Table 4.1. Water quality sampling locations

Sample Type	Area	Sampling Station	Date	UTM (Zone 12W NAD 83)		Latitude	Longitude
				Easting	Northing		
Fish Survey Limnology	**Exposure**	Seep Creek Dam 1a Lake (SCD1)	29-Aug-05	485788	7289683	65° 41' 42.60" N	111° 18' 35.39" W
		Seep Creek 1 (SC1)	19-Aug-05	481435	7290663	65° 41' 13.42" N	111° 24' 17.57" W
		Seep Creek 1 (SC1)	22-Aug-05	481424	7290658	65° 44' 13.27" N	111° 24' 18.43" W
		Seep Creek 2 (SC2)	20-Aug-05	483174	7289998	65° 43' 52.32" N	111° 22' 00.70" W
		Seep Creek 3 (SC3)	25-Aug-05	483986	7289971	65° 43' 51.56" N	111° 20' 56.36" W
		Seep Creek 4 (SC4)	02-Sep-05	483917	7289948	65° 43' 50.88" N	111° 21' 02.34" W
	Reference	Fingers Creek, near mouth to Contwoyto Lake (FC3)	03-Sep-05	496327	7290999	65° 44' 26.16" N	111° 04' 48.36" W
		Fingers Creek (FC2)	27-Aug-05	494609	7288868	65° 43' 48.72" N	111° 06' 08.64" W
		Fingers Creek, at outlet to Fingers Lake (FC1)	05-Sep-05	494623	7288989	65° 43' 21.44" N	111° 07' 01.92" W
Invertebrate Survey Limnology	**Exposure**	Seep Creek Pond 2 (SCP1)	24-Aug-05	480913	7290274	65° 44' 00.78" N	111° 24' 58.28" W
		Seep Creek Pond 2 (SCP2)	05-Sep-05	480595	7290520	65° 44' 08.67" N	111° 25' 23.41" W
		Seep Creek Pond 1 (SCP3)	22-Aug-05	481268	7290730	65° 44' 15.58" N	111° 24' 30.71" W
		Seep Creek Pond 1 (SCP4)	24-Aug-05	481268	7290730	65° 44' 04.63" N	111° 25' 11.35" W
		Seep Creek Pond 1 (SCP5)	06-Sep-05	481252	7290713	65° 44' 15.04" N	111° 24' 31.90" W
Laboratory Water Quality Samples	**Exposure**	Seep Creek Dam 1a Lake (SCD1)	29-Aug-05	485788	7289683	65° 41' 42.60" N	111° 18' 35.39" W
		Seep Creek Ponds composite	06-Sep-05	n/a	n/a	n/a	n/a
	Reference	Fingers Creek (FC2)	27-Aug-05	494609	7288868	65° 43' 48.72" N	111° 06' 08.64" W
		Fingers Lake composite	05-Sep-05	n/a	n/a	n/a	n/a

Notes: n/a=not applicable

Table 4.2. Sediment sampling locations

Sample Type	Area	Sampling Station	Date	UTM (Zone 12W NAD 83)		Latitude	Longitude
				Easting	Northing		
Sediment Quality Samples	**Exposure**	Seep Creek Pond 1 (SCP3)	24-Aug-05	480913	7290274	65° 44' 15.58" N	111° 24' 30.71" W
		Seep Creek Pond 1 (SCP4)	24-Aug-05	480748	7290394	65° 44' 04.63" N	111° 25' 11.35" W
		Seep Creek Pond 1 (SCP5)	24-Aug-05	480595	7290520	65° 44' 15.04" N	111° 24' 31.90" W
		Seep Creek Pond 2 (SCP1)	24-Aug-05	481252	7290713	65° 44' 00.78" N	111° 24' 58.28" W
		Seep Creek Pond 2 (SCP2)	24-Aug-05	481109	7290489	65° 44' 08.67" N	111° 25' 23.41" W
	Reference	Fingers Lake (FL1)	01-Sep-05	492619	7286326	65° 41' 54.98" N	111° 09' 38.63" W
		Fingers Lake (FL2)	01-Sep-05	492927	7287021	65° 42' 17.46" N	111° 09' 14.62" W
		Fingers Lake (FL3)	01-Sep-05	493930	7286995	65° 42' 16.69" N	111° 07' 55.67" W
		Fingers Lake (FL4)	01-Sep-05	494157	7287794	65° 42' 42.51" N	111° 07' 38.29" W
		Fingers Lake (FL5)	01-Sep-05	493801	7287081	65° 42' 19.46" N	111° 08' 06.10" W

4.1.1.3 Quality Assurance and Quality Control

Quality assurance for the water sampling program included the use of field and trip blanks that were analysed identical to test samples. These blanks are used to detect potential sample contamination during collection, shipping, and analysis. Field blank samples were prepared during field sampling by filling a set of sample bottles with deionized water and adding appropriate preservatives, as done for test samples. A trip blank is an analyte-free sample (usually containing deionized water), supplied by the laboratory in the same type of container as for field samples, that is transported to field sampling sites and returned to the laboratory unopened.

Field equipment were calibrated frequently, and all samples were collected by experienced personnel following standard protocols. Concentrations of water quality variables were considered significant in blanks if they were greater than five times the corresponding method detection limit (MDL).

4.1.2 Sediment Quality

Sediment samples were collected concurrently with the BIC samples. All sediment samples were collected at a water depth ranging between 0.5 to 1.0 m. Five sub samples were collected at each of the five BIC replicate stations using a core sampler (diameter 67 mm). At each replicate station, the five subsamples were combined into a single composite sample. The sample represented the top 4 cm of sediment at each BIC replicate station. These samples were submitted to Enviro-Test Laboratories for a metal scan, total organic carbon (TOC), content, and particle size determination to the following classification:

- gravel (2 to 16 mm);
- course sand (0.2 to 2 mm);
- fine sand (0.062 to 0.2 mm);
- silt (0.0039 to 0.062 mm); and,
- clay (<0.0039 mm).

Samples were stored in sterile sediment polyethylene bags, double bagged and double labeled with waterproof ink, then frozen for shipment to Enviro-Test Laboratories.

4.2 Results

4.2.1 Water Quality

4.2.1.1 Field Measurements

Overall, water depth and flow rates were low at the reference (Fingers Creek) and exposure creek (Seep Creek) sampling sites (Table 4.3). Mean depth at the exposure creek station ranged from 0.10 to 0.20 m with current velocities of 0.10 to 0.20 m/s and discharge rates of 0.03 to 0.20 m^3/s. Mean depth was 0.10 m at the reference creek station with a current velocity 0.09 m/s and a discharge rate of 0.01 m^3/s. Wetted channel width was greater at exposure sites than at the reference sites. For lentic sites, water depths were slightly lower in the exposure area (Dam 1a Lake and Seep Creek Ponds 1&2) than in the reference area (Fingers Lake) (Table 4.3).

Table 4.3. Summary of physical characteristics of sampling sites

Area	Station	Wetted Width (m)	Bankfull Width (m)	Water Depth (m)		Velocity (m/s)		Discharge (m^3/s)
				Mean (±SD)	Range	Mean (±SD)	Range	
Exposure	Dam 1a Lake (SCD1)	n/a	n/a	0.50 ± 0.09	0.4 - 0.62	n/a	n/a	n/a
	Seep Creek (SC1)	4	4	0.10 ± 0.09	0.0 - 0.21	0.20 ± 0.16	0.0 - 0.47	0.1
	Seep Creek (SC2)	4.4	7.2	0.10 ± 0.09	0.0 - 0.28	0.06 ± 0.09	0.0 - 0.25	0.04
	Seep Creek (SC3)	3	4.7	0.20 ± 0.11	0.0 - 0.32	0.03 ± 0.03	0.0 - 0.08	0.03
	Seep Creek (SC4)	3	4.5	n/a	n/a	n/a	n/a	n/a
	Seep Creek Ponds 1&2[1]	n/a	n/a	0.39 ± 0.13	0.28 - 0.62	n/a	n/a	n/a
Reference	Fingers Creek (FC2)	0.97	1.25	0.10 ± 0.05	0.0 - 0.13	0.09 ± 0.14	0.0 - 0.39	0.01
	Fingers Lake[1]	n/a	n/a	0.94 ± 0.21	0.8 - 1.30	n/a	n/a	n/a

Note: n/a = not applicable; [1] Mean of five sampling stations (see Figures 4.1 and 4.2).

Air temperature during the survey period ranged from 2 to 18°C. Water temperatures ranged from 4.7 to 13.6°C at the exposure stations and from 7.7 to 13.4°C at the reference stations (Appendix C). All DO concentrations were well above the Canadian Water Quality Guideline (CWQG) minimum concentration of 6.5 mg/L for the protection of aquatic life (CCME 2005).

Conductivity at exposure stations varied considerably, but was much higher than at the reference stations (Table 4.4). Similarly, turbidity varied among stations, but was lower in the reference area than in the exposure area. Water pH was slightly acidic both in the exposure and reference areas, and ranged from 5.3 to 5.9. These pH values were non-

compliant with the CWQG, but were typical of the range of pH values in Nunavut barrenlands waterbodies reported by RCPL and RL&L (1985).

Due to equipment malfunction, field limnology measurements are not available for Fingers Lake. Although slightly higher than field values, laboratory-determined pH and conductivity were similar between lake and creek samples in the reference area, and the exposure station nearest to the FDP (Dam 1a Lake) had higher conductivity and lower pH than the exposure stations farther downstream from the FPD (Seep Creek Ponds) (Appendix C).

4.2.1.2 Laboratory Analysis

Generally, concentrations of most water quality variables were higher in the exposure area than in the reference area (Appendix C). Within the exposure area, concentrations were typically higher at the sampling station nearest to the final discharge point (i.e., Dam 1a Lake) than at stations farther downstream (i.e., Seep Creek Ponds 1&2) (Appendix C).

Nitrate and ammonia concentrations were elevated in the exposure area nearest the FDP (Dam 1a Lake), and total phosphorus and nitrite were below the MDL in all samples (Appendix C). Nitrate concentrations were 5.7 mg/L in Dam 1a Lake, and declined to 0.4 mg/L in Seep Creek Ponds 1 & 2. In the reference area, nitrate was equal to, or below, the MDL (0.1 mg/L). Ammonia concentrations were 0.51 mg/L in Dam 1a Lake, and were below the MDL (less than 0.05 mg/L) in all other samples.

In the exposure stations and Fingers Creek, pH was below the CWQG (Appendix C). Concentrations of aluminum, arsenic, cadmium, copper, lead, nickel, and zinc in the exposure area were above the CWQG. All metal concentrations in the reference area were compliant with the CWQG (Appendix C). For most of these metals, the dissolved component (soluble form) accounted for greater than 70% of the total concentrations. Aluminum and arsenic concentrations exceeded the guidelines in the exposure station nearest the FDP, whereas lead was elevated in the exposure station furthest from the FDP (Table 4.5).

Table 4.4. Field-measured water quality variables

Survey	Area	Sampling Station	Date	Temperature (°C)	DO (mg/L)	pH	Conductivity (µS/cm)	Turbidity (NTU)
Fish Population	**Exposure**	Seep Creek Dam 1a Lake (SCD1)	29-Aug-05	4.7	12.3	5.3	740	0.9
		Seep Creek 1 (SC1)	19-Aug-05	11	n/a	5.6	126	n/a
			22-Aug-05	10.8	n/a	n/a	n/a	0.6
		Seep Creek 2 (SC2)	20-Aug-05	n/a	n/a	n/a	n/a	n/a
		Seep Creek 3 (SC3)	25-Aug-05	9.8	11	5.6	130	0.56
		Seep Creek 4 (SC4)	02-Sep-05	8.4	11.4	5.3	120	n/a
	Reference	Fingers Creek (FC3)	03-Sep-05	7.7	10.6	5.3	120	n/a
		Fingers Creek (FC2)	27-Aug-05	13.4	10.3	5.7	10	n/a
		Fingers Creek (FC1)[1]	05-Sep-05	8.1	10.6	5.9	10	0.54
Benthic Invertebrate Community	**Exposure**	Seep Creek Pond 2 (SCP1)	24-Aug-05	12	n/a	5.8	200	0.91
		Seep Creek Pond 2 (SCP2)	05-Sep-05	13.6	11.7	5.7	130	2.36
		Seep Creek Pond 1 (SCP3)	22-Aug-05	10.8	n/a	5.9	110	n/a
		Seep Creek Pond 1 (SCP4)	24-Aug-05	n/a	n/a	n/a	n/a	1.46
		Seep Creek Pond 1 (SCP5)	06-Sep-05	12.1	11.2	5.9	90	n/a
		Seep Creek Ponds composite	06-Sep-05	n/a	n/a	n/a	n/a	2.36
	Reference	Fingers Lake composite[2]	05-Sep-05	n/a	n/a	n/a	n/a	0.67

Note: n/a = not available; [1] Data for this station used as surrogate for Fingers Lake sampling stations; [2] Composite sample from five sampling stations.

Table 4.5. Total and dissolved concentrations of water quality constituents that exceed CWQG in the exposure area

Variable	Unit	MDL	CWQG	Dam 1a Lake		Seep Creek Ponds 1&2	
				Total	Dissolved	Total	Dissolved
Aluminum	µg/L	2	100	**110**	92.1	72.4	33.6
Arsenic	µg/L	0.04	5	**6.8**	3.78	2.93	2.1
Cadmium	µg/L	0.006	0.017	**0.411**	0.373	**0.0913**	0.0783
Copper	µg/L	0.1	2	**13.1**	12.2	**6.53**	5.15
Lead	µg/L	0.006	1	0.115	0.057	**1.39**	0.638
Nickel	µg/L	0.06	25	**133**	123	**28.4**	26.5
Zinc	µg/L	0.2	30	**314**	303	**40.4**	39.5

MDL = method detection limit; Concentrations of total metals above CWQG are bold and shaded.

4.2.1.3 Quality Assurance and Quality Control

Except for conductivity, constituents analysed in both field and trip blanks were below the quality criterion of five times the MDL. Thus it appears that contaminants were not introduced into samples during field sampling, shipping, or analysis (Appendix C).

Although conductivity values were higher than five times the MDL (0.2 µS/cm), the similarity between the field and trip blank values indicate that any potential contamination may be related to the deionized water supplied by ETL. Nonetheless, the elevated conductivity values should have negligible effect on the results, given the high field-measured values.

The pH in both blank samples differed from the expected 6.9 to 7.1 (range provided by ETL Lab), but this variation may be an artifact of analytical procedure, because the holding time for this variable was exceeded.

4.2.2 Sediment Quality

4.2.2.1 Particle Size and Total Organic Carbon

Particle size composition was uniform across the five reference stations. The particle size of sediment samples collected within the exposure area varied among stations, and generally had higher silt content compared to the reference samples. The texture of the exposure sediment samples ranged from silt to sandy loam. Reference sediment samples were composed primarily of sand (92.4 to 99.1%), with lesser contributions of silt and clay. Silt composition within the reference samples ranges from 0.7 to 6.7%, as compared

to silt composition in exposure samples, which ranged from 9.7 to 78.6% silt (Table 4.6; Appendix D).

TOC within the study area was low. TOC values within the exposure area ranged from 0.4% to 4.3% and were higher than the reference area (less than 0.1% to 0.4%) (Table 4.6; Appendix D).

Table 4.6. Physical and chemical characteristics of bottom sediments at benthic invertebrate replicate stations

Treatment	Station	Particle Size					TOC (%)
		Clay (%)	Silt (%)	Fine Sand (%)	Coarse Sand (%)	Gravel (%)	
Exposure	SCP1	5.5	78.6	7.3	8.6	0	2.6
	SCP2	1.8	61	29.6	7.6	0	0.5
	SCP3	4.6	48.6	4.6	42.2	0	4.3
	SCP4	0.8	22.7	52.4	24.1	0	0.4
	SCP5	1.2	9.7	49.9	39.2	0	0.4
	Mean	**2.8**	**44.1**	**28.8**	**24.3**	**0**	**1.6**
Reference	FL1	0.4	0.7	36.8	62.1	0	0.1
	FL2	1	4	45	50	0	0.2
	FL3	1	6.1	43.7	49.2	0	0.3
	FL4	0	0.9	45.4	53.7	0	<0.1
	FL5	0.9	6.7	34.4	58	0	0.4
	Mean	**0.7**	**3.7**	**41.1**	**54.6**	**0**	**0.2**

Note: TOC = total organic carbon

4.2.2.2 Metal Analysis

In general, metal concentrations were elevated within the exposure area as compared to the reference area. Sediments collected within the exposure area had elevated levels of arsenic, barium, cobalt, chromium, copper, nickel, vanadium, and zinc relative to the reference area. Arsenic and chromium concentrations exceeded the ISQG for the protection of aquatic life at a number of sample stations. Arsenic concentrations were above the ISQG (5.9 mg/kg) at all exposure stations, as well as one station within the reference area (Table 4.1; Appendix D). Arsenic concentrations at stations within the exposure area ranged from 9.6 mg/kg to 45.6 mg/kg. Chromium concentrations were above the ISQG sediment guidelines (37.3 mg/kg) for two stations within the exposure area. Exposure Stations SCP1 and SCP3 had chromium values of 64.9 and 57.5 mg/kg, respectively. The arsenic concentration at FL1, within the reference area, was slightly higher than the ISQG, with a value of 7.0 mg/kg (Table 4.7; Appendix D).

Table 4.7. Sediment Quality Metal Concentrations Exceeding ISQG

Variable	Unit	MDL	ISQG	Area	Station	Concentration
Arsenic	mg/kg	0.2	5.9	Reference	FL1	7.0
				Exposure	SCP1	45.6
					SCP2	17.6
					SCP3	38.9
					SCP4	9.6
					SCP5	18.3
Chromium	mg/kg	0.5	37.3	Exposure	SCP1	64.9
					SCP3	57.5

Note: MDL=method detection limit; ISQG=Interim Sediment Quality Guideline (CCME 2005)

4.3 Summary

Generally, the physical environment was similar in the exposure and reference areas. Seep Creek and Fingers Creek were shallow, with low flow. Fingers Lake was deeper than Dam 1a Lake and Seep Creek Ponds 1 & 2.

The pH was slightly acidic in both reference and exposure stations. Conductivity was higher in the exposure area than in the reference area, and decreased with distance from the FDP.

Nitrate was elevated in the exposure area, with a higher concentration near the FDP (Dam 1a Lake) than farther downstream (Seep Creek ponds). Ammonia was slightly elevated in Dam 1a Lake. Total phosphorus and nitrite were at or below the MDL in all samples.

In general, water quality variables were elevated in the exposure area relative to the reference area. Aluminum, arsenic, cadmium, copper, lead, nickel and zinc exceeded the CWQG in the exposure water quality samples.

Sediment samples were collected from the benthic invertebrate sample stations in depositional habitats. Exposure sediments were composed of sand and silt, whereas reference sediments consisted of mainly sand, with little silt or clay.

Sediment quality variables were elevated in the exposure area relative to the reference area. Sediment arsenic concentrations in the exposure area, and one reference sample exceeded the ISQG for the protection of aquatic life. Chromium exceeded the ISQG in two exposure sediment samples.

5.0 BENTHIC INVERTEBRATE COMMUNITY SURVEY

The BIC in Fingers Lake (reference area) and Seep Creek Ponds 1 & 2 (exposure areas) were surveyed in 2005 to meet MMER EEM requirements. The objective of the BIC survey was to provide sufficient data to determine whether the Mine effluent has had a significant negative effect on the BIC within the aquatic receiving environment. Supporting environmental variables (limnology, water quality, and sediment) were collected at each replicate station.

5.1 Methods

5.1.1 Field Methods

5.1.1.1 Benthic Invertebrate Community

Benthic invertebrate sampling occurred concurrently with the sediment quality survey on 24 August and 1 September 2005. Sampling station suitability was verified before samples were collected by checking water depth and substrate characteristics. Attempts were made to standardize physical habitat between stations to the maximum extent possible. Due to the boulder substrate and lack of suitable depositional material within the originally identified reference area (Concession Creek and Concession Lake), Fingers Lake was selected as an alternate reference area.

As outlined in the TAP approved study design, both the exposure and reference areas contained five replicate stations in depositional habitats (Table 5.1). Replicate stations were spaced approximately 100 m apart (Figures 5.1 and 5.2). At each replicate station, five benthic sub-samples were collected from within a 100 m^2 area. Benthic sub-samples were collected using an Ekman grab, with an area of 0.0232 m^2, following procedures outlined in the EEM guidance document (EC 2002). These five sub-samples were combined into a single composite sample for a total sample area of 0.116 m^2. All benthic samples were collected at a water depth ranging between 0.3 to 1.3 m. Benthic samples were sieved in the field using a 243 µm mesh sieve bag, and preserved with 10% buffered formalin in one litre Nalgene containers. Samples were shipped in sealed coolers, to the Edmonton Golder office, then to J. Fedoruk & Associates Environmental Consultants of Redwater, Alberta, for enumeration and taxonomic identification.

Table 5.1. Benthic sampling station locations

Treatment	Sampling Station	Date	UTM (Zone 12W NAD 83)		Latitude	Longitude
			Easting	Northing		
Exposure	Seep Creek Pond 1 (SCP3)	24-Aug-05	480913	7290274	65° 44' 15.58" N	111° 24' 30.71" W
	Seep Creek Pond 1 (SCP4)	24-Aug-05	480748	7290394	65° 44' 04.63" N	111° 25' 11.35" W
	Seep Creek Pond 1 (SCP5)	24-Aug-05	480595	7290520	65° 44' 15.04" N	111° 24' 31.90" W
	Seep Creek Pond 2 (SCP1)	24-Aug-05	481252	7290713	65° 44' 00.78" N	111° 24' 58.28" W
	Seep Creek Pond 2 (SCP2)	24-Aug-05	481109	7290489	65° 44' 08.67" N	111° 25' 23.41" W
Reference	Fingers Lake (FL1)	01-Sep-05	492619	7286326	65° 41' 54.98" N	111° 09' 38.63" W
	Fingers Lake (FL2)	01-Sep-05	492927	7287021	65° 42' 17.46" N	111° 09' 14.62" W
	Fingers Lake (FL3)	01-Sep-05	493930	7286995	65° 42' 16.69" N	111° 07' 55.67" W
	Fingers Lake (FL4)	01-Sep-05	494157	7287794	65° 42' 42.51" N	111° 07' 38.29" W
	Fingers Lake (FL5)	01-Sep-05	493801	7287081	65° 42' 19.46" N	111° 08' 06.10" W

5.1.1.2 Supporting Environmental Variables

Limnology and Water Quality

Field water quality parameters were measured within the exposure area (Seep Creek Ponds 1 & 2), but not within the reference area (Fingers Lake) due to equipment malfunction.

Water samples in the reference and exposure areas were collected according to the methods outlined in the MMER TGD (EC 2002). Samples were analysed for metals, deleterious substances, major ions, and nutrients. Detailed methods and results are provided in Section 4.0 of this report. A summary of the results is provided below to provide information regarding the supporting environmental variables associated with the BIC habitat.

Sediment

Sediment samples were collected concurrently with the BIC samples. One sediment sample, composed of five subsamples, was collected at each replicate station using a core sampler (diameter 67 mm) for metal analysis, TOC content, and particle size determination. Detailed methods and results are provided in Section 4.0 of this report. A summary of the results is provided below to provide information regarding the supporting environmental variables associated with the BIC habitat.

5.1.1.3 Field QA/QC

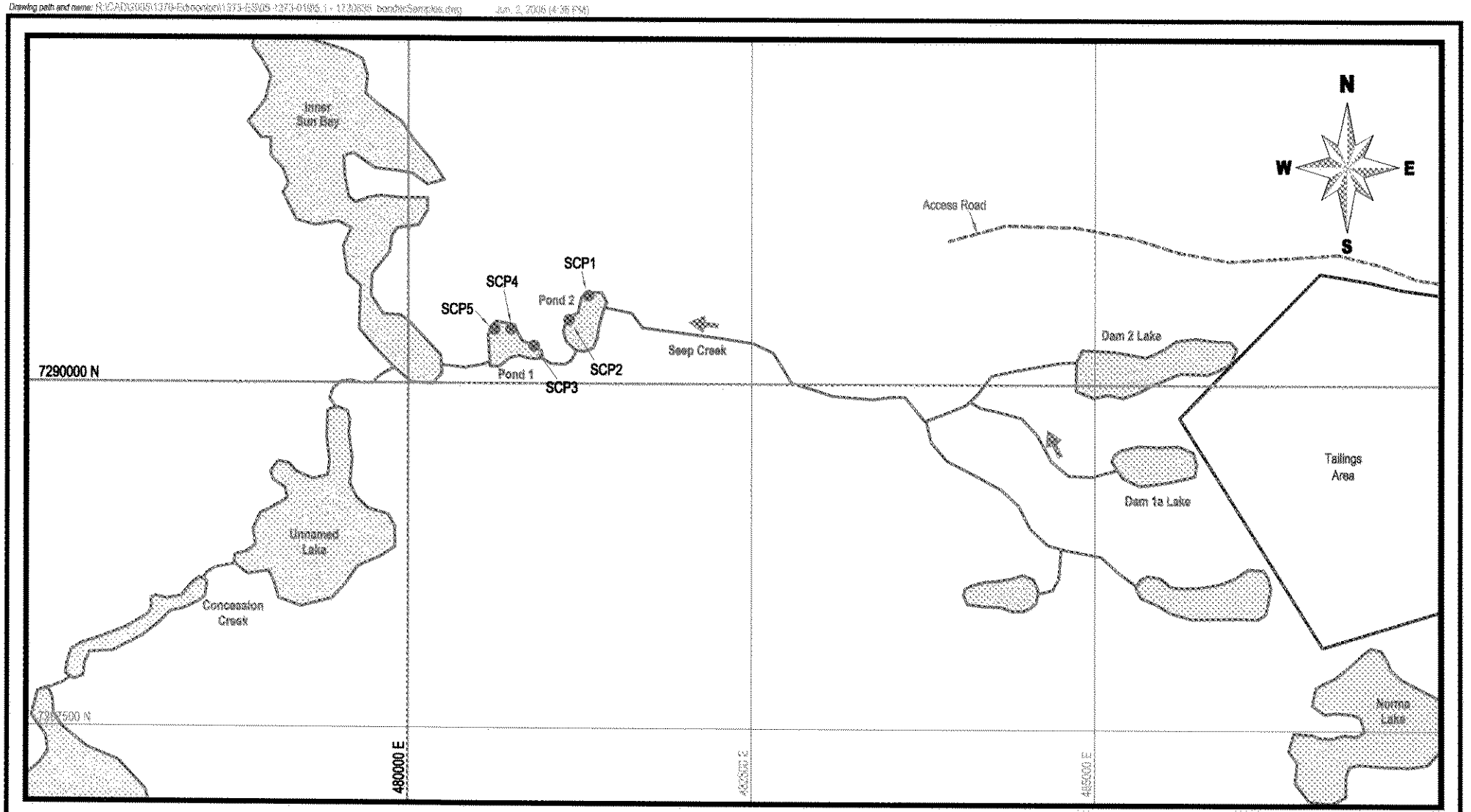
Specific work instructions outlining each field task in detail were provided to field personnel by the task manager prior to the field program. Samples were collected by experienced personnel, and were collected, labelled, preserved, and shipped according to EC (2002). Detailed field notes were recorded in waterproof field notebooks and on pre-printed waterproof field data sheets. Sample jars were labelled in waterproof ink, and a second waterproof label was inserted into each jar. Data collected during the field survey underwent a variety of individual quality assurance checks. Field data sheets were checked at the end of each day for completeness and accuracy. Chain-of-Custody forms were used to track sample shipment from the field, to the Edmonton Golder office, and finally to the taxonomist.

5.1.2 Laboratory Analyses

5.1.2.1 Benthic Invertebrate Community

Due to large sample size and large amounts of organic debris, two composite BIC samples (FL3 and SCP5) were divided into 1.0 mm, 500 µm and 250 µm fractions, which were all sub-sampled using standard taxonomic methods. The remaining composite BIC samples were divided into coarse (500 µm) and fine (250 µm) fractions. The coarse fraction was sorted and fine fractions were sub-sampled as outlined in the MMER TGD (EC 2002).

Invertebrates were identified to the lowest practical taxonomic level (typically to the family level), using current literature and nomenclature. Organisms that could not be identified to the desired level (e.g., immature or damaged specimens) were reported as a separate category, at the lowest level of taxonomic resolution possible, typically family. Organisms that required detailed microscopic examination for identification (e.g., Chironomidae and Oligochaeta) were mounted on microscope slides using an appropriate mounting medium (i.e., Hoyers'). The most common taxa were distinguishable based on gross morphology, and required only a few mounts (5 to 10) as checks. All rare or less commonly occurring taxa were mounted for identification. A reference collection was prepared, consisting of several representative specimens from each taxon.



LEGEND

- Direction of flow
- Watercourse
- Benthic invertetrate community sampling station

800 0 800

Scale Metres

PROJECT

Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report,
Lupin Gold Mine

TITLE

Benthic Invertetrate Community Sampling Stations in the Exposure Area

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730636
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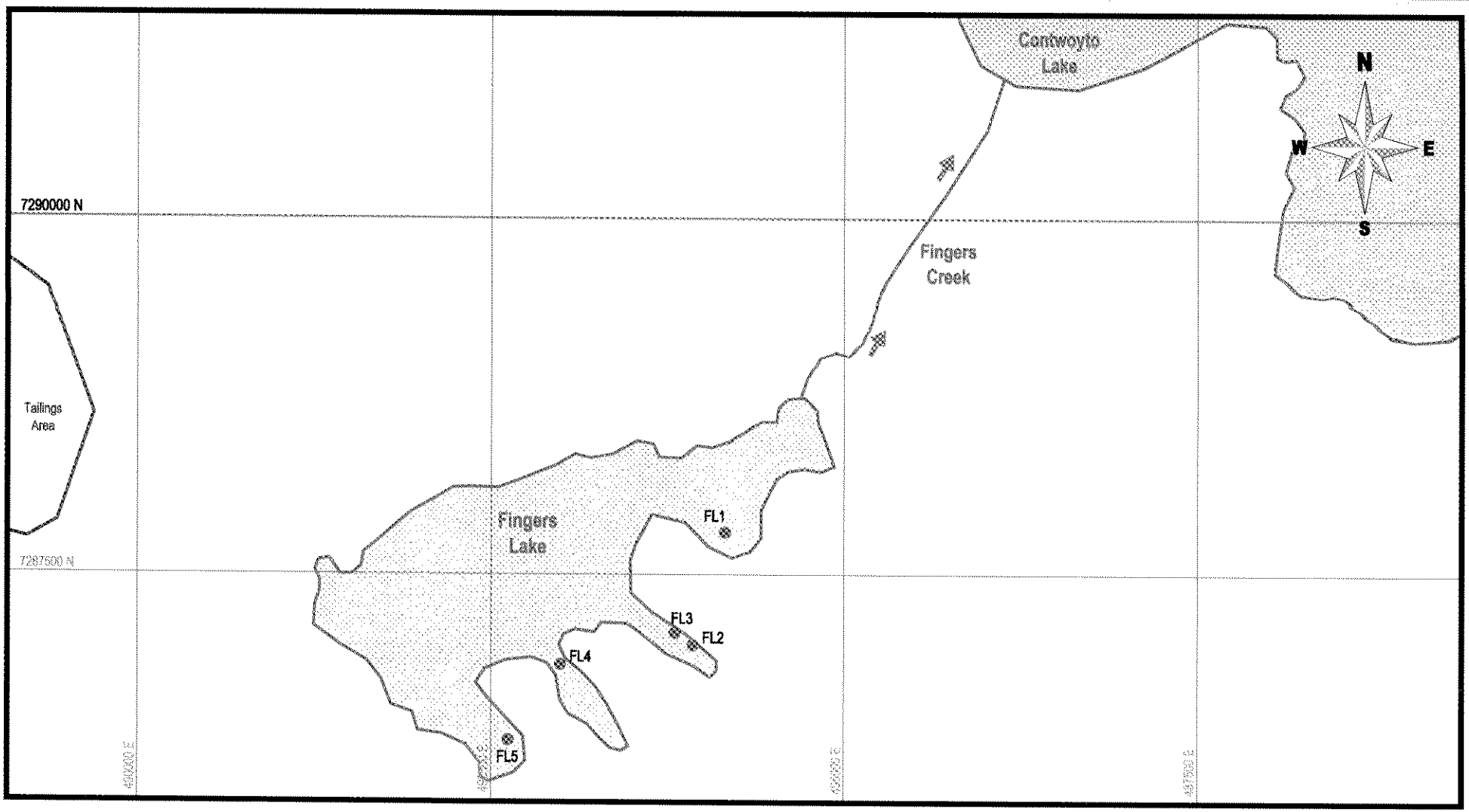
CADD	RW	23/05/06			
CHECK					
REVIEW					

Figure: 5.1



LEGEND

- Direction of flow
- Watercourse
- Benthic invertetrate community sampling station

800 0 800

Scale Metres

PROJECT

Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report,
Lupin Gold Mine

TITLE

Benthic Invertetrate Community Sampling Stations in the Reference Area

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730637
DESIGN	AH	23/05/06	SCALE	As shown	REV. 0
CADD	RW	23/05/06			
CHECK					
REVIEW					

Figure: 5.2

5.1.2.2 Benthic Invertebrate Taxonomist QA/QC

QA/QC for laboratory work consisted of verifying invertebrate removal efficiency and taxonomic identification. Identification of specimens was conducted by one person (Joanna Fedoruk). As part of standard quality control measurements, one sample (10% of all samples) was re-sorted. A removal efficiency of greater than 90% was considered acceptable. QA/QC results are presented and discussed in Appendix E.

5.1.3 Data Analysis

5.1.3.1 Data Entry and Screening

Taxonomic data were received from the taxonomist in both electronic format and hard copy. A quality control check was completed between the hard copy and the electronic data to verify no transcription errors. Supporting invertebrate community survey data from the field were added to the electronic taxonomy data, and the complete dataset was imported into the Golder Associates electronic database. All non-benthic organisms were removed from the dataset and recorded for future reference. Data from the 500 µm fraction were used in all analyses. Raw data for the 250 µm fraction are provided in Appendix E.

Data were entered into an Excel spreadsheet, and results were converted to individuals per square metre area. Converted results were used for the calculation of the following community descriptors and biotic indices at the family level:

- total invertebrate density;
- taxon richness;
- Simpson's Diversity Index (SDI);
- Bray-Curtis Index (BCI);
- evenness;
- taxon density;
- taxon proportion; and,
- taxon presence/absence.

Calculations of the community descriptors and biotic indices were based on the formulas provided in the MMER TGD (EC 2002).

Density was calculated as the number of organisms per square metre.

Richness is the total number of taxonomic groups within a station, at the family level. Richness provides an indication of the diversity of benthic invertebrates in an area; a higher richness value usually indicates a more healthy and balanced community.

Evenness is a measure of the relative abundance of the different species making up the richness of an area.

SDI measures the proportional distribution of organisms in the community, given that not all organisms have the same success in the environment, since certain conditions may favour or affect one organism over another. SDI values range between 0 and 1, where lower values indicate a community dominated by fewer taxonomic groups (less diverse); these are often referred to as stressed communities, which may be caused by natural and/or anthropogenic conditions. High values indicate a community consisting of more taxa that are more evenly distributed among the taxonomic groups.

The above indices are measures of total density and taxon richness, but do not take into account any quantitative information on the types of organisms present. Therefore, the ***BCI***, which is a dissimilarity index, was calculated to compare entire communities among sampling areas. The BCI summarizes the overall difference in community structure between the reference and exposure stations. BCI values range between 0 and 1, where lower values indicate that the community in the exposure area is similar to the reference community.

5.1.3.2 Statistical Analyses

An effect on the BIC was determined if there were statistical differences in any of the following endpoints:

- total invertebrate density;
- family richness;
- BCI;
- SDI; and
- evenness

The following descriptors were calculated, and are included as supporting variables (i.e., they are not statistically analyzed to determine "effects"):

- major family density;
- family proportion; and,
- family presence/absence.

Summary statistics for each descriptor (i.e., arithmetic mean, median, minimum, maximum, standard deviation, standard error, and sample size) were calculated and summarized by area.

Statistical analyses were conducted on total density, richness, and index data calculated for each replicate station. With the exception of the raw total invertebrate density data, the data met the assumptions of normality and equality of variances. Total invertebrate density was log-transformed to meet the assumptions for statistical analyses.

A two-sample *t*-test was used to determine whether there was a statistically significant difference in density and richness between the two sampling areas (α=0.1). A Mann-Whitney *U* test was used to determine whether there was a statistically significant difference in the derived endpoints (evenness, BCI and SDI). As stated in the study design, non-parametric analyses are more appropriate for derived variables due to the unusual statistical properties of these types of variables (Golder 2004). Statistical tests were run using PC-Ord™ version 4.0 and SSPS™ version 14.0 software packages.

Power Analysis

Retrospective power analysis was conducted for each invertebrate community variable with the statistical software package SYSTAT version 11.0. To estimate power, effect size was set to ±2SD and sample size (i.e., number of stations per area) was set to five, corresponding to the number of stations sampled per area during this study. Power was estimated for both α and β set at 0.05 and 0.1.

5.1.3.3 Data QA/QC

Data entered into the Golder Associates database underwent a 10% check for accuracy by a second person not involved in the initial entry process. All tables and data sets generated by the database underwent an additional 10% QA/QC screening.

5.2 Results

5.2.1 Supporting Environmental Variables

Limnology and Water Quality

Limnology variables were measured in the exposure and reference exposure areas. The pH values in the exposure and reference areas were non-compliant with the CWQG, but were typical of the range of pH values in Nunavut barrenlands waterbodies reported by RCPL and RL&L (1985). The laboratory measured pH in the exposure area (6.1) was

lower than the reference area (6.5). Conductivity in the exposure sample (141 µS/cm) was higher than in the reference sample (14.8 µS/cm) (Table 4.4).

Nitrate concentrations were higher within the Seep Creek Ponds than in Fingers Lake. Ammonia, nitrite and total phosphorus concentrations were at or below the detection limit for both reference and exposure areas (Appendix C).

In general, metal concentrations were elevated in the BIC exposure area compared to the reference area. Metal concentrations did not exceed the CWQG in the reference area. In the BIC exposure area, cadmium, copper, lead, nickel and zinc concentrations exceeded the CWQG for the protection of aquatic life (Appendix C).

Sediment Quality Monitoring

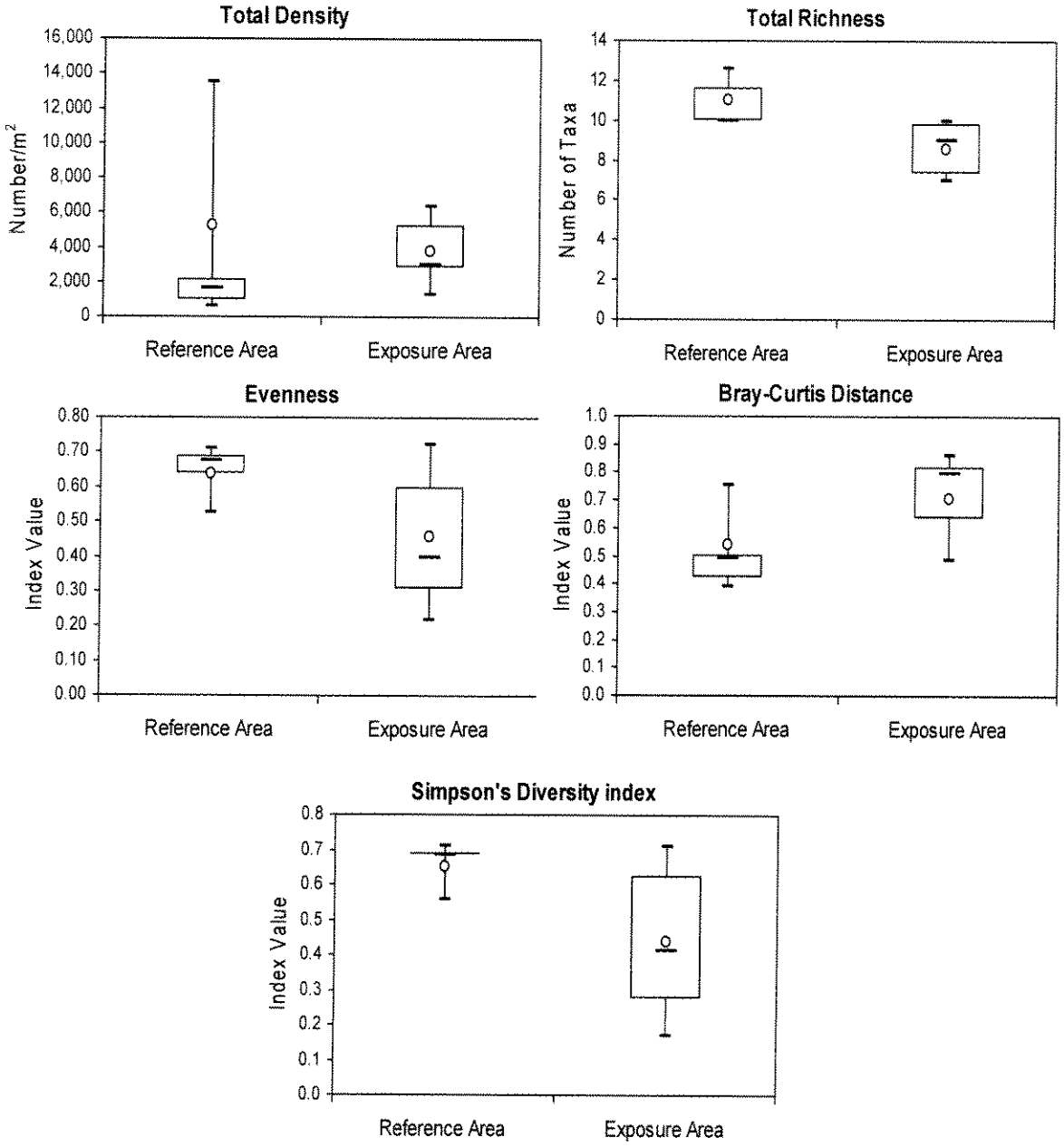
The texture of the exposure sediment samples ranged from silt to sandy loam. Reference sediment samples were composed primarily of sand, with lesser contributions of silt and clay. The particle size composition within the reference area generally had lower silt content compared to the exposure samples (Table 4.5; Appendix D). TOC values within the exposure area (mean of 1.6%) were higher than the reference area (mean of 0.3%).

In general, sediment metal concentrations were elevated within the exposure area as compared to the reference area. Arsenic concentrations were above the ISQG (5.9 mg/kg) at all exposure stations (range from 9.6 to 45.6 mg/kg), as well as one station within the reference area (7.0 mg/kg). Chromium concentrations were above the ISQG sediment guidelines (37.3 mg/kg) for two stations within the exposure area (64.9 and 57.5 mg/kg) (Table 4.6; Appendix D).

5.2.2 Data Screening

Results of taxonomic identification and enumeration are summarized as station means and standard deviations (Appendix E). Data screening, using box and whisker plots for total invertebrate density, family richness, evenness, SDI and BCI, identified potential outliers at some of the stations; however, data checks confirmed the validity of the data and thus no data were removed (Figure 5.3). The following results are based on mean values calculated for each of the five replicate stations in each area.

Figure 5.3. Box plots of benthic invertebrate effect endpoints



Box plot range: 30th and 70th percentiles
Error bar range: 10th and 90th percentiles
Open circles: means
Horizontal bars: medians

5.2.3 Statistical Analyses

5.2.3.1 Density

Mean total invertebrate density was higher in the reference area compared to the mean value from the exposure area (5107 and 3710 organisms/m^2, respectively) (Table 5.2; Figure 5.4). Mean density did not differ significantly between the two areas (*t*-test, $P>0.1$; Table 5.3).

5.2.3.2 Richness

Richness was similar between areas, ranging from three to six families in the exposure area and three to nine families in the reference area (Table 5.2; Figure 5.5). Richness was not significantly different between areas (*t*-test, $P>0.1$; Table 5.3).

5.2.3.3 Evenness

Evenness was lower in the exposure area (0.170) as compared to the reference area (0.308) (Table 5.2; Figure 5.6). The Mann-Whitney *U* test indicated that the difference between areas was significant at $\alpha = 0.1$, but non-significant at $\alpha = 0.05$ (Table 5.3).

5.2.3.4 Simpson's Diversity Index

The mean SDI value was lower in the exposure area (0.104) as compared to the reference area (0.226). The variation in the SDI among exposure stations was smaller than the variation among reference stations (Table 5.2; Figure 5.7). The difference in the mean SDI between areas was significant (Mann-Whitney *U* test, $P<0.05$; Table 5.3).

5.2.3.5 Bray-Curtis Index

The mean BCI for the reference area provided an indication of background variability within the reference area, since each station was compared to the median of the reference stations. The reference area displayed considerable variation in BCI values compared to the exposure area (Table 5.2; Figure 5.8). The BCI values were not significantly different between the exposure and reference areas (Mann-Whitney *U* test, $P>0.1$; Table 5.3).