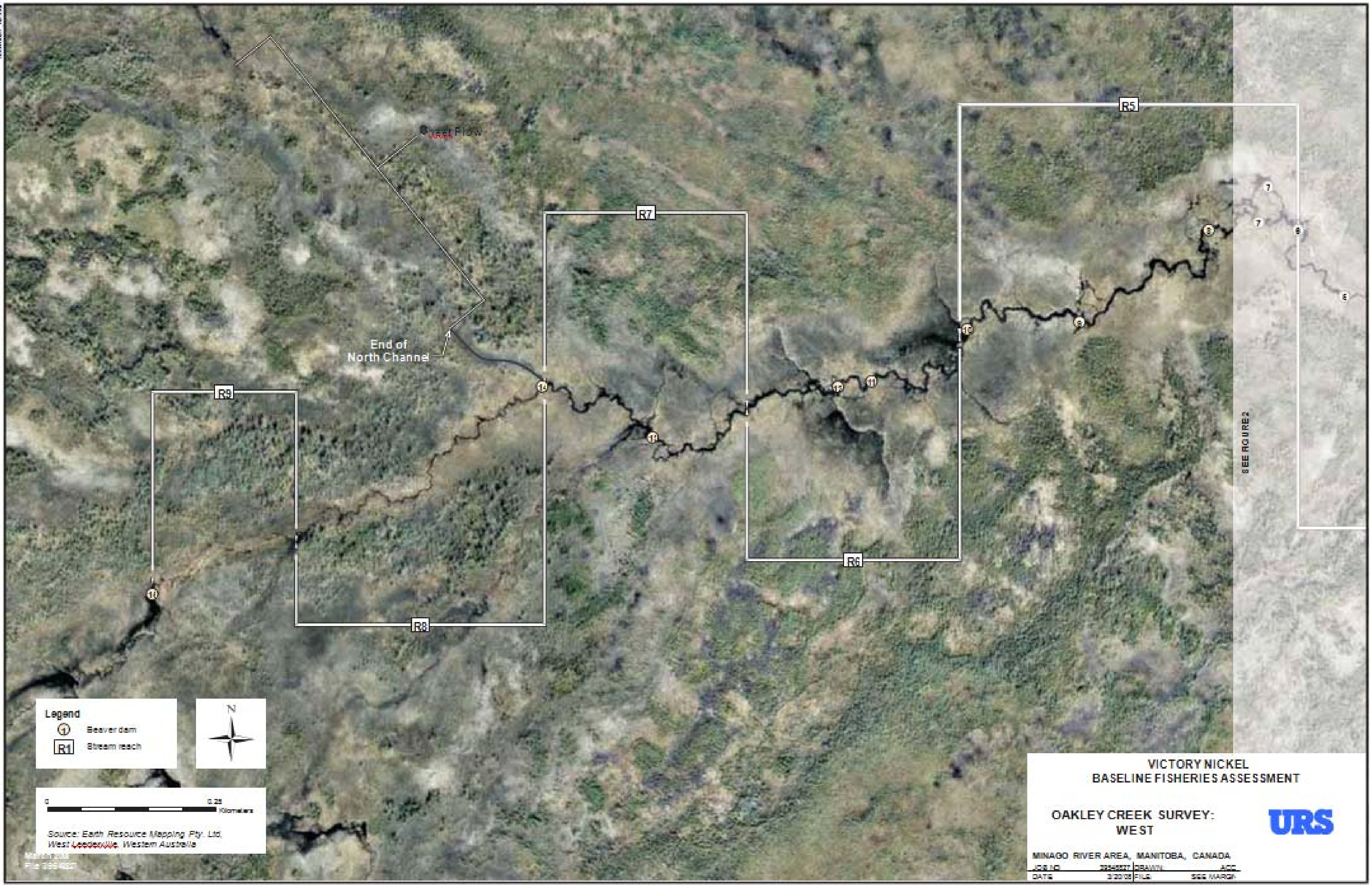
With the exception of areas in the back of larger beaver dams that were vegetated with emergent wetland vegetation of sedge, rushes, herbs, and grasses; the broad floodplain was vegetated primarily by a deciduous shrub vegetation dominated by myrtle-leaved willow (*Salix myrtillfolia*). The emergent wetland vegetation was dominated by beaked sedge (*Carex ultriculata*) and water sedge (*Carex aquatilis*). The edge of the floodplain consisted of intermediate closed evergreen forest dominated by black spruce with some tamarack (*Larix laricina*) present and a shrub community of diamond leaf willow (*Salix planifolia*), green alder (*Alnus crispa*), and small paper birch (*Betula papyrifera*) (URS, 2008b).

William River

At all three William River stations (WRF1, WRF2, WRF3) surveyed in 2007, William River has relatively steep streambanks and the stream channel floodplain is incised about 1.2 to 2.4 m below the surrounding forested area (URS, 2008b). The river flows through a closed canopy

Source: URS, 2008b

Figure 7.8-5 Oakley Creek Fish Survey Reaches (East)



Source: URS, 2008b

Figure 7.8-6 Oakley Creek Fish Survey Reaches (West)

Table 7.8-2 Oakley Creek Stream Reach Data (May and June, 2007)

Oakley Creek Stream Reach	Length (m)	Distance Endpoint is Upstream of Highway 6 (m)	Bank Full Width (m)	Average Depth (m)	Glide/Riffle ratio	Length of side channels (m)	Average Floodplain Width (m)
1	551	106	3.2	0.8	50/50	160	90
2	383	489	8	0.8	100/0	110	120
3	698	1,187	4.8	1.3	100/0	488	120
4	708	1,895	3.5	1.1	100/0	230	140
5	893	2,788	6.5	1.2	100/0	670	250
6	558	3,346	6.5	0.7	100/0	1,030	290
7	479	3,825	5	0.6	95/5	890	185
8	587	4,412	2.5	0.5	90/10	40	60
9	275	4,687	1	0.3	60/40	271	30
North Tributary	59	3,884	1	0.15	95/5	0	22

Source: URS, 2008b

Table 7.8-3 Location of Oakley Creek Beaver Dams

Beaver Dam No.	Distance upstream of Highway 6 (m)
1	106
2	237
3	371
4	1454
5	1691
6	1895
7	1992
8	2151
9	2527
10	2788
11	3073
12	3154
13	3573
14	3825
15	4687

Source: URS, 2008b

Note: Beaver dam locations are illustrated in Figures 7.8-5 and 7.8-6.

forest dominated by black spruce (*Picea mariana*) and white spruce (*Picea glauca*). The floodplain was mostly nonexistent, but where present, consisted of a shrub community. The river channel is a deep and sinuous, steep-sided channel (glide) with a substrate composed primarily of silt and organic debris at sample locations WRF1 and WRF2 and silt and sand at sample location WRF3 (URS, 2008b). The river channel varies between about 8 and 14 m in width and 1 to 2 m in depth. Streambanks are steep and there were no gravel bars and few side channels present. Perhaps due to the close proximity of large streambank trees, log-jams and large wood debris are common throughout the river. Aquatic plants are abundant and weedbeds occur frequently, wherever the river becomes less than a metre deep.

Due to a high silt load, the William River has relatively high turbidity during high flows. During the late spring and summer months, the outlet stream of Little Limestone Lake (a large marl lake) discharges a heavy load of calcite precipitates into the William River (URS, 2008b).

Minago River

The sample locations chosen by URS for the Minago River fish monitoring stations were clustered near Highway 6 (Figures 7.8-1 and 7.8-2) (URS, 2008b). Sample location MRF1 was located in the pool and riffle immediately downstream from the Highway 6 Bridge. Sample location MRF2-2007 was on a small tributary of the Minago River just west of Highway 6 and MRF3 was located at the head of a large pool approximately 550 m west of Highway 6.

The Minago River flows through a broad floodplain with an average width of about 500 m. At the Minago River sampling locations MRF1 and MRF3, the river flows over limestone cobble into a large pool. Substrate consists of large limestone cobble in the riffles and sand and silt in the pools. Riffle habitat has an average width of about 40 m and a depth of up to about 1 m. Pool habitat had an average width of about 90 m and a depth of up to 3 m (URS, 2008b).

Minago River flows through a burn area, with deciduous forest along the riparian zone/floodplain and a jack pine (*Pinus banksiana*) forest above the floodplain incision. The shoreline frequently has shallow areas filled with aquatic vegetation along both the riffle and pool habitat. Riffle and pool habitat in the vicinity of Highway 6 was roughly evenly divided, but much of the river observed from a helicopter over-flight consisted of glide and pool habitat, with several long, narrow lakes. No barriers to fish migration were observed on the Minago River in the vicinity of the project area (URS, 2008b).

The small tributary of the Minago River at sample location MRF2-2007 flows out from a burned-over jack pine plateau to the Highway 6 roadside and then into the Minago River. The reach that was sampled flows through an area of deciduous forest and shrubs. The tributary has an average width of 3 metres and an average depth of about 0.5 metre. The pool/riffle ratio was about 50/50, with many of the pools filled with aquatic weeds. The stream channel was relatively straight, with a gravel and cobble substrate in the riffles and a combination of cobble gravel, sand, and silt in the pools.

Table 7.8-4 presents the streamflow and temperature conditions encountered during the 2007 fisheries program.

Table 7.8-4 Flow and Temperature Data for the 2007 Fisheries Program

SAMPLE LOCATION	DATE	FLOW (m^3/s)	TEMPERATURE (^oC)
OCF1	30-May-07	2.0	16.0
OCF2-2007	03-Jun-07	1.7	19.6
OCF3	03-Jun-07	0.8	20.2
MRF1	30-May-07	7.9	15.8
MRF2-2007	30-May-07	0.33	17.4
MRF3	04-Jun-07	7.9	15.8
WRF1	06-Jun-07	3.2	18.0
WRF2	06-Jun-07	5.0	17.8
WRF3	04-Jun-07	3.0	17.8

Source: URS, 2008b

7.8.2.1.3 Fish Habitat Survey - 2008

Table 7.8-5 describes the main fish habitat encountered by Roche in 2008.

7.8.2.2 Baseline Fish Distribution

Detailed results of the 2006, 2007 and 2008 fish distribution surveys are presented and discussed below. A complete list of fish potentially present in the William and Minago River watersheds is presented in Tables 7.8-6 and 7.8-7. Table 7.8-6 summarizes the scientific and common names of these fishes and Table 7.8-7 details their trophic guild and approximate distribution.

Most of the fishes listed in Tables 7.8-6 and 7.8-7 are small, stream resident insectivors (insect eaters) or Omnivores (eating plants and small insects or crustaceans). The Channel catfish and the Northern pike are the only resident Piscivores (fish eating) fish to occur in the streams. Resident Northern pike are probably confined to the mainstream rivers, with Northern pike entering tributary streams to spawn in the early spring, soon after ice-out.

In addition to the above documented distribution of fishes in the three surveyed streams, additional information is available from two major Manitoba or Lake Winnipeg specific references, entitled 'The fish and fishes of Lake Winnipeg, the first 100 years' (Franzin *et al*. 2003) and 'The freshwater fishes of Manitoba' (Stewart and Watkinson 2004). These references document the presence of stream resident carp (*Cyprinus carpio*), Fathead minnow (*Pimephales promelas*), and Channel catfish (*Ictalurus punctatus*) in the lower reaches of the William River. They also indicate that resident stream populations of Blackchin shiner (*Notropis heterodon*), Spottail shiner

(*Notropis hudsonius*), Longnose dace (*Rhinichthys catractae*), Trout-perch (*Percopsis omiscomaycus*),

Table 7.8-5 *In Situ* Physical Parameters for the 2008 Fish Survey Program

Stations	Water Body	Fishing Equipment	Geographical Coordinates X (mE)	Geographical Coordinates y (mN)	Type of Substrate	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Temperature (°C)	Secchi Disk (m)	Water Depth (m)
CLF1	Cross Lake	Net	555 324	6 046 198	Mud, clay	91.7	11.91	178.3	7.9	4.2	1.08	4.20
		Bait trap									-	0.77
HLF1	Hill Lake	Net	502 060	6 012 816	Mud, clay	91.8	10.85	151.7	7.7	8.1	1.70	1.70
		Bait trap									-	0.80
LBF1	Limestone Bay	Net	503 911	5 969 136	Organic, clay	94.8	12.10	240.0	8.0	5.0	0.29	1.20
		Bait trap									-	0.70
MRF2	Minago River	Bait trap	488 562	6 005 007	Mud, herbs	54.5	6.57	124.5	7.5	7.2	-	0.58
MRF3	Minago River	Bait trap	488 362	6 005 308	Mud, dead trunk	83.2	10.27	134.0	7.5	6.8	-	0.54
MRW2x	Minago River	Bait trap	472 465	6 001 209	Mud, clay	88.4	10.20	300.0	7.8	9.0	-	0.32
OCF1	Oakley Creek	Bait trap	489 238	5 990 528	Mud, clay, herbs	81.1	10.83	230.0	7.7	3.1	-	0.66
OCF2	Oakley Creek	Bait trap	487 235	5 990 908	Mud, clay, herbs	73.0	9.16	290.0	7.7	5.9	-	0.75
WRF1	William River	Bait trap	495 419	5 987 166	Mud, clay, herbs	95.7	11.50	360.0	8.2	7.4	-	0.27
WRF2	William River	Bait trap	498 578	5 986 330	Mud, clay, herbs	93.9	11.49	260.0	8.2	6.7	-	0.34
WRF3	William River	Bait trap	484 762	5 973 598	Mud, gravel, herbs	84.8	10.35	290.0	8.3	6.6	-	0.26

Source: adapted from Roche, 2008a

Table 7.8-6 Scientific and Common Names of Fish Potentially Present in William and Minago River Watersheds

SCIENTIFIC NAME	COMMON NAME
Cyprinidae: Minnows	
Cyprinus carpio	Common carp
Margariscus margarita	Pearl dace
Notropis atherinoides	Emerald Shiner
Notropis heterodon	Blackchin shiner
Notropis heterolepis	Blacknose shiner
Notropis hudsonius	Spottail shiner
Pimephales promelas	Fathead minnow
Rhinichthys cataractae	Longnose dace
Catostomidae: Suckers	
Catostomus catostomus	Longnose sucker
Catostomus commersoni	White sucker
Ictaluridae: Catfishes	
Ictalurus punctatus	Channel catfish
Esocidae: Pikes	
Esox lucius	Northern pike
Umbridae: Mudminnows	
Umbra limi	Central mudminnow
Osmeridae: Smelts	
Osmerus mordax	Rainbow smelt
Percopsidae: Trout-perches	
Percopsis omiscomaycus	Trout-perch
Gasterosteidae: Sticklebacks	
Culaea inconstans	Brook stickleback
Cottidae: Sculpins	
Cottus bairdi	Mottled sculpin
Cottus cognatus	Slimy sculpin
Percidae: Perches	
Etheostoma exile	Iowa darter
Etheostoma nigrum	Johnny darter
Sander vitreus	Walleye

Source: URS, 2008b

Note: Common and Scientific names derived from Nelson et al. (2004)

Table 7.8-7 Trophic Guild and Approximate Distribution of Fish Potentially Present in the William and Minago Rivers

COMMON NAME	TROPHIC GUILD	DISTRIBUTION
Common carp	Omnivore	Resident in low velocity habitat of lower William River
Pearl dace	Insectivore	Resident in surveyed portion of Oakley Creek and associated beaver ponds. Captured in Minago River in large pool upstream of Highway 6.
Emerald Shiner	Zooplanktivore	Lake Winnipeg Emerald shiners spawn in low velocity habitat of the William River.
Blackchin shiner	Insectivore	May occur as resident in low velocity habitat in William River.
Blacknose shiner	Insectivore	Resident in William River and Oakley Creek.
Spottail shiner	Insectivore	Resident in mainstem William and Minago Rivers (associated with weedbeds).
Fathead minnow	Omnivore	Resident in low velocity habitat of lower William River.
Longnose dace	Insectivore	May occur as resident in William and Minago Rivers (associated with riffle habitat).
Longnose sucker	Omnivore	Resident and lake-run in William and Minago Rivers.
White sucker	Omnivore	Lake Winnipeg fish spawn throughout William, Minago, and Oakley Creek drainages. Resident fish occur in mainstem William and Minago Rivers.
White sucker (dwarf)	Omnivore	Resident fish in headwater streams and ponds.
Channel catfish	Piscivore	Low velocity habitat in lower William River.
Northern pike	Piscivore	Resident fish occur in Minago and William Rivers and may occur in lower Oakley Creek. Lake Winnipeg fish spawn in William River and Oakley Creek.
Central mudminnow	Insectivore	Resident fish in low velocity habitat of William R., Minago R. & Oakley Creek.
Rainbow smelt	Zooplanktivore	Introduced pelagic fish in Lake Winnipeg, documented to spawn in William River.
Trout-perch	Insectivore	Resident in mainstem Minago and William Rivers (associated with rocky substrates).
Brook stickleback	Insectivore	Resident in low velocity habitat of William R., Minago R. and Oakley Creek.
Mottled sculpin	Insectivore	May occur as resident in riffle habitat of lower William River.
Slimy sculpin	Insectivore	May occur as resident in lower William and Minago Rivers.
Iowa darter	Insectivore	Resident in the Minago River and possibly William River drainage.
Johnny darter	Insectivore	Resident in the William and Minago River drainages.
Walleye	Piscivore	Pelagic fish in Lake Winnipeg, William Lake, and Minago River Lakes. Lake-run fish spawn in William and Minago Rivers and reported to occur in Oakley Creek.

Source: URS, 2008b

Note: Distribution data from project surveys, Wardrop (2007), Crossman and Scott (1973), Stewart and Watkinson (2004), Franzin et al. (2003), and Anderson (2008).

Mottled sculpin (*Cottus bairdi*), and Slimy sculpin (*Cottus cognatus*) are likely to occur within either the William and Minago River drainages (Table 7.8-6).

The 2006-2008 fisheries results are discussed in chronological order in the next sections. A summary of all fishes caught or observed during the 2006-2008 fisheries surveys is presented in Table 7.8-8.

7.8.2.2.1 Fish Community Results (2006 Program)

Wardrop captured a total of 90 fishes on May 16, 2006 (Tables 7.8-8 and 7.8-9) (Wardrop, 2007). Brook stickleback (*Culaea inconstans*) were the dominant species followed by Pearl dace (*Margariscus margarita*) and White sucker (*Catostomus commersoni*; Table 7.8-9). Two adult White suckers were captured and released. Adult suckers (*Catostomus* spp.) were observed in deeper pools of Oakley Creek as far upstream as OCW-2 on 17 May, 2006.

On 22-23 August 2006, Wardrop captured fishes at all sites surveyed (OCW-1, OCW-2, OCW-3 and MRW-1) (Wardrop, 2007). Forty-nine fishes were captured at OCW-1 and species richness increased from three species in May to six in August 2006. Central mudminnow (*Umbra limi*) dominated the catch followed by Brook stickleback, Pearl dace, White sucker, Blacknose shiner (*Notropis heterolepis*) and Johnny darter (*Etheostoma nigrum*). At OCW-2, a total of 49 fishes were captured with Central mudminnow being the dominant species followed by Brook stickleback and Pearl dace. At OCW-3, a total of 17 fishes were captured with the catch being dominated by Brook stickleback followed by Central mudminnow and Pearl dace.

At MRW-1, a total of 56 fishes were captured, with Johnny darter being the dominant species followed by Central mudminnow, White sucker, Iowa darter (*Ethiostoma exile*), and Longnose sucker (*Catostomus catostomus*) (Wardrop, 2007).

Overall, species diversity was greatest at OCW-1 in August 2006, with six species from five families captured (*Umbridae, Cyprinidae, Catostomidae, Gasterosteidae*, and *Percidae*). Five species were captured at MRW-1, representing three families (*Umbridae, Catostomidae*, and *Percidae*). Three species, representing three families (*Umbridae, Cyprinidae, Gasterosteidae*) were captured at OCW-3 in August, 2006 (Table 7.8-9) (Wardrop, 2007).

The order of fish abundance (from high to low) for the Minago fish monitoring stations was as follows: OCW-2, OCW-1 (May, 2006), OCW-3, OCW-1 (Aug., 2006), and MRW-1 (Table 7.8-9).

The greatest Catch Per Unit Effort (CPUE) for a species (5.70 fish/min) was recorded for Brook stickleback at station OCW-1 in May 2006 (Table 7.8-9). However, CPUE decreased to 0.81 fish/min in late summer (August 2006). The CPUE for the other two species present in May 2006, Pearl dace and White sucker, did not differ greatly between May and August 2006. The lowest CPUE for a species (0.05 fish/min) occurred at MRW-1 where a single Longnose sucker was captured in August 2006. At OCW-1 in August, 2006, two species were represented by a single capture: Blacknose shiner (0.07 fish/min) and Johnny darter (0.07 fish/min).

Table 7.8-8 Summary of Fish Species Encountered During Various Surveys (2006, 2007 and 2008)

		OCW-1	OCW-1	OCF-1	OCW-2	OCF2 2007	OCF2 2008	OCW-3	OCF-3	MRW-1	MRF1	MRF2	MRF3	WRF1	WRF2	WRF3	Hill Lake	Limestone Bay	Cross Lake
Scientific Name	**Common Name**	**16 May, 2006**	**22-23 August, 2006**	**May 16 & 31 & Jun. 7, 2007**	**22-23 August, 2006**	**May 16 & 31 & Jun. 7, 2007**	**May 6-8, 2008**	**22-23 August, 2006**	**May 16 & 31 & Jun. 7, 2007**	**22-23 August, 2006**	**May 16 & 31 & Jun. 7, 2007**	**May 16 & 31 & Jun. 7, 2007**	**May 16 & 31 & Jun. 7, 2007**	**May 16 & 31 & Jun. 7, 2007**	**May 16 & 31 & Jun. 7, 2007**	**May 16 & 31 & Jun. 7, 2007**	**May 6-8, 2008**		
Umbra limi	Central mudminnow		19	Present	20			5	Present	13	Present	Present		Present					
Notropis heterolepis	Blacknose shiner		1													Present			
Notropis atherinoides	Emerabld shiner													Present	Present				
Margariscus margarita	Pearl dace	9	11		13	Present	4	4			Present		Present						
Catostomus commersoni	White sucker	3	5	Present		Present			Present	8		Present					7		
Catostomus catostomus	Longnose sucker									1								5	
Culaea inconstans	Brook stickleback	78	12	Present	16	Present	3	8	Present					Present	Present				
Etheostoma nigrum	Johnny darter		1							28				Present	Present	Present			
Etheostoma exile	Iowa darter									6			Present						
Notropis atherinoides	Emerabld shiner													Present	Present				
Osmerus mordax	Rainbow smelt														Present		2	1,028	
Esox lucius	Northern pike																19	67	27
Sander vitreus	Walleye																19	1	
Perca flavescens	Yellow perch																2		6
Sculpin sp.																	1		

Source: Wardrop, 2007; URS, 2008b; Roche, 2008a.

Table 7.8-9 Summary of Fish Community and Abundance for the 2006 Survey

Scientific Name	Common Name	OCW-1 Number Captured	OCW-1 Catch per Unit Effort (fish/min)	OCW-1 Number Captured	OCW-1 Catch per Unit Effort (fish/min)	OCW-2 Number Captured	OCW-2 Catch per Unit Effort (fish/min)	OCW-3 Number Captured	OCW-3 Catch per Unit Effort (fish/min)	MRW-1 Number Captured	MRW-1 Catch per Unit Effort (fish/min)
		16 May, 2006	Fishing Time: 821 min	22-23 August, 2006	Fishing Time: 890 min	22-23 August, 2006	Fishing Time: 304 min	22-23 August, 2006	Fishing Time: 271 min	22-23 August, 2006	Fishing Time: 1294 min
Umbra limi	Central mudminnow			19	1.28	20	3.95	5	1.11	13	0.6
Notropis heterolepis	Blacknose shiner			1	0.07						
Margariscus margarita	Pearl dace	9	0.66	11	0.74	13	2.57	4	0.89		
Catostomus commersoni	White sucker	3	0.22	5	0.34					8	0.37
Catostomus catostomus	Longnose sucker									1	0.05
Culaea inconstans	Brook stickleback	78	5.7	12	0.81	16	3.16	8	1.77		
Etheostoma nigrum	Johnny darter			1	0.07					28	1.3
Etheostoma exile	Iowa darter									6	0.28
	Total	90	**6.58**	49	**3.3**	49	**9.67**	17	**3.76**	56	**2.6**
	Mean		**2.19**		**0.55**		**3.22**		**1.25**		**0.52**

Source: adapted from Wardrop, 2007

7.8.2.2.2 Fish Community Results (2007 Program)

URS found that lake-run White suckers (*Catostomus commersoni*) were abundant throughout the distance of Oakley Creek surveyed by canoe and schools of large adult White sucker spawners were observed during an over-flight by helicopter as far upstream as the end of stream reach 8 (URS, 2008b). URS (2008b) assumed that lake-run White suckers spawn as far upstream as beaver dam 15 at the end of reach 9 (Table 7.8-3 and Figure 7.8-6). No schools of large White suckers were observed from the air in beaver ponds or channels above beaver dam 15, but resident fishes may be present. Large lake-run White suckers were not observed in the mainstream William and Minago Rivers and it is possible that most of them may have been spawning in more headwater reaches of those rivers or their tributary streams. In addition to large White sucker spawners from Lake Winnipeg (and possibly the lower William River), field crews captured a dwarf resident form of the White sucker that occurs in headwater streams and beaver ponds. Dwarf White suckers were captured in both the Oakley Creek and in the tributary of the Minago River at sample location MRF2-2007.

Other than White suckers, the only other lake-run fish captured were Emerald shiners (*Notropis atherinoides*), which were collected at sample locations WRF1 and WRF2. A single Rainbow smelt (*Osmerus mordax*) was also collected at sample location WRF2.

With the exception of Walleye, Northern pike, Rainbow smelt, Emerald shiner, White sucker, and longnosed sucker (*Catostomus catostomus*), all other fish species present in the sampled watersheds are resident (non-migratory) fish. Although the two sucker species and the Northern pike may also be residents in larger streams; Rainbow smelt are strictly a lake species and Walleye and Emerald shiners are probably confined to lakes within the surveyed drainages.

The spawning migrations of Walleye (*Sander vitreus*) and Northern pike (*Exox lucius*) from Lake Winnipeg (Oakley Creek and the William River) and Hill Lake (Minago River) were over before URS began sampling in May/June 2007. Lake-run fish of these two species were not present at the locations sampled. Walleye enter the streams in the surveyed watersheds for a few weeks in early spring to spawn and quickly migrate back down to Lake Winnipeg or Hill Lake (or other lakes in the Minago River system).

Following is a list of species collected during the 2007 fish sampling program by URS:

- OCF1: Central mudminnow, Brook stickleback (*Culaea inconstans*), and White sucker (both lake-run and dwarf resident);
- OCF2-2007: Brook stickleback, White sucker (both lake-run and dwarf resident), and Pearl dace (*Margriscus margrita*);
- OCF3: Central mudminnow, Brook stickleback, and lake-run White sucker,
- MRF1: Central mudminnow and Pearl dace;
- MRF2-2007: Central mudminnow and dwarf White sucker;
- MRF3: Pearl dace and Iowa darter (*Etheostoma exile*);

- WRF1: Central mudminnow, Brook stickleback, Emerald shiner, and Johnny darter (*Etheostoa nigrum*);
- WRF2: Brook stickleback, Johnny darter, Emerald shiner, and Rainbow smelt; and
- WRF3: Johnny darter and Blacknose shiner (*Notropis heterolepis*).

Anecdoctal Observations

Mr. Jonathan Anderson (2008), a trapper and commercial fisherman whose trap line is within the project area, observed Walleye in Oakley Creek immediately below Highway 6 in the spring of 2006. This indicates that spawning Walleye from Lake Winnipeg travel as far upstream in the Oakley Creek drainage as Highway 6. Mr. Greg King (2007) (a retired Manitoba Conservation employee who owns a boat repair shop in Grand Rapids, Manitoba) stated that the majority of north basin Lake Winnipeg Walleye spawn over clean sandy substrates in Limestone Bay, but that some Walleye also spawn in the William River drainage. Mr. Don MacDonald (2007), a biologist with the Manitoba Conservation Northeastern Region at Thompson, Manitoba, confirmed this and stated that Northern pike are also resident in the William and Minago Rivers and that Walleye are present in Hill Lake and other Minago River lakes.

7.8.2.2.3 Fish Community Results (2008 Program)

Roche caught a total of 1184 fishes using experimental nets installed in Cross Lake, Hill Lake and Limestone Bay of Lake Winnipeg between May 6-9, 2008 (Table 7.8-10) (Roche, 2008a). Rainbow smelts (*Osmerus mardax*) represented 86.8% of all fishes caught at station LBF1 and 86.99% of the overall May 2008 catch. Northern pikes (*Esox lucius*) were the second most abundant species, representing 9.5% of the overall catch. Northern pikes represented 73.3% of the non rainbow smelt species caught.

Table 7.8-10 Fishing Net Results for the 2008 Program

Species	Hill Lake		Limestone Bay		Cross Lake	
	Number	%	Number	%	Number	%
Northern pike	19	38.0	67	6.1	27	81.8
Walleye	19	38.0	1	0.1	0	0.0
Yellow perch	2	4.0	0	0.0	6	18.2
White sucker	7	14.0	0	0.0	0	0.0
Rainbow smelt	2	4.0	1,028	93.4	0	0.0
Sculpin sp.	1	2.0	0	0.0	0	0.0
Longnose sucker	0	0.0	5	0.5	0	0.0
TOTAL	50	100	1,101	100	33	100

Source: Roche, 2008a

During the 2008 fish survey, only 3 Brook sticklebacks (*Culaea inconstans*) and 4 Pearl daces (*Margariscus margarita*) were caught using bait traps. These species were all caught at station OCF2-2008.

7.8.2.3 Fish Tissue Metal Concentrations

This section discusses the metal concentrations in fish tissues for the baseline program. Detailed 2007 and 2008 baseline fish tissue metal concentrations are presented after these introductory remarks.

To assess the effects of contaminants on tissues, the critical body residue is frequently used. The tissue body burden or critical body residue (CBR) is based on the premise that toxicity occurs when the concentration of a chemical reaches a certain critical value. However, the CBR concept is supported only by studies of organic chemicals that exert their toxicity by narcosis. With metals, there is less of a relationship between tissue residue concentrations and effects (URS, 2008b). In addition, studies conducted on laboratory test species cannot be generalized to other species because different organisms have different sensitivities. Nevertheless, the U.S. Army Corps of Engineers (USACE) has compiled a database of information on CBRs, which includes metals. This database is the Environmental Effects Residue Database (ERED) (USACE, 2008). The ERED contains concentrations of metals as well as other chemicals associated with effects and no-effects from selected bioassays (URS, 2008b).

Several metals, such as chromium, cobalt, copper, manganese, molybdenum, nickel, selenium, and zinc are essential trace elements that can cause symptoms of deficiency when present below minimum daily requirements (MDRs) and can be toxic when exposures exceed physiological needs. The chemicals antimony, arsenic, cadmium, lead, mercury, strontium, thallium, and vanadium have no known metabolic requirements. Such chemicals produce toxicity by supplanting essential micronutrients from their normal roles. Nevertheless, non-essential chemicals have always been components of the environment without apparent adverse effects. This is because small amounts are insufficient to disrupt normal physiological functions and the body has also evolved other mechanisms for dealing with non-essential metals. Toxicity only occurs when the capacity of the body to adapt is overwhelmed by the dose received. It should be noted that the dose to body tissues is dependent to a large extent on the bioavailability of the contaminant (URS, 2008b).

The following facts should be kept in mind when reviewing measured concentration and effects levels (URS, 2008b):

- all organisms acquire larger concentrations of non-essential metals as they age, but concentrations of essential elements typically do not increase with age;
- some organisms are better regulators of essential element concentrations than others;
- normal concentrations of essential and non-essential elements vary in different organisms;

- there is no causal relationship between whole body metal concentration in an organism and adverse effects because metal-binding proteins and amino acids are produced as required, except when overwhelmed by acutely toxic conditions;
- elements tend to accumulate in particular target organs; and
- metal cations compete for uptake sites and single metal body residues cannot be causally related to effects from multiple metal exposures.

7.8.2.3.1 Fish Tissue Metal Concentrations for the 2007 Program

Results of 2007 Minago fish tissue analyses are presented in Table 7.8-11 for Oakley Creek, in Table 7.8-12 for Minago River, and in Table 7.8-13 for William River (URS, 2008b). A summary of 2007 fish tissue metal concentrations and published toxicity threshold levels is given in Table 7.8-14. Laboratory certified reports for metals present in fish tissues are presented in Appendix L7.8.

All species examined during the 2007 fisheries program exhibited concentrations of aluminum (Al), barium (Ba), manganese (Mn), and zinc (Zn) within the effects range of these elements and these levels of concentrations were found in all three watersheds sampled (Table 7.8-14). Only aluminum and zinc concentrations in examined specimens exceeded published threshold levels. None of the concentrations measured exceeded the 2007 Canadian Food Inspection Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products (Table 7.8-14). All examined fish tissue samples were relatively small with a maximum weight of 45.4 g.

The concentrations did not significantly increase as sample locations moved downstream. It is likely that in most cases, concentrations of the four elements (Al, Ba, Mn, and Zn) exceeding thresholds for sublethal effects may be due to ingestion of stream sediments. The four metals are frequently found in fine stream sediments and might have been ingested by small fish while foraging.

An examination of metal concentrations in local stream sediments would likely find a lot of naturally occurring metals that can elevate concentrations in whole fish tissue samples (URS, 2008b). Aluminum, in particular, would likely show elevated concentrations if high levels of aluminum oxyhydroxides or hydroxysilicates are present in stream water and sediments (URS, 2008b). This often also applies to barium (URS, 2008b). Bradley (1977) found zinc concentrations in zinc-sensitive whole fish to be no different from those in zinc-insensitive whole fish. Therefore, tissue residues are not causally associated with toxicity.

As discussed in the surface water quality section of this report, aluminum concentrations are indeed elevated in watercourses surrounding the Minago Project.

Table 7.8-11 Summary of Oakley Creek Fish Tissue Analysis (2007 Program)

Location Code	**OCF3**	**OCF3**	**OCF2**	**OCF2**	**OCF2**	**OCF1**	**OCF1**	**OCF1**
Species Code	**MM**	**BS**	**PD**	**BS**	**WS**	**MM**	**BS**	**WS**
Species	**Central mudminnow**	**Brook stickleback**	**Pearl dace**	**Brook stickleback**	**White sucker**	**Central mudminnow**	**Brook stickleback**	**White sucker**
Number in sample	3	2	4	1	2	2	3	2
Sample weight (g)	4.6	2.8	14.9	1.7	27	15.6	2	31.7
Aluminum (Al)	2.0	<1.31	5.0	16.8	<2.08	7.2	11.5	4.0
Antimony (Sb)	<0.00925	<0.00655	<0.0132	<0.010	<0.0104	<0.01085	<0.010	<0.011
Arsenic (As)	0.044	0.009	<0.0132	0.042	<0.0104	<0.01085	0.060	<0.011
Barium (Ba)	0.48	0.36	0.36	2.30	0.43	0.53	1.56	0.35
Beryllium (Be)	<0.0555	<0.0393	<0.0792	<0.10	<0.0624	<0.0651	<0.10	<0.066
Bismuth (Bi)	<0.0555	<0.0393	<0.0792	<0.030	<0.0624	<0.0651	<0.030	<0.066
Cadmium (Cd)	<0.00555	<0.00393	<0.00792	0.0238	<0.00624	<0.00651	0.0165	<0.0054
Chromium (Cr)	<0.0925	<0.0655	<0.132	<0.10	<0.104	<0.1085	<0.10	<0.11
Cobalt (Co)	<0.0185	<0.0131	<0.0264	<0.020	<0.0208	<0.0217	<0.020	<0.022
Copper (Cu)	0.213	0.148	0.237	1.34	0.185	0.184	1.26	0.220
Lead (Li)	0.033	<0.0131	<0.0264	<0.020	<0.0208	<0.0217	<0.020	<0.022
Lithium (Pb)	<0.0925	<0.0655	<0.132	<0.10	<0.104	<0.1085	<0.10	<0.11
Mangnese (Mn)	0.95	3.94	0.97	10.1	0.61	4.10	11.7	0.82
Mercury (Hg)	0.0453	0.0073	0.0136	0.0322	0.0254	0.0170	0.0562	0.0205
Molybdenum (Mo)	<0.00925	<0.00655	0.013	0.037	<0.0104	<0.01085	0.032	<0.011
Nickel (Ni)	<0.0925	<0.0655	<0.132	<0.10	<0.104	<0.1085	<0.10	<0.11
Selnium (Se)	<0.185	<0.131	<0.264	0.20	<0.208	<0.217	0.26	<0.22
Strontium (Sr)	0.67	0.60	0.74	3.93	0.92	0.84	2.79	0.83
Thallium (Tl)	<0.00555	<0.00393	<0.00792	<0.010	<0.00624	<0.00651	<0.010	<0.0066
Tin (Sn)	<0.037	<0.0262	<0.0528	<0.050	<0.0416	<0.0434	<0.050	<0.044
Uranium (U)	<0.00185	<0.00131	<0.00264	0.0028	<0.00208	<0.00217	<0.0020	<0.0022
Vanadium (V)	<0.0925	<0.0655	<0.132	<0.10	<0.104	<0.1085	<0.10	<0.11
Zinc (Zn)	35.3	5.4	9.1	33.2	4.1	35.6	31.3	4.2

Source: URS, 2008b

Notes: Concentrations expressed in mg/kg wwt. Laboratory certified data is presented in Appendix L7.8.

Table 7.8-12 Summary of Minago River Fish Tissue Analysis (2007 Program)

Location Code	**MRF3**	**MRF3**	**MRF2**	**MRF2**	**MRF1**	**MRF1**
Species Code	**ID**	**PD**	**MM**	**WS**	**MM**	**PD**
Species	**Iowa darter**	**Pearl dace**	**Central mudminnow**	**White sucker**	**Central mudminnow**	**Pearl dace**
Number in sample	2	5	1	6	5	2
Sample weight (g)	1.0	2.1	3.9	22.1	45.4	0.6
Aluminum (Al)	26.5	27.8	12.8	4.7	2.4	47.3
Antimony (Sb)	<0.010	<0.010	<0.01125	<0.00945	<0.0107	<0.010
Arsenic (As)	0.123	0.123	0.024	0.013	0.015	0.166
Barium (Ba)	1.04	2.46	0.58	0.35	0.32	2.66
Beryllium (Be)	<0.10	<0.10	<0.0675	<0.0567	<0.0642	<0.10
Bismuth (Bi)	<0.030	<0.030	<0.0675	<0.0567	<0.0642	<0.030
Cadmium (Cd)	0.0142	0.0124	<0.00675	<0.00567	<0.00642	0.0581
Chromium (Cr)	<0.10	<0.10	<0.1125	<0.0945	<0.107	<0.10
Cobalt (Co)	0.033	0.020	<0.0225	<0.0189	<0.0214	0.034
Copper (Cu)	1.08	1.01	0.261	0.285	0.227	1.09
Lead (Li)	<0.020	<0.020	<0.0225	<0.0189	<0.0214	0.039
Lithium (Pb)	<0.10	<0.10	<0.1125	<0.0945	<0.107	<0.10
Mangnese (Mn)	8.54	6.35	6.68	3.36	0.81	11.9
Mercury (Hg)	0.0495	0.0807	0.0101	0.0067	0.0113	0.0538
Molybdenum (Mo)	0.034	0.025	<0.01125	0.011	<0.0107	0.025
Nickel (Ni)	<0.10	<0.10	<0.1125	<0.0945	<0.107	<0.20
Selnium (Se)	<0.20	0.30	<0.225	<0.189	<0.214	0.34
Strontium (Sr)	3.84	7.05	0.99	1.44	1.22	9.28
Thallium (Tl)	<0.010	<0.010	<0.00675	<0.00567	<0.00642	<0.010
Tin (Sn)	<0.050	<0.050	<0.045	<0.0378	<0.0428	0.059
Uranium (U)	<0.0020	<0.0020	<0.00225	<0.00189	<0.00214	0.0033
Vanadium (V)	0.11	0.10	<0.1125	<0.0945	<0.107	0.17
Zinc (Zn)	31.1	50.2	17.4	4.2	14.7	69.9

Source: URS, 2008b

Note: Concentrations expressed in mg/kg wwt. Laboratory certified data is presented in Appendix L7.8.

Table 7.8-13 Summary of William River Fish Tissue Analysis (values expressed in mg/kg wwt) for the 2007 Field Program

Location Code	WRF3	WRF3	WRF1	WRF1	WRF1	WRF1	WRF2	WRF2	WRF2	WRF2
Species Code	JD	BS	ES	BS	JD	MM	RS	BS	ES	JD
Species	Johnny darter	Blacknosed shinner	Emerald shinner	Brook stickleback	Johnny darter	Central mudminnow	Rainbow smelt	Brook stickleback	Emerald shinner	Johnny darter
Number in sample	7	1	1	1	1	1	1	3	10	2
Sample weight (g)	3.6	0.2	0.4	0.4	0.2	0.8	8.7	1.7	5.6	0.8
Aluminum (Al)	8.1	16.5	105	11.1	95.4	79.6	2.1	2.3	11.2	53.9
Antimony (Sb)	<0.009	<0.010	<0.010	<0.010	<0.010	<0.010	<0.00945	<0.0076	<0.01305	<0.010
Arsenic (As)	0.019	0.078	0.165	0.037	0.037	0.107	0.016	0.012	0.043	0.157
Barium (Ba)	0.44	7.42	4.57	1.93	3.14	2.74	0.28	0.33	0.78	2.27
Beryllium (Be)	<0.054	<0.10	<0.10	<0.10	<0.10	<0.10	<0.0567	<0.0456	<0.0783	<0.10
Bismuth (Bi)	<0.054	<0.030	<0.030	<0.030	<0.030	<0.030	<0.0567	<0.0456	<0.0783	<0.030
Cadmium (Cd)	0.0164	0.0308	0.103	0.0362	0.0426	0.0483	0.0081	<0.00456	0.0084	0.0536
Chromium (Cr)	<0.09	<0.10	0.20	<0.10	0.20	0.15	<0.0945	<0.076	<0.1305	<0.10
Cobalt (Co)	<0.018	<0.020	0.052	<0.020	0.064	0.082	<0.0189	<0.0152	<0.0261	0.087
Copper (Cu)	0.200	0.851	1.10	0.548	1.31	1.13	0.091	0.144	0.208	1.45
Lead (Li)	<0.018	0.028	0.061	<0.020	0.063	0.037	<0.0189	<0.0152	<0.0261	0.045
Lithium (Pb)	<0.09	<0.10	0.19	<0.10	0.16	0.12	<0.0945	<0.076	<0.1305	0.12
Mangnese (Mn)	0.82	2.36	8.80	4.71	7.95	9.22	0.43	2.60	1.38	17.5
Mercury (Hg)	0.0086	0.0801	0.0387	0.0396	0.0191	0.0146	0.0074	0.0042	0.0120	0.0258
Molybdenum (Mo)	<0.009	0.014	0.022	0.021	0.014	0.025	<0.00945	<0.0076	<0.01305	0.030
Nickel (Ni)	<0.09	0.12	<0.20	<0.10	0.35	<0.30	<0.0945	<0.076	<0.1305	0.15
Selnium (Se)	<0.18	0.47	0.55	<0.20	0.26	0.35	<0.189	<0.152	<0.261	0.37
Strontium (Sr)	0.50	6.47	19.2	2.96	3.82	5.69	1.70	0.69	3.76	3.02
Thallium (Tl)	<0.0054	<0.010	<0.010	<0.010	<0.010	<0.010	<0.00567	<0.00456	<0.00783	<0.010
Tin (Sn)	<0.036	<0.050	<0.050	<0.050	<0.050	<0.050	<0.0378	<0.0304	<0.0522	<0.050
Uranium (U)	<0.0018	0.0021	0.0051	<0.0020	0.0076	0.0044	<0.00189	<0.00152	<0.00261	0.0038
Vanadium (V)	<0.09	<0.10	0.25	<0.10	0.24	0.18	<0.0945	<0.076	<0.1305	0.19
Zinc (Zn)	6.1	58.7	78.9	25.9	35.3	112	5.7	6.1	14.1	34.3

Source: URS, 2008b

Notes: Concentrations expressed in mg/kg wwt.

Laboratory certified data is presented in Appendix L7.8.

Fish samples WRF3-JD and WRF3-BS submitted to ALS Laboratory Group were mislabeled as MRF3-JD and MRF3-BS.

Table 7.8-14 Summary of Fish Tissue Residue Data Compared to Effects Levels

Parameter		Summary of Data			ERED*			*Guidelines for Chemical Contamiants and Toxins in Fish and Fish Products (Canadian Food Inspection Agency, 2007)*
		Min	Average	Max	Effects Range	Survival	Toxicity Threshold**	
Aluminum (Al)	mg/kg wwt	1.31	23.19	105.00	12-100	12-50		
Antimony (Sb)	mg/kg wwt	0.01	0.01	0.01	no data	no data		
Arsenic (As)	mg/kg wwt	0.01	0.06	0.17	1-100	>12	5.4-11.6	3.5
Barium (Ba)	mg/kg wwt	0.28	1.57	7.42	0.2-8	insuff. data		
Beryllium (Be)	mg/kg wwt	0.04	0.06	0.08	no data	no data		
Bismuth (Bi)	mg/kg wwt	0.04	0.06	0.08	no data	no data		
Cadmium (Cd)	mg/kg wwt	0.00	0.02	0.10	0.8-600	12-100	2-8	
Chromium (Cr)	mg/kg wwt	0.07	0.12	0.20	1-80	30		
Cobalt (Co)	mg/kg wwt	0.01	0.03	0.09	6	6		
Copper (Cu)	mg/kg wwt	0.09	0.62	1.45	>10 - 1000	100	11.1-11.7	
Lead (Li)	mg/kg wwt	0.01	0.03	0.06	0.5-250	>100	0.4	0.5
Lithium (Pb)	mg/kg wwt	0.07	0.11	0.19	no data	no data		
Manganese (Mn)	mg/kg wwt	0.43	5.28	17.50	2-230	230		
Mercury (Hg)	mg/kg wwt	0.00	0.03	0.08	6	12	0.1-0.3	0.5
Molybdenum (Mo)	mg/kg wwt	0.01	0.02	0.04	9	insuff. data		
Nickel (Ni)	mg/kg wwt	0.07	0.12	0.35	1-400	110		
Selenium (Se)	mg/kg wwt	0.13	0.26	0.55	3-100	9-80	0.75-1.0	
Strontium (Sr)	mg/kg wwt	0.50	3.46	19.20	no data	no data		
Thallium (Tl)	mg/kg wwt	0.00	0.01	0.01	no data	no data		
Tin (Sn)	mg/kg wwt	0.03	0.04	0.06	no data	no data		
Uranium (U)	mg/kg wwt	0.00	0.00	0.01	2	insuff. data		
Vanadium (V)	mg/kg wwt	0.07	0.13	0.25	1-8	no data		
Zinc (Zn)	mg/kg wwt	4.10	30.12	112.00	10-1200	80-120	40-64	

* ERED (Environmental Effects Residue Database (USACE, 2008)
** Hinck et al. (2006)

Source: adapted from URS, 2008b

7.8.2.3.2 Fish Tissue Metal Concentrations for the 2008 Program

In the 2008 fisheries program by Roche, tissue samples were collected in order to evaluate total metal content (As, Pb, Se, Ni and Hg) in 20 specimens. Tissue samples were collected from four Walleyes (*Stizostedion vitreum)*, seven Northern pikes (*Esox lucius)*, three White suckers (*Catostomus commersoni)*, four Longnose suckers (*Catostomus catostomus)*, and two Yellow perch (*Perca flavescens)*. Northern pike, Walleye and perch are predators while suckers are preys. Table 7.8-15 summarizes the main characteristics of the 20 fishes selected for metal content analysis. Laboratory certified reports for the fish tissues are presented in Appendix L7.8.

Usually, Northern pike is the biggest and largest fish among the examined species followed by Walleye. One of the Northern pike specimens weighed 4.5 kg, which is more than the average for this species (1 to 2 kg) (Roche, 2008a). The smallest fish sampled weighed 0.22 kg (Yellow perch). Males represented 60% of all sampled fishes. (The sex of one Northern pike specimen was not identified.)

None of the analyzed tissue samples exceeded the 2007 Canadian Food Inspection Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products criteria for arsenic and lead. In fact, metal concentrations for arsenic, selenium and lead were always below the detection limit. However, twenty-five percent (25%) of all sample fishes showed mercury concentrations above the 2007 Canadian Food Inspection Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products (Roche, 2008a). Measured mercury concentrations varied from 0.06 to 1.6 mg/kg. These exceedances were essentially observed for Northern pike (40%) and Walleye (60%).

The elevated mercury concentrations may be explained by the trophic level of Northern pike and Walleye. Mercury bioaccumulation along the food chain occurs and highest contamination levels are often found in predators at the top of the food chain. It is also important to note that the highest mercury concentration (1.6 mg/kg) was observed for the Northern pike specimen weighing 4.5 kg and measuring nearly 1 m. This individual was assumed to have been older than the other sampled fishes and might therefore have accumulated more mercury over a longer period of time and also have eaten bigger and thus more contaminated fishes (Roche, 2008a).

7.8.3 Scope of Effects Assessment

For the purposes of this effects assessment, “fish” refers to all life stages of resident species known or suspected to occur within the project area. Fish habitat refers to spawning, egg incubation, rearing, overwintering areas and migratory corridors used by fish or other organisms that fish depend upon directly or indirectly in order to carry out their life processes. Habitat includes instream physical habitats (as characterized by channel gradient, width, residual pool depth, etc.), riparian habitats (that is stream bank vegetation that provides shade, cover and organic input to instream habitat), invertebrate food production, and stream water quality (dissolved oxygen, temperature, pH, turbidity, etc.). Protection of fish, fish habitats and the management of fisheries resources are regulated by the federal *Fisheries Act*; therefore, the environmental effects of the project on freshwater fish and fish habitat are considered.

Table 7.8-15 Fish Tissue Analysis Results (2008 Program)

Parameters	Units	Method detection limit	CFIG Criteria [1]	1	2	3	4	5	6	7	8	9	10	1	2	13	14	15	16	17	18	19	20
Flesh Sample Information																							
Certificate of Analysis number				08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389
Laboratory sample number				1186501	1186502	1186503	1186504	1186505	1186506	1186507	1186508	1186509	1186510	1186511	1186512	1186513	1186514	1186515	1186516	1186517	1186518	1186519	1186520
Date of sampling				2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12
Date Laboratory received sample				2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22
Sampling Location				Hill Lake	Hill Lake	Hill Lake	Hill Lake	Hill Lake	Hill Lake	Hill Lake	Hill Lake	Limestone Bay	Limestone Bay	Limestone Bay	Limestone Bay	Limestone Bay	Limestone Bay	Limestone Bay	Cross Lake	Cross Lake	Cross Lake	Cross Lake	Cross Lake
Species Characteristics																							
Species	-			ESLU	ESLU	STVI	STVI	CACO	CACO	CACO	STVI	STVI	CACA	CACA	CACA	CACA	ESLU	ESLU	PEFL	PEFL	ESLU	ESLU	ESLU
Sex	-			N/D	F	M	M	F	M	M	M	M	M	M	M	F	F	M	F	F	M	F	F
Maturity	-			2	2	5	3	3	4	3	3	5	5	5	4	3	4	5	4	4	4	3	4
Length	mm			800	910	520	460	515	425	415	380	620	465	405	430	435	910	575	240	230	430	720	830
Weight	g			3 000	4 500	1 200	800	1 800	900	800	400	2 300	1 200	800	700	1 100	6 100	1 200	220	180	400	1 900	3 400
Tissue Concentrations																							
Arsenic	mg/kg	0.5	3.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.6	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Lead	mg/kg	0.5	0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Mercury	mg/kg	0.01	0.5	**0.67**	**1.6**	0.38	**0.88**	0.16	0.16	0.09	**0.62**	**0.78**	0.17	0.06	0.06	0.08	0.29	0.13	0.17	0.22	0.27	0.42	0.38
Selenium	mg/kg	0.1	-	< 0.1	< 0.1	0.2	< 0.1	< 0.1	< 0.1	0.2	< 0.1	0.2	0.5	0.3	0.3	0.4	< 0.2	0.2	0.2	0.1	0.1	< 0.1	0.1

[1] Canadian Food Inspection Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products (2007) .

Value exceeding Canadian Food Inspection Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products (2007)

ESLU = *Esox lucius (Northern pike)*
STVI = *Stizostedion vitreum (Walleye)*
CACO = *Catostomus commerson (White sucker)*
CACA = *Catostomus catostomus (Longnose sucker)*
PEFL = *Perca flavescens* (Yellow Perch)

Source: adapted from Roche, 2008a

Issues and Selection of Valued Ecosystem and Cultural Components (VECCs)

Project activities have the potential to affect a number of fish bearing and non-fish bearing streams that flow into Minago River, Cross Lake, Oakley Creek and William River. Fish species that have been documented in some of the sub-basins and that may be affected by the project development are summarized in Table 7.8-6. Of these species, Walleye (*Sander vitreus*) have been designated as a "sensitive" species by the fishers. Sensitive indicates that a "species is not believed to be at risk of immediate extirpation or extinction but may require special attention or protection to prevent them from becoming at risk."

As Walleye are relatively widespread throughout the area, they have have been identified as sentinel species for this assessment. By protecting the habitat requirements necessary to sustain this species, the habitat quality and quantity of the other fishes and the fish populations themselves will also be protected.

Project activities that have the potential to affect fish and fish habitat include the following:

- Changes in stream flows from effluent discharge affecting physical habitat capability in Oakley Creek and Minago River;
- Habitat disturbance during construction;
- Changes in water quality in Oakley Creek or Minago River due to effluent discharge, with potential direct toxic effects on fish, effects on benthic community that provide food for fish, and/or potential metal accumulation in fish tissue; and
- Erosion and runoff from disturbed areas at the mine site and along the transportation corridors with potential for sedimentation of instream habitat or stress to fish from elevated suspended solids in water.

The VECCs selected for assessment of effects on fish resources and the rationales for their selection are summarized in Table 7.8-16. Fish habitat is defined in terms of observed fish presence or physical habitat that is suitable or accessible for use by fish, in particular Walleye (a "sensitive" indicator species). Project effects on metals accumulation in fish, in particular selenium, while difficult to predict are of growing concern in relation to mining developments. Therefore, metal levels in fish tissue are identified as a VECC for this assessment and for the purpose of baseline characterization for future monitoring.

Study Area

The local and regional study areas for the assessment of effects on fish resources are the same as those used for the water and sediment quality assessment.

Table 7.8-16 Fish Resource VECCs, Selection Rationale and Baseline Data Sources

VECC	Rationale for Selection	Linkage to EAP and Other Regulatory Drivers	Baseline Data for EAP
Fish habitat	• Potential project effects on physical habitat due to facility and transportation corridor construction and maintenance potentially resulting in loss/alteration of instream and riparian habitat, siltation, barriers to fish passage). • Potential effects on productive capacity of fish habitat due to changes in water quality and associated toxic effects or effects on benthic organisms (fish food). • Habitat provides effective proxy for assessing effects on fish.	• Environmental Baseline Study (EBS) and Assessment Work Plan • Protection regulated by *Fisheries Act*	• 2006 field data • 2007 and 2008 field data
Metals in fish tissue	• Bioaccumulation of metals (e.g., Se) provides a link between project impacts and effects of fish and wildlife. • Species such as Walleye can provide human food sources.	• EBS and Assessment Work Plan	• 2006 field data • 2007 and 2008 field data

The local study area (LSA) includes all streams and associated water bodies that may be influenced by construction or operation of the mine and transportation corridors. This includes streams in the Oakley Creek and Minago River watersheds:

- Oakley Creek, which is near (> 500 m) the mine site area, will receive permitted discharges of effluent that meet discharge criteria;
- Minago River will receive permitted discharges of effluent that will meet discharge criteria;
- William River, which partly receives water from the Oakley Creek, drains to the Limestone Bay.

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

- Hargrave River that drains to the Minago River and then to Cross Lake;
- Oakley Creek, upstream and downstream of the William River confluence;
- Minago River, upstream and downstream of the effluent discharge point;
- Little Limestone Lake; and
- Cross Lake.

Temporal Boundaries

The temporal boundaries applicable to fish and fish habitat include all phases of the project – construction, operation, decommissioning and closure. The potential direct effects on instream habitat are greatest during transportation corridors construction, in particular construction of stream crossings. The potential for introduction of silt and sediment to fish habitat will be present in all phases, but greatest during construction. The potential for introduction of metals or nitrogen to area streams will be present in all phases, but greatest during operation. The assessment of the closure phase assumes stabilization of water quality and associated effects on benthic organisms and fish. 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, waste rock and groundwater.

7.8.4 Effects Assessment Methodology

Potential effects of the project on fish resources during construction; operations; decommissioning, and closure are discussed in detail in the following sections. For each phase of the project, effects on fish resource VECCs were assessed as follows:

- Potential project interactions with fish and fish habitat are characterized and the locations of effects identified. This section describes potential project effects on physical habitat. Effects due to changes in water quality and benthic communities are assessed on the basis of effects findings detailed in Sections 7.5: Surface Water Quality and Section 7.7: Periphyton and Benthos, respectively.
- Magnitude of effect is considered based on the documented fish presence or fish bearing classification of affected areas, as described in the Environmental Baseline Study (EBS).
- Identified mitigation measures and commitments in VNI's Environmental Protection Plan (Section 9) are considered in terms of proven effectiveness to protect fish resources.
- Follow-up and monitoring plans with identified contingency measures to address unexpected effects are discussed.
- Predicted residual effects (taking into consideration mitigation and contingency measures) are characterized.
- The potential for residual project effects to contribute to cumulative effects is assessed in terms of multiple project effects on fish resources, effects in combination with existing activities, and effects with foreseeable future activities or events.

Project and cumulative effects on the fish resource VECCs are characterized in accordance with effects attributes defined in Table 7.8-17. The ecological and social contexts of effects are integrated in the attributes for effect magnitude and elaborated upon as appropriate in the text. The likelihood of occurrence of residual effects happening as predicted is stated with a supporting rationale.

Table 7.8-17 Effect Attributes for Fish Resources

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 resident fish populations, and does not compromise economic or social/cultural values.
Moderate	Clearly an effect but unlikely to pose a serious risk to resident fish populations or represent a management challenge from an ecological, economic or social/cultural standpoint.
High	Effect is likely to pose a serious risk to resident fish populations and represents a management challenge from an ecological, economic or social/cultural standpoint.
Geographic Extent	
Site- Specific	Effect on VECC confined to a single small area within the Local Study Area (LSA).
Local	Effect on VECC confined to the Local Study Area (LSA).
Regional	Effect on VECC extends into the Regional Study Area (RSA).
Duration	
Short-term	Effects on VECC are measurable for less than 1 year.
Medium term	Effects on VECC are measurable for 1 to 5 years (Ford et al. 1995).
Long-term	Effects on VECC are measurable after 5 years but do not extend more than 10 years after decommissioning and final reclamation.
Far future	Effects on VECC are measurable more than 10 years after decommissioning and abandonment.
Frequency (Short-term duration effects that occur more than once)	
Low	One time event and does not pose a serious risk to the VECC or its economic or social/cultural values.
Moderate	Occurs annually but is unlikely to pose a serious risk to the VECC or its economic or social/cultural values.
High	Occurs more than once a year and is likely to pose a serious risk to the VECC or its economic or social/cultural values.
Reversibility	
Reversible	Effect on VECC is reversible through natural processes or compensation.
Irreversible	Effect 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.

Determination of Effects Significance for Fish Resources

The significance of residual project and cumulative effects are determined based on the defined effects attributes, as follows:

- a residual effect on fish habitat is considered significant, if it results in Harmful Alteration, Disruption or Destruction of fish habitat (HADD) that cannot be mitigated or compensated for;
- a residual effect on fish tissue is considered significant, if Contaminants of Concern (COC) levels are elevated above interim tissue guidelines;

otherwise, effects will be rated as not significant.

7.8.5 Project Effects

This section provides an analysis of the environmental effects of key project activities on the fish resource VECCs by phase.

7.8.5.1 Construction

Construction phase activities with the potential to affect fish resources may include the following:

- Site clearing and ground disturbance for construction of mine site facilities and the transportation corridors.
- Changes in stream flow due to pumping water from the Polishing Pond to Minago River and Oakley Creek;
- Potential introduction of contaminants from fuel spills, concrete mixing; and
- Potential increase in angling pressure from construction crews.

Further discussion of potential effects and management measures are presented in the next sections.

7.8.5.1.1 Riparian Habitat Disturbance and Sedimentation

The mine site, ancillary facilities and transportation corridors are not located in fish-bearing streams, and preparation and construction-related activities will not occur in fish-bearing streams. All these activities will occur outside fish-bearing streams/reaches and outside the riparian areas. Site preparation work for construction activities generally includes clearing, grubbing and grading of trees, brushing vegetation along the transportation corridors and mine site facility areas. Graders, bulldozers, and in some cases, excavators will be used to strip and stockpile topsoil, surface organic material and upper mineral soils. Following removal of topsoil, grading will be conducted on slopes and irregular ground surfaces to provide a safe and clean work surface. No riparian habitat will be disturbed as there are no creeks and rivers in the vicinity of the work site.

Riparian Habitat

Mine site development and access transportation corridors construction (clearing and grubbing activities) will not occur near or in fish bearing streams and therefore will not result in loss and / or alteration of riparian habitat structure (species, canopy height, etc.) through removal of mixed forest and shrub communities (i.e., area covered by road surface) beyond the life of the project (access road retention). The closest creek – Oakley Creek is located more than 500 metres from the boundaries of the property.

Sedimentation and Instream Habitat

Increased sediment loads entering a watercourse or waterbody may adversely affect fish and fish habitat. High concentrations of sediment are detrimental to benthic organisms, fish ova (eggs) and alevin (young fish) survival and habitat productive capacity. DFO Land Development Guidelines (DFO and MELP, 1992) recommend that total suspended solids (TSS) concentrations should not increase by more than 25 mg/L above background levels of the receiving waters during normal, dry weather conditions and less than 75 mg/L above background levels during storm events. The TSS concentration is set at 15 mg/L in the *Metal Mining Effluent Regulations* (MMER). However, all construction activities will not be near fish bearing streams. In addition, the area is surrounded by peat bogs and any discharges will pass through the peat bogs before it reaches the fish bearing streams. Peat bogs will assist to clean up the accidental discharges.

The extent of these potential environmental effects depends on the concentration of suspended sediment, event duration, species and life stage of fish present within the increased TSS zone of influence, and sensitivity of the habitat type affected (spawning, overwintering, wetland, etc.). Exposure of fish and habitats to low levels of suspended sediments and seasonal freshet-related instantaneous increases occurs naturally. During increased TSS events, juvenile and adult fish most frequently avoid the zone of influence and return once TSS levels subside. However, high concentrations of suspended sediments over extended durations of exposure will reduce fish feeding success (reduced prey capture and predator avoidance rates), reduce growth rates, damage gill membranes, decrease disease resistance, and/or impair ova development and embryonic development (hypoxia). Increased suspended sediments may also interfere with the production of benthic invertebrates and other aquatic fish food organisms. Behavioral, physiological and other sub-lethal and/or lethal effects may also occur depending on the concentration and duration of exposure, stream discharge, fish life stage, as well as TSS, particle hardness, size and angularity. For this project, there are no fish bearing streams within the project boundaries and VNI will not discharge effluents that will exceed the legal limits (MMER Limits), as mitigative measures will be implemented for all components of the project.

In the mine site area, part of the Site Water Management Plan will include diversion of clean water flows around construction sites and collection of drainage from disturbed areas for settlement of suspended solids in settling ponds prior to discharge (Section 2.14: Site Water Management). A comprehensive Erosion and Sediment Control Plan will be developed and implemented for all phases of the project. Key elements of the plan are listed in the Environmental Protection Plan (Section 9). Best practices will be outlined along with conditions for application. Additional site-specific requirements will be included based on the detailed design of facilities, access road and Site Water Management Plans.

If at all, any work within 20-70 m of a watercourse will only proceed under the appropriate regulatory permits and approvals. Instream work in fish bearing watercourses will be undertaken during the approved fisheries work windows and will use identified mitigative procedures and structures. It is important to note that very little to no work will be undertaken in and around fish bearing streams.

Monitoring of total suspended solids in streams will be conducted during the construction phase in fish bearing streams, in accordance with permit requirements. If results are out of compliance with permit requirements, activities will cease and mitigative measures applied or enhanced as required to achieve compliance.

Project effects of sedimentation on instream habitat during construction are expected to be adverse, low magnitude, local in extent, short-term in duration and reversible given that:

- there will be little or no work to be conducted in and around fish bearing streams; and
- effective mitigation options exist.

The likelihood of effects as predicted is high based on observations of project effects and mitigation effectiveness at many comparable developments.

Culvert Installation

No culverts will be installed in fish-bearing streams as there are no creeks and rivers in the LSA where development will take place. Culverts will only be installed on the mining site for local drainage purposes.

All instream work (if any) will proceed only under the appropriate regulatory permits and approvals. Instream work at known fish bearing watercourses will be undertaken during the approved fisheries work windows and will use identified mitigative procedures and structures for the protection of fish and fish habitat as specified in the Environmental Protection Plan (Section 9).

Instream construction (if required/requested) timing constraints are designed to protect fish species during sensitive life-stages (i.e., alevins, eggs). To avoid potential conflict with fish spawning timings, instream construction for all fish-bearing (known and inferred) watercourses will be scheduled during the period of least risk to fish and fish habitat (mid-late summer, low or no flow, or ice-in period(s)), unless specifically permitted by regulatory authorities. As there are no streams in the vicinity of the project area, it is unlikely that access culvert placement will affect downstream fish and fish habitats during a constrained instream work.

7.8.5.1.2 Changes in Stream Flow

Project effects on surface flows during construction include the following:

- potential effects of open pit dewatering during pre-production mining on ground water regimes; and
- discharge of effluent from the Polishing Pond to the Minago River/Oakley Creek.

On the basis of work completed by Golder Associates (2008b), there is no hydraulic connection between Oakley Creek and the limestone and sandstone aquifers. Effects of flow reduction, if any, will be monitored during operations. Stage discharge relationships will be refined (Section 7.4: Surface Water Hydrology) and the potential for effects on overwintering habitat (pools) will be clarified.

Changes in stream flow due to open pit dewatering will be adverse, low in magnitude, site specific, long-term in duration and reversible. Therefore, the likelihood of this effect as predicted is low.

7.8.5.1.3 Runoff of Contaminants

A number of site construction activities may generate wastewater. Direct release of wastewaters, such as concrete wash water or storm water that has been in contact with uncured concrete, into a stream may result in degradation of water quality and subsequent fish kills. Residual hydrocarbons leaked from heavy equipment usage during construction activities or concentrations of lime in concrete wastewaters could also exceed water quality guidelines for the protection of freshwater aquatic life (CCME, 2007).

To minimize such releases, the on site concrete batch plant will be entirely self-contained with no disposal of wash water to surface waters. Refueling, equipment maintenance and inspection procedures will be implemented to minimize the risk of spills that could make their way to surface waters (Section 9: Environmental Protection Plan). Accordingly, effects of contaminant runoff affecting fish habitat are expected at worst to be low, site-specific, short-term, and infrequent. The small volumes potentially involved and the self-renewing nature of streams would make any such effects reversible. The likelihood of this effect as predicted is high.

7.8.5.1.4 Angling Pressure

Construction personnel on site may increase fish mortality in the project area due to sports fishing. A policy to protect fish stocks will be incorporated into the project's environmental education and orientation program. All project personnel living on site will be apprised of potential pressures on fish stocks from fishing. Fishing regulations will be reviewed, including requirements for licenses, use of single barbless hooks, bait bans and catch and release strategies.

Because of the low occurrence of fish in streams that may be affected by the project, any effects would likely be confined to the Oakley Creek and the Minago River. However, there are many fish bearing lakes and rivers in Minago's vicinity that require a low level of effort to catch fish. Oakley Creek and Minago River will not be the preferred options. Potential effects would be greatest during the two-year construction period when onsite personnel numbers will be highest, but would continue to a lesser extent throughout the life of the project. Effects are therefore expected to be adverse, low magnitude, regional, short-term and irreversible. The likelihood that effects will occur as predicted is high.

7.8.5.2 Operations

During operations, some of the effects identified during construction will persist. The main incremental project effect on fish and fish habitat during operations will be changes in water quality and quantity in Oakley Creek and Minago River due to effluent discharges from the Polishing Pond, with related potential for toxic effects, effects on stream productivity and potential for metals accumulation in fish tissue. The effluent quality will meet *Metal Mining Effluent Regulations* (MMER) discharge water quality objectives.

7.8.5.2.1 Riparian Habitat Disturbance and Sedimentation

As noted above, riparian vegetation is an important component of a stream's ecosystem as it provides shade, over stream fish cover, nutrients and woody debris, and maintains channel bank integrity. Operational activities will have no effect on riparian habitat as no disturbances will be experienced.

7.8.5.2.2 Changes in Stream Flow

Project effects on stream flows are discussed and assessed in Section 7.4: Surface Water Hydrology.

7.8.5.2.3 Impacts on Biological Aspects

Two main components of the receiving environment could be impacted by how the final effluent will be managed, namely wetlands and stream habitats.

Impacts on Wetlands

From May to October, the final effluent will first be discharged in a vast treed bog before being released to the receiving streams. These bogs still have the capacity to store additional water by creating ponds.

A marsh will certainly be created where the final effluent will be discharged. However, it would be quite surprising to see such a significant transformation over the entire bog's surface (creation of ponds and reduction of the tree cover) given that:

- no ponds at all have been observed within these bogs;
- they cover significant areas and are parts of a vast complex of wetlands that are hydrologically connected together and form one of the most important ecosystem in the region;
- the flow of water being discharged within the receiving bogs will not even represent what the waterways typically discharge during the summer period in this region (about 0.4 m^3/s for the Minago River compared to the Minago River flow between June and October of 1.9 m^3/s and less than 0.2 m^3/s for the Oakley Creek compared to the Oakley Creek flow between June and October of 0.5 m^3/s).

Still, if a significant transformation of the bog's surface were to occur, it is important to note that it is widely accepted that open bogs with ponds represent more attractive habitats for many wildlife species such as waterfowl and amphibians. Ducks Unlimited Canada, as well as Québec's ministère du Développement durable, de l'Environnement et des Parcs (Department of Sustainable Development, Environment and Parks), has recognized this general concept and use it to evaluate the ecological value of a bog. Poulin (2002) has also proposed a set of criteria to assess a bog's ecological value, including the area covered by ponds.

A diffuser will be installed to reduce erosion at the point where the final effluent will be released in the bog. A perforated pipe will be installed perpendicularly to where the final effluent will be released. Rocks (riprap) will also be installed at this same location.

7.8.5.2.4 Impacts on Stream Habitats

The fact that water will first be discharged in a bog before being released in the receiving streams means that the flow increases, detailed in Section 7.4, should be considered as maximum values since they represent a situation in which water is being directly discharged in the Oakley Creek or the Minago River without passing through a wetland before. Given the capacity of wetlands, such as these bogs, to slow the water flow coming to the receiving streams, the impact on stream habitats should be low, or not significant, particularly in May (See Section 7.4). However, if an increase in the amount of water flowing in those streams should occur, the impact on stream habitat quality would likely be positive, especially in winter low flow conditions.

Low flows are defined as those typical during a prolonged dry period (Smakhtin, 2001), or more precisely in the Canadian context, those that occur during periods without significant rainfall or snowmelt input. During low flows, most stream habitat types are reduced in extent and changes in water quality can occur, which can be stressful for fish and other biota (IFC, 2004).

Therefore, especially from November to April, higher water flow and thus water level would help maintain the existing stream habitat types and limit changes in water quality that can occur, therefore limiting seasonal stresses for fish and other biota. Such positive impacts of higher winter flow have been observed in northern Québec by Hydro-Québec along rivers regulated for hydroelectric power generation purposes.

Water coming out of a mine is usually not at the same temperature than water flowing in the surrounding streams. However, before being released as the final effluent, that water will have to flow through the TWRMF and the Polishing Pond, therefore will be exposed to rainfall and ambient temperatures for some days. Based on these facts, the thermal impact of the water being discharged to the receiving environment is considered to be not significant.

The effects of discharge additions on fish habitat capability in Minago are expected to be minimal, low magnitude, local in geographic extent, long-term and reversible. The likelihood of effects as predicted is high. Monitoring and mitigation measures will be established to ensure that river base flows are not exceeded significantly.

7.8.5.2.5 Angling Pressure

Effects predicted for construction are expected to continue during operations. Angler education for operations personnel, use of barbless hooks, catch-and-release strategies and compliance with the applicable regulations will reduce or eliminate project effects on the fisheries resources associated with potential increases in angler pressure. As such, projects effects associated with increased angling pressure by operations personnel are expected to be adverse, low magnitude, regional in geographic extent, long-term and irreversible. The likelihood of effects as predicted is high. It is important to note that there are other fish bearing lakes and rivers in Minago’s vicinity that require a low level of effort to catch fish. Therefore, potential anglers will likely go to such lakes and rivers to do sports fishing.

7.8.5.3 Decommissioning

During decommissioning, most ancillary facilities and mine site infrastructure will be removed. However, the access road and the Tailings and Ultramafic Waste Rock Management Facility (TWRMF) will be remain at closure.

Riparian Habitat Disturbance and Sedimentation

No effects are anticipated.

Change in Stream Flows

During decommissioning, water discharge from the Polishing Pond to Oakley Creek and Minago River will cease. As discussed in Section 7.4, the impacts of increasing or decreasing the water flow in the Minago River and the Oakley Creek will be low, or not significant, in terms of hydrology since they are within the natural variation occurring in this region.

The impacts of a reduction in the water flow on stream habitats would be significant. Indeed, especially in winter low flow conditions, lower water flow and thus water level reduces stream habitat types and increases the risk of changes in water quality, increasing seasonal stresses for fish and other biota.

Therefore, mitigation measures will have to be implemented in order to limit the potential impacts of such a change in water level conditions, meaning that water will have to be stored in the PP in such a way that the final effluent flow will be gradually reduced and not drastically. This would enable a comeback to pre-mining conditions. In addition, the discharge flow will still have to change according to the seasons.

Cessation of discharges to the Minago River and Oakley Creek will be staged to recondition the streams to pre-mining conditions. The staging process is outlined in Section 7.4: Surface Water Hydrology. Site water management facilities (e.g. diversions and drainage collection ditches) will be decommissioned and natural drainage patterns restored in both drainages. Drainage from the TWRMF within the Oakley Creek basin will be discharged to Oakley Creek.

Angling Pressure

Effects predicted for mine construction and operations may continue during the decommissioning phase. Angler education for personnel, use of barbless hooks, catch-and-release strategies and compliance with applicable regulations will reduce or eliminate project effects on the fisheries resources associated with potential increases in angler pressure. Accordingly, effects are expected to be adverse, low magnitude, regional in geographic extent, long-term and irreversible. The likelihood of this effect is high.

7.8.5.4 Closure

Riparian Habitat Disturbance and Sedimentation

There will be no effects as there are no rivers and creeks within the LSA that will be disturbed.

TWRMF Decant to Oakley Creek Watershed

The TWRMF will be maintained and monitored as described in the Mine Closure Plan to ensure no elevated metals are released into the Oakley Creek watershed. Accordingly, no effects on fish and fish habitat are expected at closure.

Angling Pressure

There will be no angling pressure as there are better fish bearing lakes and rivers in the area. Accordingly, effects are expected to be adverse, low magnitude, regional in geographic extent, long-term and irreversible. The likelihood of this effect is high.

7.8.6 Residual Project Effects and Significance

7.8.6.1 Site Preparation

For this project, there will be no mine site effects as there will be no activities taking place near streams. However, established standards for mitigation measures to minimize effects on fish and fish habitat (Site Water Management Plan, Sediment and Erosion Control Plan, Fish Habitat Protection Plan) will be implemented. Inspection during construction and operation and reporting to regulators will ensure compliance. Egg mortality due to sedimentation is expected to be very low. At no time during the life of the project are effects expected to be greater than low magnitude and local in extent. In all cases, effects will be ultimately reversible. The likelihood of effects as predicted is high based on observations of effects and mitigation effectiveness at many similar projects. Based on criteria listed in Table 7.8-17, effects of the project related vegetation clearing, erosion and sedimentation are determined to be not significant. In addition, there will be no construction activities near the fish bearing streams.

7.8.6.2 Water Quality Effects on Fish Habitat and Fish Tissue

Oakley Creek

At closure, Tailings and Waste Rock Management Facility (TWRMF) decant discharges to the Oakley Creek watershed will meet discharge criteria. There is no potential for a Harmful Alteration, Disruption or Destruction of fish habitat (HADD) that cannot be mitigated; therefore effects are determined to be not significant.

Water quality effects on Oakley Creek and Minago River during operations and decommissioning have the potential to contribute to metals accumulation in fish tissue. Mitigating factors such as compliance with discharge criteria in fish bearing reaches, swift flowing conditions and probable dispersion of metal bearing sediments within the larger William River and Minago River basins indicate that the risk of this occurrence is low. Monitoring will provide an early warning of metals trends in sediments and trigger follow-up tissue monitoring as required. Adaptive management to mitigate any observed effects will be developed and implemented in consultation with regulatory bodies. Accordingly, the effect of the project on metals levels in fish tissue is determined to be not significant.

Minago River

As discharges of Polishing Pond waters into the Minago River during the closure phase are not planned, project effects of water quality on fish habitat and fish tissue are not anticipated.

7.8.6.3 Flow Changes

Discharges from the Polishing Pond will be gradually reduced in the closure phase. The proposed Water Discharge Cessation Plan is outlined in Section 7.4: Surface Water Hydrology.

Oakley Creek

There will be no discharges from the mine to Oakley Creek; therefore, there will be no effect on the Oakley Creek flow regime.

Minago River

There will be no discharge from the mine to Minago River. Therefore, there will be no effect on the Minago River flow regime.

7.8.6.4 Summary of Residual Effects

Residual project effects on fish, fish habitat and fish tissue metals levels are expected to be not significant. Residual low level effects may include:

- potential metals accumulation in fish tissue; and
- potential increased mortality due to angling pressure.

All of these effects are expected to be of low magnitude and localized in extent, as discharges will meet legal discharge criteria.

7.8.7 Cumulative Effects and Significance

It is not expected that multiple localized project impacts on fish habitat will result in a measurable cumulative effect on fish populations or habitat in the regional receiving drainages (Minago River, Cross Lake, William Lake and Limestone Bay).

Other activities within the mine site that may combine with project effects to influence fish resources include:

- increased traffic on the PTH6 due to the project with potential for introduction of contaminated runoff (due to potential spills, accidents, and road maintenance) to fish habitat in William River and Minago River;
- effects of future mining projects in the same drainages (there are currently no mining projects under review that would incur cumulative effects on fish habitat in the area);
- increased risk of forest fires due to mining activity with the potential for sedimentation of instream habitat.

The effects of a contaminant introduction to fish habitat from the PTH6 are variable depending on the amount and toxicity of the contaminant and habitat use of the affected reach at the time (potential concentrations in fish or ova). The magnitude of effects could range from low to high and a HADD could result. In any instance, the contribution of the project to cumulative effects from this source will be low and not significant.

Increased angler effort associated with the Minago Project and various other development activities within the LSA may increase fish mortality through retention fisheries. Implementation of an angler education program and signage postings along the access road or at the PTH6 intersection encouraging the use of single barbless hooks, bait bans and catch-and-release strategies will reduce the contribution of the project to cumulative effects.

A forest fire could destroy vegetation and alter water quality within the assessment area, resulting in environmental effects on fish resources, including fish mortality. Fire within the LSA could occur during any phase of the project due to natural or anthropogenic activities. Factors influencing the severity and duration of environmental effects caused by a forest fire include time of year, weather conditions (wind, ground moisture, etc.), extent of fire damage and type of fire.

A fire during the late summer or early fall could affect fish migrations, and timing and success of spawning depending on duration, size and intensity. If a forest fire were to affect a large proportion of a watershed (i.e., Oakley Creek/Minago River/William River) and were to occur during the late fall, the magnitude of the environmental effect would be moderate to severe. Reversibility of physical environmental effects is high, but would occur over a long duration (five to ten years), particularly due to the high latitude. Increased bed load transport and sedimentation would result in substrate aggradations in some reaches and infilling of critical habitats (spawning gravels and overwintering pools) downstream and bank degradation in other reaches during subsequent spring freshets/snow melts until substantial revegetation occurs. Changes to groundwater patterns, base flows and instantaneous discharge rates in the stream may also be altered during this period due to changes in evaporation and infiltration rates. Although individual fish and ova mortality may occur as a result of a forest fire, the environmental effects on the population of resident and migratory fish are likely to be reversible as individuals from other reaches/sub basins would eventually re-colonize the affected areas.

While project activities and increased traffic in the area could increase the risk of fire, the presence of people in the area can also support earlier detection and suppression. VNI will establish procedures to prevent and respond to fires in the project area. All personnel and contractors will be provided with an orientation in these procedures and key personnel will have appropriate training to implement emergency response procedures. Project mitigation measures will minimize the risk of project related fires and support effective management of natural fires. Moreover, major roads, such as PTH6, and power lines usually act as fire barriers slowing down fire progression.

Nevertheless fires can and have occurred in the past, as the charred remains of past fire(s) were observed during the 2007 fisheries assessment. Associated effects on fish habitat could range in magnitude from low to high, local to regional in extent and could result in a HADD. The contribution of predicted project related effects on fish habitat to cumulative effects due to fire would be low and not significant.

7.8.8 Mitigation Measures

Mitigation measures for protection of fish and fish resources during all project phases are summarized in Table 7.8-18.

7.8.9 Monitoring and Follow-up

Follow-up Studies

No further follow-up studies are planned for the Fish Resource VECCs based on sufficient fish species assemblage data obtained during previous studies (the 2006-2008 programs), confirmation of fish distribution limits and generally low fish densities or absence. However, to confirm the accuracy of the effects predications on metals bioaccumulations in fish tissue, follow-up sampling consisting of annual, single season collection and metal analyses of fish samples will be initiated.

Monitoring Programs

All construction activities will require inspection and monitoring of sediment input to local streams and receiving waters, to ensure that erosion and sediment control structures are appropriately installed, maintained and removed in accordance with regulatory requirements, the Site Water Management Plan, and commitments stated in the Environmental Protection Plan (Section 9). An on-site monitor (environmental inspector) will be present during all mine site and ancillary facilities development and access road construction to conduct monitoring and ensure compliance with all requirements.

Project-related HADD is unlikely. VNI will develop an Environmental Protection Plan (EPP), and sediment control, revegetation, mitigation and monitoring programs. As such, the project is expected to achieve DFO's no net loss principle (NNL; DFO, 1986) and it is expected that the productive capacity of fish habitats will be maintained.

Water levels in Oakley Creek and the Minago River will continue to be monitored to check impact predictions and ensure protection of fish habitat, as required.

Table 7.8-18 Mitigation Measures for Effects on the Fish Resources

Potential Project Effect	Mitigation Measures
Effects of site clearing, grubbing, grading and sedimentation of instream fish habitat	**NOTE: NO WORK WILL BE DONE NEAR RIPARIAN MANAGEMENT AREAS.** • Locate buildings, TWRMF and facilities outside of Riparian Management Areas. There will be no infrastructure near of in the vicinity of the riparian zone. • Implement a Sediment Control Plan (Section 9: Environmental Protection Plan). • Implement a Fish Habitat Protection Plan (Section 9: Environmental Protection Plan). • Implement a Site Water Management Plan (Section 2.14: Site Water Management). • Revegetate stream banks with native plants, grasses, shrubs and trees. • Obtain required DFO and MB Gov.'t Authorizations for instream and riparian works, if any such works were to be needed.
Effects of construction works on fish and fish egg mortality and instream fish habitat	**NOTE: THERE ARE NO CULVERT OR STREAM CROSSINGS CONTEMPLATED FOR THE PROJECT.** • Adhere to *Standards and Best Practices for Instream Works,* if any such works were to be needed. • If any crossing construction will be needed, it will be completed in the dry during the summer low flow period or in winter when streams are frozen solid (surface to substrate), i.e. during the period of least risk to fish and fish habitat. • Implement a Sediment and Erosion Control Plan (Section 9: Environmental Management Plan). • Implement a Fish Habitat Protection Plan (Section 9: Environmental Protection Plan). • Where applicable, conduct blasting in accordance with *Guidelines for Use of Explosives in Canadian Fisheries Waters.* • Maintain all culverts in good working order; replace dysfunctional culverts as required in association with sedimentation control measures.
Changes instream flow due to mine dewatering, stream diversions and drainage collection and diversion with potential effects on instream habitat in Oakley Creek and Minago River	• Implement the Site Water Management Plan (Section 2.14: Site Water Management and Section 7.4: Surface Water Hydrology)

Table 7.8-18 (Cont.'d) Mitigation Measures for Effects on the Fish Resources

Potential Project Effect	Mitigation Measures
Potential introduction of contaminants to fish habitat from fuel spills, concrete mixing	• Discharge all wastewater in accordance with MB Gov.'t regulations and more than 100 m from fish habitat. • Implement a Site Water Management Plan (Section 2.14: Site Water Management). • Implement a Sediment Control Plan. • Adhere to protocols for refueling and equipment inspection and maintenance. • Implement the Mine Closure Plan. • Ensure stabilization of water quality prior to closure. • Maintain a water cover on the TWRMF as designed. • Conduct regular/routine monitoring of the TWRMF water quality and for potential leaks.
Potential increase in angling pressure from project personnel	• Implement personnel environmental awareness training and environmental protection policy (Section 9: Environmental Management Plan). • All personnel will abide by applicable MB Gov.'t fishing regulations. • Signage will be posted along access road / PTH6 intersection describing responsible angling techniques.

Monitoring of project facilities, effluents and receiving water quality will occur as required by provincial and federal permits and regulations. If Environmental Effects Monitoring (EEM) suggests increasing metals levels in water and sediments, monitoring of fish tissue metals levels will be initiated to check for potential bioaccumulation. Based on monitoring results, requirements and approaches for adaptive management of project effects will be developed and implemented in consultation with the responsible provincial and federal agencies.

Proposed monitoring programs for fish resources are summarized in Table 7.8-19 and will be implemented by the proponent.

7.8.10 Summary of Effects

Project and cumulative effects on fish resources are summarized in Tables 7.8-20, 7.8-21, 7.8-22 and 7.8-23 for the construction, operations, decommissioning, and closure phases of the project, respectively.

Table 7.8-19 Monitoring Programs for the Fish Resource VECCs

Potential Project Effect	Program Objectives	General Methods	Reporting	Implementation
Alteration of instream habitat quality due to sedimentation from clearing, ground disturbance and culvert installation during construction	• To monitor effectiveness and best management practices for sediment control and fish habitat protection and ensure compliance with permit regulations	• Turbidity and TSS monitoring during construction as required by permit	• MB Gov.'t and other regulatory Agencies (ORA) as required	Proponent
Alteration of instream habitat quality due to culvert installation (if it happens)	• To confirm effectiveness of sediment control and fish habitat protection measures, and to address compliance issues immediately	• Post-construction evaluation of instream habitat in the vicinity of culvert installations (sedimentation, fish passage, bank erosion, culvert effectiveness) • Complete remedial action for any failed culvert, bank protection measures, etc.	• MB Gov.'t and other regulatory agencies (ORA) as required	Proponent
Metals bioaccumulation in fish tissues	• To confirm effects predictions • To initiate contingency plans to address unexpected effects, as required	• Conduct EEM Monitoring (Section 7.5: Surface Water Quality). • Set aside contingency to initiate fish tissue sampling & analysis. • Collect fish samples at identified monitoring sites, and analyze for metals levels.	• MB Gov.'t as required • Reporting schedule according to *Metal Mining Effluent Reguations* (MMER)	Proponent

Table 7.8-20 Summary of Effects on Fish Resources during Construction

Potential Effect	Level of Effect [1]						Effect Rating [2]	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Construction								
Effects of site clearing, grubbing, grading and sedimentation of instream fish habitat	Adverse	Low	Local	Long-term for mine site	Reversible	High	Not significant	Not significant
Effects of culvert placement on fish and fish egg mortality and sedimentation of instream fish habitat. No culverts will be installed.	Neutral	Low	Local	Short-term Low frequency	Reversible for sedimentation Irreversible for mortality	High	Not significant	Not significant
Changes in stream flow (Minago River and Oakley Creek) due to discharges from the Polishing Pond with potential effects on instream habitat	Adverse	Low	Site-specific	Long-term	Reversible	High	Not significant	Not significant
Potential introduction of contaminants to fish habitat from fuel spills and concrete mixing	Adverse	Low	Site-specific	Short-term Low frequency	Reversible	High	Not significant	Not significant
Potential increase in angling pressure from construction crews	Adverse	Low	Regional	Short-term	Irreversible	High	Not significant	Not significant

Notes:

1 Based on effects attributes in Table 7.8-17.

2 Based on significance criteria.

Table 7.8-21 Summary of Effects on Fish Resources during Operations

Potential Effect	Level of Effect [1]						Effect Rating [2]	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Operations								
Effects of vegetation management on the mine site and transportation corridors right-of-way on sedimentation of instream fish habitat **NOTE:** There are no fish bearing streams within the project area.	Adverse	Low	Local	Local Long-term for mine site Far future for access road	Reversible	High	Not significant	Not significant
Changes in stream flow and habitat capability due to pit dewatering in Oakley Creek and from the TWRMF	Adverse	Low	Local	Long-term	Reversible	High for TWRMF Unknown for Oakley Creek	Not significant	Not significant
Potential increase in angling pressure from project personnel	Adverse	Low	Regional	Long-term	Irreversible	High	Not significant	Not significant

Notes:

1 Based on effects attributes in Table 7.8-17.

2 Based on significance criteria.

Table 7.8-22 Summary of Effects on Fish Resources during Decommissioning

Potential Effect	Level of Effect [1]						Effect Rating [2]	
	Direction	**Magnitude**	**Extent**	**Duration/ Frequency**	**Reversibility**	**Likelihood**	**Project Effect**	**Cumulative Effect**
Decommisioning								
Effects of mine infrastructure removal on riparian and instream fish habitat in Oakley Creek (sedimentation) **NOTE:** There are no fish bearing streams within the project area.	Adverse	Low	Local	Medium term for mine site Far future for access road	Reversible	High	Not significant	Not significant
Effects of Polishing Pond decant on instream fish habitat (water quality) and fish tissue metals levels in Oakley Creek and Minago River	Adverse	Low	Local	Medium term	Reversible	Unknown	Not significant	Not significant
Changes in stream flow and habitat capability due to the recovery of the groundwater table in the Oakley Creek basin	Adverse	Low	Site specific	Long-term	Reversible	Unknown	Not significant	Not significant
Potential increase in angling pressure from project personnel	Adverse	Low	Regional	Short-term	Irreversible	High	Not significant	Not significant

Notes:

1 Based on effects attributes in Table 7.8-17.

2 Based on significance criteria.

Table 7.8-23 Summary of Effects on Fish Resources during Closure

Potential Effect	Level of Effect [1]						Effect Rating [2]	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Closure								
Effects of Polishing Pond decant on instream fish habitat (water quality) and fish tissue metals levels in Oakley Creek and Minago River	Adverse	Low	Local	Medium term	Reversible	Unknown	Not significant	Not significant
Potential increase in angling pressure from public access	Adverse	Low	Regional	Long-term	Irreversible	High	Not significant	Not significant

Notes:

1 Based on effects attributes in Table 7.8-17.

2 Based on significance criteria.