macroinvertebrates tended to be greater during the 1990 and 1991 surveys than during the two 1985 sampling sessions.

The four most dominant taxa identified during all studies were *Heterotrissocladius*, Nematoda, *Pisidium* and *Tanytarsus*. To keep reporting brief, results of statistical analyses for these taxonomic groups are described below. In general, most of the other dominant taxa had similar results as the four most dominant taxa. *Heterotrissocladius* densities at all stations except Station 5, tended to be significantly ($p<0.001$) greater during the two 1985 surveys than the 1990 and 1991 surveys. At Station 5, densities of this taxon did not differ significantly among the four sampling dates. Nematode densities tended to be significantly ($p<0.05$) greater during the 1990 study and sometimes the 1991 survey than during the two 1985 sampling sessions; however, there were no significant differences in densities among all surveys at Station 2. At all stations, except stations 3 and 5, densities of *Pisidium* were significantly ($p<0.025$) greater during September 1985, and sometimes during August 1985 as well, than during the 1990 and 1991 studies. *Pisidium* densities at Station 3 did not differ significantly among the four sampling sites. At Station 5, *Pisidium* densities were significantly ($p<0.05$) lower during August 1985 than during 1990 and 1991 surveys, and all of these surveys were significantly ($p<0.05$) lower than September 1985. *Tanytarsus* densities were significantly ($p<0.001$) greater during the two 1985 sampling sessions than during the 1990 and 1991 surveys at all stations, except Station 3. At Station 3, densities of *Tanytarsus* were significantly ($p<0.02$) greater during September 1985 than during August 1985 and the 1990 survey; densities did not differ significantly between September 1985 and the 1991 survey. These temporal trends in data, where stations 3 and/or 5 had different results than the remaining stations, were observed for the majority of the dominant taxonomic groups.

Table 4.19 Results of ANOVA and SNK multiple comparison tests, on Log_{10} $(x+1)$ transformed data, comparing densities of dominant (≥1% of total numbers) taxonomic groups, total common taxa, and total number of macroinvertebrates as a whole. Date rankings are listed in ascending order of abundance. 1=August 1985, 2=September 1985, 3=August 1990, and 4=August 1991.

Taxonomic Group	Station	ANOVA p value	Date Rankings*
Paratanytarsus sp.	2	0.284	4 2 3 1
	3	0.007	1=2 3 4
	5	<0.001	1=4 2 3
	6	0.032	3=4 1 2
	7	<0.001	4 3 2 1
Tanytarsus sp.	2	<0.001	4 3 2 1
	3	0.020	3 1 4 2
	5	<0.001	4 3 1 2
	6	<0.001	3 4 1 2
	7	<0.001	4 3 2 1

. Continued.

Table 4.19 Continued.

Taxonomic Group	Station	ANOVA p value	Date Rankings*
Protanypus sp.	[illegible]	0.019	4 2 1 3
	[illegible]	0.015	4 3 2 1
	5	0.009	1 4 3 2
	6	0.072	4 1 3 2
	7	0.205	1 4 2 3
Cricotopus sp.	2	0.629	1=2=4 3
	3	0.626	1=2 4 3
	5	<0.001	2 4 1 3
	6	0.105	4 1=3 2
	7	<0.001	4 3 2 1
Heterotrissocladius sp.	2	<0.001	4 3 2 1
	3	<0.001	4 1 2 3
	5	0.061	3 4 2 1
	6	<0.001	3 4 2 1
	7	<0.001	3 4 2 1
Parakiefferiella sp.	2	0.426	1=4 2 3
	3	0.005	1 2 4 3
	5	0.082	1 2 3 4
	6	0.008	2 1 4 3
	7	0.132	1 2=4 3
Ablabesmyia sp.	2	1.00	1=2=3=4
	3	0.010	2 1 4 3
	5	0.042	1=2 4 3
	6	0.872	1=2 3=4
	7	0.085	2=3=4 1
Procladius sp.	2	0.053	4 3 1 2
	3	0.598	1 2 3=4
	5	0.081	4 3 1 2
	6	0.892	4 3 1=2
	7	<0.001	4 3 2 1
Thienemannimyia sp.	2	1.00	1=2=3=4
	3	0.041	3 1 2 4
	5	<0.001	1=4 2 3
	6	0.347	1=3 4 3
	7	0.004	1 3 4 2

... Continued.

Table 4.19 Concluded.

Taxonomic Group	Station	ANOVA p value	Date Rankings*
Pisidium sp.	2	0.005	4 3 1 2
	3	0.096	4 1 3 2
	5	<0.001	1 3 4 2
	6	0.025	4 3 1 2
	7	<0.001	4 3 1 2
Nematoda	2	0.457	4 2 1 3
	3	0.018	1=2 4 3
	5	<0.001	1 2 3 4
	6	0.030	2 1 4 3
	7	0.005	2 1 4 3
Tubificidae with capilliform chaetae	2	0.337	1=2=3 4
	3	0.010	3 2 4 1
	5	0.002	4 2 3 1
	6	0.085	1=3=4 2
	7	0.003	1=3 2 4
Total Common Taxa	2	<0.001	4 3 2 1
	3	0.080	4 1 2 3
	5	0.380	1 3 4 2
	6	0.005	4 3 2 1
	7	<0.001	4 3 2 1
Total Number of Invertebrates as a whole	2	<0.001	4 3 2 1
	3	0.047	2 4 1 3
	5	0.949	1 2 3 4
	6	0.092	4 3 2 1
	7	<0.001	4 3 2 1

Note: *Underlined rankings were not significantly (p>0.05, SNK multiple comparisons following one-factor ANOVA) different from one another.

4.2.4 Summary

Results of the statistical analyses of the 1991 data among the sampling stations (Section 4.2.2) as well as the temporal analyses among the four study periods (Section 4.2.3) both identified, for the most part, that stations 3 and 5 had a benthic macroinvertebrate community that differed from the other sampling stations. Although Station 3 was the most proximal station to the point of entry for Lupin Gold Mine's effluent, it also was the shallowest (2.7 m, Table 4.5). Station 5 was located in Outer Sun Bay and was near to stations 6 and 7; however, Station 5 had the second most shallow sampling depth (6.1 m). Shallow areas are expected to have greater temperatures and oxygen concentrations at the sediment-water interface than are deeper stations; furthermore, depth can be an important factor controlling the composition of benthic macroinvertebrate communities in lentic systems (Merritt and Cummins 1984; EVS Consultants 1992). To determine whether or not decreased abundance at an impact station is mine-related, it is necessary to compare changes at the impact stations in relation to change at a control station (Green 1979; Mudroch and Sutherland 1988). Although Station 2 was intended to be a control site, it was the second deepest station (14.6 m); in addition, there is evidence that sediment quality at this station has been impacted by Lupin Gold Mine's effluent (see sections 4.1.2 and 4.1.3). Green (1979) recommends that control samples be collected in an area where the condition, or potentially impacted area, is absent because evidence for impact effects must be based on changes in the impact area that did not occur in the control area. Mudroch and Sutherland (1988) identified this problem with their August 1985 and September 1985 data assessments and suggested that a more compatible control station be established. To properly identify effects due to mine operations, it is recommended that control stations outside of the impact area that are similar in depth to the already established monitoring stations be included in future surveys.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

1. Spatial comparisons of 1991 sediment quality data revealed that, for the most part, stations 2 ("control"), 3, and sometimes 9 had, in many cases significantly ($p<0.05$), greater concentrations of arsenic and the majority of metals than did the other monitoring stations. Mean arsenic concentrations at stations 2, 3, and 9 were approximately twice the concentrations obtained at stations 5, 6, and 7. Furthermore, arsenic had concentrations at Station 3 that were significantly ($p<0.05$) greater than at stations 5, 6, and 7. Mean concentrations of cadmium, mercury, and selenium were significantly greater at Station 2 than at the remaining five stations. Stations 2, 3, and 9 had significantly ($p<0.05$) greater concentrations of copper and zinc than did stations 5, 6, and 7. Mean concentrations or amounts of chromium, lead, nickel, particle size, and loss on ignition did not differ significantly among the six monitoring stations.

   If mine-related effects are to be found, then statistical analyses should describe significantly increased concentrations of contaminants at those stations that are more susceptible to the effects of the effluent; however, the spatial distribution patterns of sediment quality during each of the four survey periods varied considerably. Arsenic concentrations provide an example of the variability in spatial patterns among the study periods. At the sampling stations that were sampled during all four surveys, Station 2 had the greatest mean arsenic concentrations during August 1985 and September 1985 (43.4 and 40.3 mg/kg, respectively), whereas, stations 5 and 3 had the greatest mean concentrations of this element during 1990 and 1991 (79.2 and 65.0 mg/kg, respectively). During 1990 and 1991, Station 2 had the second lowest (15.7 mg/kg) and second highest (56.8 mg/kg) mean concentrations of arsenic, respectively. The lowest mean concentrations of arsenic during 1990 and 1991 were found at stations 6 (14.7 mg/kg) and 5 (20.8 mg/kg), respectively. Confounding factors (see No. 3 below) may have contributed towards these and other variable results.

2. In general, surface sediment concentrations of arsenic and metals among the four surveys (August 1985, September 1985, August 1990, and August 1991) were variable and trends were inconsistent; however, some of the sediment quality variables illustrated results suggesting an impact occurred. At Station 2 ("control"), mean copper, lead, and zinc concentrations tended to be significantly ($p<0.05$) greater during 1991 than during the three previous sampling sessions. At Station 3, mean arsenic concentrations during the 1990 and 1991 surveys were significantly ($p<0.05$) greater than those reported during the two 1985 sampling sessions and during 1991, concentrations of arsenic were significantly ($p<0.05$) greater than 1990 concentrations. Mean arsenic, copper, and mercury concentrations at Station 5 tended to be lower, and in many cases significantly ($p<0.05$), during 1991 than during all previous surveys. At all of the sampling stations, mean cadmium and selenium concentrations were significantly ($p<0.05$) greater during 1991 than during 1990. Mean chromium concentrations at all stations, except Station 3, were significantly ($p<0.05$)

greater during 1990 than during 1991. At Station 3, chromium concentrations did not differ significantly between the two sample dates. To date, accurate accumulations of arsenic and metals in the sediments of Contwoyto Lake cannot be determined because of high variability and opposing trends in results. Few variables, such as arsenic at Station 3, have illustrated a consistent trend of decreasing sediment quality over the four study periods.

3. During the two 1985 surveys, sediment samples consisted of the top five centimetres; whereas, the 1990 and 1991 surveys collected and analyzed the 0 to 1 centimetre portion of sediments. Project managers decided that the collection of the top 0-1 cm of sediment would have the most recent deposition of sediments thereby allowing for early detection of changes in sediment quality. Three of the surveys (August 1985, September 1985, and 1991) had the sediment samples analyzed at Environment Canada, Environmental Protection Branch's analytical laboratory. The sediment samples collected during 1990 were analyzed by Chemex Labs Alberta Inc. Use of different methodologies and analytical laboratories contributed towards the variable results. The original study design designated Station 2 as a control site; however, Station 2 is located in Contwoyto Lake where it is exposed to Lupin Gold Mine's effluent. Subsequent sampling and analysis of data suggest that this station may be showing initial signs of effluent impacts. The original design of this monitoring program was to emphasize temporal changes in sediment quality and benthic macroinvertebrate community structures. Station 2 was chosen as a "twin" bay to Outer Sun Bay, and as long as sediment quality is not considerably impacted, it has the potential to be used as a spatial control station.

4. Mudroch and Sutherland (1988) postulated that deep Contwoyto Lake stations may be acting as a repository for solids and metals (known as sediment focussing, Wetzel 1983). During the present, 1991 study, three replicate cores were collected from Station 9 (27.1 m deep) and ten, individual 1-cm vertical sub-sections of each replicate core were submitted for laboratory analysis. Statistical analyses revealed that there were significant and nonsignificant trends of decreased sediment quality in the surface sub-sections of these vertical cores.

5. Statistical power analysis was performed on the sediment quality data. Results of the data analyses on the spatial distribution (i.e., among stations during 1991) of sediment quality suggested that most of the statistical tests had high power; however, by increasing the number of replicates from five to six, power would considerably improve for most variables and a significant difference in nickel concentrations would likely be detected. Statistical power for arsenic would increase from 0.832 under the present sampling design to 0.959 with the collection of six replicates per station. Results of the statistical power analysis on temporal distribution (i.e., among the four sample periods) indicated that the power of the majority of tests, under the present sampling design, that had detected a significant difference (i.e., rejected the null hypothesis) was relatively greater than those statistical tests that did not find a significant difference among

the four study periods. Increasing or decreasing the number of replicates collected by one (i.e., collect six or four samples per station per date) would not considerably alter the power of statistical tests.

6. A total of 52 taxonomic groups of benthic organisms were identified during the 1991 survey year; this was intermediate of the 32 and 73 taxa that were identified during the 1985 and 1990 studies, respectively. In 1991, densities of the six most abundant (taxa that contributed towards $\geq 1\%$ of the total number of benthic invertebrates and were found in $\geq 50\%$ of samples collected) taxa, except *Mesocricotopus*, were significantly ($p < 0.05$) greater at stations 3 or 5, and sometimes both. *Mesocricotopus* densities did not differ significantly among the sampling stations during the 1991 survey.

7. There were 21 taxonomic groups of macroinvertebrates that were common to all four sampling sessions. These 21 taxa contributed towards 67% of all invertebrates collected during 1985 through 1991. Of the 21 common taxa, 12 contributed towards $\geq 1\%$ of the total number of macroinvertebrates among all four sampling periods, and were deemed dominant. The dominant taxa tended to have consistent observations in densities, either increasing or decreasing significantly ($p < 0.05$), among the four sampling sessions at all stations, except stations 3 and/or 5. In stations 3 and/or 5, the following trends were observed among most of the dominant taxa: 1) densities did not differ significantly ($p < 0.05$) among the sampling periods, 2) densities were significant, but highly variable (i.e., no obvious trends), and 3) densities differed significantly ($p < 0.05$) among the four sampling sessions, but were in an opposing direction to those observed the other stations.

8. Relative to all other sampling stations, Station 3 and, to some degree, Station 5 had unique results in sediment quality and the benthic macroinvertebrate community. These two stations were shallow relative to the other sampling stations. Shallow areas are expected to have higher bottom temperatures and dissolved oxygen concentrations than deeper stations; furthermore, depth is an important factor influencing the composition of benthic macroinvertebrate communities in lakes (Merritt and Cummins 1984). Natural variability within sampling stations and among sampling periods also may account for results observed at stations 3 and 5.

9. To determine the lowest level of taxonomic classification needed to demonstrate significant differences among stations, Mantel's test (Mantel 1967) was used. The rationale behind this exercise is to minimize the effort needed to determine "impact - no impact." In the Lupin study, the results indicated future studies should still focus on the lower taxonomic levels (i.e., genus and species).

10. As with the sediment quality data, there were some confounding factors that contributed towards the variability and tenuous interpretation of benthic macroinvertebrate data. Some of the benthic samples had portions that were not preserved well. Some specimens were decomposed and calcarious shells of molluscs

were dissolved. Benthic invertebrate samples collected during the two 1985 surveys were analyzed by The Environmental Applications Group Ltd., Toronto, Ontario, whereas, the 1990 and 1991 samples were analyzed by EVS Consultants, North Vancouver, B.C. Utilizing one laboratory for sample processing will provide for consistent quality control and identifications of taxa, thereby reducing variability in data as a result of analytical procedures and identification biases. More importantly, however, as with the sediment samples a "good" spatial control site is missing. The benthic macroinvertebrate community should be sampled at an area outside of the potential influence of Lupin Gold Mine's effluent. This will provide insight into the natural spatial variability in data trends within and among study periods.

5.2 RECOMMENDATIONS

1. Continuation of the sediment sampling program will help to further delineate potential trends in accumulation of arsenic, metals, and particles in Contwoyto Lake. Inclusion of control stations outside of Contwoyto Lake would help to assess spatial variations due to natural factors. Concession Lake could be considered as a control (see Figure 1.1); however, an appropriate spatial control that has compatible sediment accumulations and benthic habitat may be difficult to locate.

2. Continued sampling of three or more replicate cores from Station 9, the deepest and farthest station from the effluent discharge location, to evaluate vertical contamination transport is recommended. One and three replicates were collected during 1990 and 1991, respectively. Thus, there are too few replicates and sampling sessions to include definitive temporal analyses and results in the present report. At least three replicate cores for vertical analysis should be collected during future investigations.

3. Some of the extraneous factors affecting sediment quality data can be removed or alleviated by having all samples analyzed by Environment Canada, Environmental Protection's analytical laboratory and selectively collecting the top five centimetres of sediments for analyses. Following the first two surveys in 1985, it was decided that the top 0-1 cm of sediment should be collected. The intent was to quickly detect temporal changes in sediment quality because sedimentation rates were considered to be low. Since the first, pre-discharge survey collected samples from the top five centimetres, a few stations could be selected for similar sediment collections to provide a comparison with pre-discharge data to post-discharge data. Alternatively, selected stations that have five or more 1-cm subsections (i.e., vertical contaminant core sections) could have the results of the top five 1-cm sections composited or averaged and then compared to pre-discharge data. Consistent methodologies among pre- and post-impact assessments would facilitate succinct data interpretation.

4. Results of the statistical power analyses suggested that the collection of six replicate samples instead of five would provide a stronger ability to detect significant differences in sediment quality trends among the sampling stations. Conversely, power analyses on the temporal data (i.e., among the four sample periods)

suggested that reducing the number of replicates from five to four would have minor effects on the ability to detect significant differences in sediment quality. Depending on the objectives of future monitoring programs and pressure to reduce costs, researchers will have to decide whether or not it is necessary to increase or decrease the number of replicates collected per station by one. A compromise would be to leave the number of replicates at five. The number of replicate surface sediment samples collected at Station 9 should be the same as those collected at all of the other stations (i.e., depending on the sampling design, increase the number of replicates from three to four or five).

5. Continuation of the benthic macroinvertebrate sampling program will help to reduce uncertainty in results and to further monitor for potential benthic impacts. In addition, the biological component of the Lupin study may help further refine mine monitoring methods (e.g., biological monitors) that may be useful in developing generic monitoring and assessment techniques for existing and future mine sites.

6. To facilitate the interpretation of benthic macroinvertebrate data, control sites are required. As with the sediment quality data, control stations, outside of the potential influences of Lupin Gold Mine's effluent, were not sampled. Establishment of control stations in Concession Lake could provide insight into the natural variability of the benthic macroinvertebrate community in the vicinity of Lupin Gold Mine. Stations 3 and 5 were much shallower than the other stations and had benthic macroinvertebrate communities that differed from the other stations. This suggests that more than one benthic macroinvertebrate control station (i.e., one or more shallow stations and one or more deep stations) is required to properly address natural variation.

7. Future monitoring studies at Lupin should focus on the lower taxonomic levels (i.e., genus, species) for determining whether or not benthic impacts have occurred. This does not preclude the need to continue to evaluate data in order to find less time-consuming methods of impact assessments (e.g., using biotic indices or higher level taxonomic classification).

8. Variability among study years was observed in the number of benthic macroinvertebrate taxa that were identified; furthermore, there were problems associated with preservation of samples (e.g., mollusc shells were dissolved and preservative(s) did not penetrate throughout the contents of some samples). Using the same field personnel, establishing specific field collection and quality control techniques, and utilizing the same laboratories for processing of benthic samples will help to reduce variation in results due to sampling, preserving, and processing.

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APPENDIX A

PRECISION AND ACCURACY ON SEDIMENT ANALYSES

PRECISION

The precision of a sample set is measured by replication of at least 10% of the samples. The percent relative standard deviation (%RSD) is an indicator as to the level of precision of the data. The level of %RSD varies depending on the variable and methodology. The results of the quality control data are provided below. All concentrations are mg/kg, unless stated otherwise. %L.O.I. = Loss On Ignition (% loss, dry weight).

Sample: Station 3, Replicate #5

Variable	Replicate		Mean	Standard Deviation	%RSD
	1	2			
Arsenic	76.1	76.5	76.3	0.28	0.37
Cadmium	0.53	0.56	0.55	0.02	3.89
Chromium	66.0	65.0	65.5	0.71	1.08
Copper	59.0	56.3	57.7	1.91	3.31
Lead	22.4	23.7	23.0	0.92	3.99
Nickel	32.3	31.9	32.1	0.28	0.88
Selenium	0.50	0.40	0.45	0.07	15.7
Zinc	66.1	65.5	65.8	0.42	0.64
%L.O.I.	3.9	3.9	3.9	0.00	0.00

Sample: Station 5, Replicate #5

Variable	Replicate		Mean	Standard Deviation	%RSD
	1	2			
Arsenic	22.5	21.8	22.2	0.50	2.24
Cadmium	0.28	0.28	0.28	0.00	0.00
Chromium	58.6	55.6	57.1	2.12	3.7
Copper	13.1	11.9	12.5	0.85	6.79
Lead	17.1	17.5	17.3	0.28	1.64
Nickel	24.5	23.8	24.2	0.495	2.05
Selenium	0.21	0.21	0.21	0.00	0.00
Zinc	51.0	48.6	49.8	1.70	3.40
%L.O.I.	4.3	4.2	4.3	0.07	1.66

Sample: Station 9, Replicate #1, 7-8 cm					
Variable	Replicate		Mean	Standard Deviation	%RSD
	1	2			
Arsenic	27.5	27.4	27.4	0.07	0.26
Cadmium	0.35	0.45	0.40	0.07	17.7
Chromium	59.7	59.4	59.6	0.21	0.36
Copper	50.9	52.3	51.6	0.99	1.92
Lead	19.4	20.6	20.0	0.85	4.24
Nickel	35.2	34.3	34.8	0.64	1.83
Selenium	0.10	0.10	0.10	0.00	0.00
Zinc	75.1	74.2	74.7	0.64	0.85
%L.O.I.	4.9	5.0	5.0	0.07	1.43

Sample: Station 9, Replicate #2, 5-6 cm					
Variable	Replicate		Mean	Standard Deviation	%RSD
	1	2			
Arsenic	16.5	16.6	16.6	0.07	0.43
Cadmium	0.36	0.29	0.33	0.049	15.2
Chromium	48.2	48.6	48.4	0.28	0.58
Copper	37.8	37.2	37.5	0.42	1.13
Lead	18.7	19.1	18.9	0.28	1.50
Nickel	27.7	26.7	27.2	0.71	2.6
Selenium	0.24	0.24	0.24	0.00	0.00
Zinc	61.7	62.0	61.9	0.21	0.34
%L.O.I.	4.6	4.5	4.6	0.07	1.55

Sample: Station 9, Replicate #3, 9-10 cm						
Variable	Replicate			Mean	Standard Deviation	%RSD
	1	2	3			
Arsenic	16.1	16.8	16.0	16.3	0.44	2.67
Cadmium	0.32	0.23	0.20	0.25	0.06	25.0
Chromium	54.0	48.4	53.4	51.9	3.08	5.92
Copper	37.2	38.0	37.4	37.5	0.42	1.11
Lead	19.9	18.6	18.5	19.0	0.781	4.11
Nickel	30.7	31.3	31.6	31.2	0.458	1.47
Selenium	0.15	0.15	0.15	0.15	0.00	0.00
Zinc	66.8	68.2	67.1	67.4	0.74	1.09
%L.O.I.	3.5	3.7	3.5	3.6	0.12	3.24

Variable: Mercury						
Sample	Replicate			Mean	Standard Deviation	%RSD
	1	2	3			
Stn 7, Rep. 2	<0.02	<0.02	<0.02	<0.02	0.00	0.00
Stn 5, Rep. 2	<0.02	<0.02		<0.02	0.00	0.00
Stn 9, Rep. 1, 5-6 cm	<0.02	<0.02		<0.02	0.00	0.00
Stn 9, Rep. 2, 8-9 cm	<0.02	<0.02		<0.02	0.00	0.00
Stn 9, Rep. 3, 9-10 cm	<0.02	<0.02		<0.02	0.00	0.00

ACCURACY

The accuracy of a methodology used to produce sample data is determined by the analysis of quality control samples. These QC samples are supplied by Environmental Protection Agency (EPA), National Institute of Standards and Technology (NIST) or in-house synthetic samples made from stock standards. The 95% Confidence Intervals indicate the acceptable range of values for which the quality control results may fall. For synthetic quality control samples, the range is 10% of the designed value. The results of the quality control data are provided below. All concentrations are mg/kg, unless otherwise stated. %RSD = % Relative Standard Deviation.

Sample: National Bureau of Standards, River Sediment 2704									
Variable	**Replicate**				**Mean**	**Standard Deviation**	**%RSD**	**Certified Concentration (95% Confidence limit)**	**% Recovery**
	1	**2**	**3**	**4**					
Arsenic	19.5	19.5			19.5	0.00	0.00	23.4 ± 0.80	83.3
Cadmium	3.90	3.93			3.92	0.02	0.54	3.45 ± 0.22	114
Chromium	113	117	108	106	111	4.97	4.47	135 ± 5.00	82.2
Copper	101	100	101	99.0	100	0.96	0.96	98.6 ± 5.20	101
Lead	172	173			173	0.71	0.41	161 ± 17.0	108
Nickel	1.40	1.46	1.35	1.48	1.42	0.06	4.15	1.47 ± 0.07	96.6
Selenium	38.0	38.9	39.3	37.4	38.4	0.86	2.24	44.1 ± 3.00	87.1
Zinc	1.15	1.16			1.16	0.01	0.61	1.12 ± 0.05	104
%L.O.I.	406	396	397	401	400	4.55	1.14	438 ± 12.0	91.3

APPENDIX B

SEDIMENT QUALITY DATA

Table B1. Sediment quality data from Contwoyto Lake (mg/kg dry weight, unless otherwise indicated).

Sample Period	Sampling Station	Replicate or Section	Variable										
			Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Zinc	% < 63um	%LOI
August 1985 Phase 1	2	1	35.9			24.9	20.1		24.0		63.0	82.5	7.4
		2	20.9			24.7	18.8		22.7		60.9	82.0	6.2
		3	60.7			26.3	17.5		23.1		65.8	85.2	7.4
		4	49.1			24.2	17.3		20.8		59.4	79.3	7.8
		5	50.2			23.7	15.2		23.7		56.6	70.9	6.9
		mean	*43.4*			*24.8*	*17.8*		*22.9*		*61.1*	*80.0*	*7.2*
	3	1	14.4			12.8	17.6		18.4		47.6	56.1	1.9
		2	14.1			12.5	18.4		17.6		48.8	55.8	2.0
		3	15.2			21.0	23.6		21.9		50.7	47.3	2.4
		4	16.4			13.5	19.4		22.0		57.6	46.5	2.7
		mean	*15.0*			*15.0*	*19.8*		*20.0*		*51.2*	*51.4*	*2.2*
	5	1	25.1			24.0	24.9		21.1		55.9	70.8	3.4
		2	33.0			19.5	20.3		23.6		59.0	74.8	4.3
		3	21.0			17.2	23.8		20.0		60.8	82.2	4.0
		4	28.4			17.0	24.5		20.8		62.0	82.7	3.6
		5	32.8			16.6	24.4		20.0		51.8	82.2	3.8
		mean	*28.1*			*18.9*	*23.6*		*21.1*		*57.9*	*78.5*	*3.8*
	6	1	30.3			15.4	22.3		17.8		53.3	93.6	3.8
		2	32.2			15.6	19.7		16.4		49.3	85.2	3.8
		3	25.1			14.8	31.3		11.3		43.6	85.1	3.3
		4	31.7			16.6	22.1		12.0		48.6	81.3	3.7
		5	19.7			15.5	21.2		9.80		43.1	87.8	3.4
		mean	*27.8*			*15.6*	*23.3*		*13.5*		*47.6*	*86.6*	*3.6*
	7	1	27.6			15.8	21.4		16.8		53.5	85.0	3.9
		2	18.8			15.7	23.0		20.7		52.2	87.6	4.5
		3	19.5			16.1	19.9		20.8		54.1	84.5	4.0
		4	14.7			15.2	21.9		19.1		53.4	87.6	3.8
		mean	*20.2*			*15.7*	*21.5*		*19.4*		*53.3*	*86.2*	*4.1*
	8	1	3.00			10.7	24.6		15.6		44.8	40.6	3.2
		2	2.90			14.2	24.3		20.1		49.6	42.5	3.5
		3	2.60			14.1	24.9		20.7		58.3	62.3	3.6
		4	3.00			12.6	19.8		17.1		47.6	38.1	3.1
		mean	*2.88*			*12.9*	*23.4*		*18.4*		*50.1*	*45.9*	*3.4*
September 1985 Phase 1	2	1	36.2			25.3	18.3		24.4		57.0	79.3	6.1
		2	46.3			24.4	22.5		23.4		52.0	75.1	5.8
		3	38.9			25.3	27.1		26.2		55.2	78.7	6.2
		4	42.0			24.6	18.9		23.6		60.5	79.5	6.2
		5	38.1			25.2	16.2		25.2		59.1	82.0	5.9
		mean	*40.3*			*25.0*	*20.6*		*24.6*		*56.8*	*78.9*	*6.0*
	3	1	9.30			13.8	18.2		24.2		49.4	53.9	2.3
		2	12.8			15.4	20.5		26.5		51.9	68.6	2.8
		3	13.9			15.7	20.9		23.5		52.8	65.7	2.8
		4	14.2			15.4	19.7		24.0		53.6	67.0	2.8
		5	11.8			15.4	22.7		21.8		50.4	75.1	2.9
		mean	*12.4*			*15.1*	*20.4*		*24.0*		*51.6*	*66.0*	*2.7*
	5	1	8.90			18.1	23.6		20.8		63.9	76.6	3.6
		2	6.70			18.6	25.3		22.8		55.3	85.3	3.5
		3	10.8			18.6	29.8		24.2		56.3	77.8	3.6
		4	7.60			18.8	22.8		24.0		58.4	83.2	3.4
		5	11.4			20.3	36.8		21.3		60.9	78.2	3.6
		mean	*9.08*			*18.9*	*27.7*		*22.6*		*59.0*	*80.2*	*3.5*
	6	1	19.8			17.4	22.4		23.3		56.9	92.2	3.1
		2	31.6			17.9	24.5		25.4		57.1	97.2	3.7
		3	23.3			17.9	21.5		25.1		55.5	96.3	3.4
		4	21.4			16.9	21.1		22.8		72.4	93.0	3.0
		5	23.5			18.9	21.6		26.1		57.8	78.5	3.3
		mean	*23.9*			*17.8*	*22.2*		*24.5*		*59.9*	*91.4*	*3.3*
	7	1	31.2			21.0	22.9		23.9		66.4	95.8	5.0
		2	17.5			20.8	20.2		26.2		62.8	97.1	4.8
		3	9.50			19.8	21.6		25.2		55.9	97.2	4.3
		4	23.6			20.3	21.3		32.4		59.1	99.9	4.8
		5	21.0			23.2	25.1		34.3		57.3	98.1	4.7
		mean	*20.6*			*21.0*	*22.2*		*28.4*		*60.3*	*97.6*	*4.7*
1990 Phase 2	2	1	12.8	<0.1	80.0	30.0	8.20	0.04	3	0.18	68.0	99.2	8.2
		2	12.1	<0.1	82.0	30.0	10.9	0.05	56	0.20	67.0	98.0	7.4
		3	14.2	<0.1	83.0	31.0	10.7	0.05	5	0.22	72.0	98.6	9.0
		4	18.9	<0.1	79.0	24.0	9.00	0.04	32	0.22	73.0	98.6	9.0
		5	20.3	<0.1	84.0	27.0	11.6	0.01	25	0.19	77.0	97.9	15.0
		mean	*15.7*	*<0.1*	*81.6*	*28.4*	*10.1*	*0.04*	*24*	*0.20*	*71.4*	*98.5*	*9.7*
	3	1	61.0	<0.1	73.0	78.0	7.00	0.05	10	0.04	60.0	83.7	3.6
		2	17.0	<0.1	58.0	8.00	10.7	0.09	<1	0.05	32.0	60.3	1.6
		3	34.0	<0.1	55.0	10.0	8.00	0.01	<1	0.06	35.0	42.5	2.2
		4	12.2	<0.1	64.0	8.00	7.60	0.01	2	0.05	37.0	66.1	2.1
		5	18.8	<0.1	73.0	9.00	7.20	0.01	<1	0.10	39.0	76.5	2.1
		mean	*28.6*	*<0.1*	*64.6*	*22.6*	*8.10*	*0.03*	*3*	*0.06*	*40.6*	*65.8*	*2.3*
	5	1	46.9	<0.1	80.0	33.0	6.30	0.08	18	0.13	93.0	95.3	7.1
		2	73.0	<0.1	84.0	27.0	7.70	0.07	<1	0.09	84.0	97.9	5.8
		3	61.0	<0.1	82.0	27.0	4.40	0.08	21	0.11	92.0	96.6	6.4
		4	93.0	<0.1	88.0	30.0	4.30	0.10	55	0.09	101	98.0	7.9
		5	122	<0.1	69.0	24.0	4.20	0.09	<1	0.07	68.0	98.5	6.5
		mean	*79.2*	*<0.1*	*80.6*	*28.2*	*5.38*	*0.08*	*19*	*0.10*	*87.6*	*97.3*	*6.7*

Table B1. Sediment quality data from Contwoyto Lake (mg/kg dry weight, unless otherwise indicated).

Sample Period	Sampling Station	Replicate or Section	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Zinc	% < 63um	%LOI
			Variable										
1990 Phase 2 Continued	6	1	18.4	<0.1	66.0	17.0	8.90	0.01	<1	0.04	42.0	91.4	2.7
		2	18.2	<0.1	84.0	45.0	6.30	0.02	<1	0.11	48.0	89.0	3.1
		3	13.5	<0.1	73.0	19.0	8.50	0.02	<1	0.11	42.0	90.3	2.5
		4	12.8	<0.1	73.0	16.0	7.50	0.03	<1	0.10	41.0	90.7	2.4
		5	10.6	<0.1	72.0	14.0	8.10	0.02	<1	0.08	43.0	89.8	2.4
		mean	14.7	<0.1	73.6	22.2	7.86	0.02	<1	0.09	43.2	90.2	2.6
	7	1	19.4	<0.1	87.0	23.0	8.00	0.05	<1	0.08	57.0	99.2	5.0
		2	34.7	<0.1	80.0	15.0	6.90	0.05	<1	0.08	52.0	96.3	3.9
		3	16.7	<0.1	85.0	20.0	9.90	0.50	35	0.14	57.0	99.2	4.6
		4	15.4	<0.1	79.0	20.0	8.60	0.10	54	0.12	58.0	99.4	5.0
		5	10.3	<0.1	89.0	26.0	6.60	0.03	21	0.09	53.0	97.5	3.8
		mean	19.3	<0.1	84.0	20.8	8.00	0.15	22	0.10	55.4	98.3	4.5
	9	0 - 1	21.0	<0.1	100	76.0	6.90	0.10	<1	0.65	71.0	98.9	11.4
		1 - 2	19.2	<0.1	89.0	79.0	7.60	0.16	18	0.38	76.0	99.2	8.9
		2 - 3	20.0	<0.1	86.0	87.0	12.4	0.21	26	0.22	73.0	98.0	8.3
		3 - 4	19.7	<0.1	88.0	71.0	7.40	0.10	4	0.23	70.0	97.8	7.6
		4 - 5	18.2	<0.1	98.0	71.0	13.5	0.14	10	0.18	75.0	98.8	6.9
		5 - 6	20.4	<0.1	95.0	67.0	8.90	0.12	<1	0.17	75.0	98.1	6.7
		6 - 7	21.4	<0.1	101	73.0	4.80	0.10	11	0.18	87.0	98.7	6.6
		7 - 8	22.2	<0.1	100	69.0	9.70	0.11	10	0.15	85.0	99.1	6.1
		8 - 9	117	<0.1	97.0	56.0	8.90	0.43	36	0.05	79.0	86.3	5.9
		mean	31.0	<0.1	94.9	72.1	8.90	0.16	13	0.25	76.8	97.2	7.6
1991 Phase 3	2	1	72.3	0.86	52.1	53.4	28.7	0.25	29.6	0.65	75.9	42.7	
		2	91.3	0.80	55.3	36.7	23.5	0.05	28.4	0.83	74.5	55.4	
		3	48.9	1.34	46.9	51.4	29.3	<0.1	57.7	1.04	75.3	66.9	
		4	40.2	1.56	45.3	31.3	27.7	<0.08	54.9	1.24	74.0	79.2	
		5	31.5	0.67	59.5	28.1	18.4	<0.02	29.2	0.54	64.5	73.3	6.7
		mean	56.8	1.05	51.8	40.2	25.5	<0.1	40.0	0.86	72.8	63.5	6.7
	3	1	57.5	0.65	59.2	23.4	23.0	<0.02	27.5	0.53	58.0	83.1	4.1
		2	63.6	0.69	62.5	122.0	28.5	<0.02	30.6	0.70	65.1	79.6	3.7
		3	53.4	0.61	55.6	69.3	21.7	<0.02	30.7	0.40	60.3	79.1	3.4
		4	74.1	0.53	62.3	46.5	25.9	<0.02	30.6	0.50	59.8	92.7	4.2
		5	76.3	0.55	65.5	57.7	22.1	<0.02	32.1	0.45	65.8	85.7	3.9
		mean	65.0	0.61	61.0	63.8	24.2	<0.02	30.3	0.52	61.8	84.0	3.9
	5	1	22.8	0.43	60.3	13.9	21.3	<0.02	26.3	0.20	53.9	75.4	4.6
		2	19.0	0.29	56.3	13.2	19.9	<0.02	25.2	0.20	49.7	69.4	4.5
		3	19.3	0.41	55.6	12.7	21.0	<0.02	25.3	0.20	50.3	62.3	4.8
		4	20.5	0.49	58.1	16.3	19.3	<0.02	36.6	0.21	65.5	63.1	4.4
		5	22.2	0.28	57.1	12.5	17.3	<0.02	24.2	0.21	49.8	84.1	4.3
		mean	20.8	0.38	57.5	13.7	19.8	<0.02	27.5	0.20	53.8	70.9	4.5
	6	1	29.9	0.40	57.4	18.9	21.1	<0.02	26.2	0.20	53.4	72.8	5.1
		2	26.4	0.46	56.8	18.1	20.1	<0.02	29.1	0.21	56.7	66.9	5.4
		3	35.3	0.51	58.6	24.3	22.6	<0.02	29.3	0.21	55.0	97.9	5.9
		4	27.8	0.51	58.0	25.4	21.9	<0.02	27.1	0.21	51.8	68.1	5.3
		5	22.7	0.50	55.2	21.0	21.6	<0.02	24.5	0.20	53.7	64.9	4.8
		mean	28.4	0.48	57.2	21.5	21.5	<0.02	27.2	0.21	54.1	74.1	5.3
	7	1	33.8	0.56	61.3	16.5	19.9	<0.02	26.5	0.40	54.2	77.4	5.3
		2	23.4	0.45	61.7	28.4	20.7	<0.02	26.4	0.50	51.9	94.2	4.7
		3	28.3	0.50	58.3	16.0	28.0	<0.02	27.1	0.20	56.3	88.3	5.1
		4	20.7	0.42	55.8	20.1	31.3	<0.02	24.7	0.20	51.0	84.4	4.1
		5	29.7	0.45	57.0	28.8	21.6	<0.02	29.4	0.10	52.8	78.5	5.1
		mean	27.2	0.48	58.8	22.0	24.3	<0.02	26.8	0.28	53.2	84.6	4.9
	9 Rep 1	0 - 1	21.5	1.04	67.9	58.5	26.9	<0.04	27.6	0.81	63.0	50.7	11.5
		1 - 2	59.5	0.84	63.3	51.6	23.5	<0.04	25.8	0.61	68.4	54.2	9.2
		2 - 3	32.0	0.55	68.3	54.3	20.3	<0.05	27.8	0.40	66.9	55.3	7.0
		3 - 4	15.9	0.42	52.9	52.9	19.8	<0.03	30.2	0.30	8.1	55.3	6.4
		4 - 5	12.2	0.35	50.1	49.8	20.4	<0.02	29.4	0.10	64.3	61.1	5.3
		5 - 6	32.1	0.35	50.8	54.1	18.9	<0.02	29.8	0.10	71.8	67.0	5.9
		6 - 7	20.3	0.49	57.7	56.5	19.4	<0.02	32.5	0.10	73.9	68.4	5.6
		7 - 8	27.5	0.40	59.6	51.6	20.0	<0.02	34.8	0.10	74.7	74.5	5.0
		8 - 9	22.6	0.35	59.4	50.6	20.4	<0.02	33.6	0.10	73.4	74.9	4.8
		9 - 10	48.8	0.43	52.2	48.1	20.7	<0.02	32.9	0.10	72.0	78.8	4.5
		mean	29.2	0.52	58.2	52.8	21.0	<0.03	30.4	0.27	63.7	64.0	6.5
	9 Rep 2	0 - 1	126	0.68	54.0	47.9	22.6	<0.02	32.1	0.10	76.6	79.5	5.1
		1 - 2	44.6	0.29	48.2	95.8	22.3	0.06	35.5	1.58	86.4	46.9	
		2 - 3	22.8	0.28	48.5	63.3	18.9	0.05	27.9	1.78	70.9	40.9	
		3 - 4	18.6	0.29	44.5	49.5	17.9	<0.04	25.1	0.80	62.3	53.4	8.6
		4 - 5	19.0	0.25	50.8	47.1	18.8	0.02	25.6	0.35	63.7	63.1	6.9
		5 - 6	17.9	0.29	49.5	41.7	17.3	<0.02	27.2	0.24	61.1	75.3	5.9
		6 - 7	16.6	0.33	48.4	37.5	18.9	<0.02	27.2	0.24	61.9	74.8	4.6
		7 - 8	18.4	0.36	47.5	39.5	17.8	<0.02	27.6	0.13	63.9	80.1	4.7
		8 - 9	17.3	0.22	42.4	35.9	18.2	<0.02	27.1	0.13	60.0	74.6	4.0
		9 - 10	18.0	0.23	50.5	38.6	18.9	<0.02	30.3	0.13	64.9	77.8	3.8
		mean	31.9	0.32	48.4	49.7	19.2	<0.03	28.6	0.55	67.2	66.6	5.5
	9 Rep 3	0 - 1	17.9	0.23	47.4	38.1	19.6	<0.02	32.1	0.13	67.0	83.4	3.5
		1 - 2	33.5	0.47	48.5	62.3	22.2	<0.08	32.5	0.94	72.9	29.3	
		2 - 3	18.1	0.47	47.4	41.5	19.8	0.02	29.9	0.47	63.9	54.0	7.0
		3 - 4	18.6	0.23	49.1	47.3	17.4	0.02	25.7	0.47	61.6	56.6	7.6
		4 - 5	18.4	0.34	47.8	42.5	18.3	<0.03	24.5	0.35	59.1	60.9	6.5
		5 - 6	18.1	0.24	42.5	38.2	17.9	<0.02	26.2	0.24	59.0	70.6	5.3
		6 - 7	17.4	0.32	45.9	36.1	19.4	<0.02	26.4	0.24	60.5	72.5	4.8
		7 - 8	16.8	0.20	45.0	36.2	19.0	<0.02	27.2	0.13	58.4	70.8	4.3
		8 - 9	17.4	0.24	49.3	36.5	17.6	<0.02	29.0	0.15	62.1	76.2	4.1
		9 - 10	16.3	0.25	51.9	37.5	19.0	<0.02	31.2	0.15	67.4	83.4	3.6
		mean	19.3	0.30	47.5	41.6	19.0	<0.03	28.5	0.33	63.2	65.8	5.2
	Unknown	A	19.2	4.06	110	79.2	252	2.64	49.7	1.34	1283		
		B	14.9	2.37	61.4	620	70.4	0.1	963	2.57	750		

Note: empty spaces = no data