Department of Environment
Environmental Protection Service
Pacific Region
Yukon Branch

BASELINE STUDY OF THE WATERSHED NEAR VENUS MINE, YUKON AND VENUS MILL, BRITISH COLUMBIA

Regional Program Report No: 81-18

by

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October, 1981

ABSTRACT

A baseline study was undertaken by the Environmental Protection Service of the watershed near Venus mine (site of a former mining and milling operation) in the Yukon, and Venus mill in British Columbia in 1980 before their planned development and start of operation in June 1981. Water quality parameters, bottom fauna characteristics and sediment quality were documented and evaluated at twenty-three sampling stations.

The environmental quality of the unaltered part of the watershed was similiar to other unaltered lakes and creeks in the Yukon River Basin.

The environmental quality near the abandoned tailings pond continues to be adversely affected by this past operation. Significantly higher concentrations of cadmium, lead and zinc were found in sediment samples in the lake near the abandoned tailings pond than in sediment samples from unaltered parts of the watershed. Arsenic concentrations in abandoned tailings pond drainage and mine water were significantly higher than those in water in the unaltered part of the watershed.

RÉSUMÉ

En 1980, le Service de la protection de l'environnement a fait une étude portant sur les secteurs du bassin hydrographique avoisinant la mine "Vénus" située dans le Yukon, à l'emplacement d'une ancienne mine et d'une ancienne usine de traitement du minerai, et de l'usine de traitement du minerai "Vénus" située en Colombie-Britannique, avant que ces deux ensembles ne soient aménagés et mis en exploitation, en juin 1981. On a choisi vingt-trois points d'échantillonnage afin d'établir et d'évaluer les paramètres de qualité de l'eau, les caractéristiques de la faune aquatique des profondeurs et la qualité des sédiments.

On a constaté que la qualité écologique des secteurs du bassin hydrographique non encore touchés par l'homme était similaire à celle d'autres lacs et rivières encore vierges du bassin fluvial du Yukon.

Le bassin où se déversaient les résidus industriels de l'ancienne exploitation continue à affecter le milieu naturel avoisinant. En analysant différents échantillons de sédiments, on a constaté que les taux de concentration du cadmium, du plomb et du zinc étaient nettement plus élevés dans les sédiments du lac situé près de l'ancien bassin de déversement que dans les secteurs du bassin hydrographique non encore touchés par l'homme. On a constaté que les taux de concentration en arsenic des effluents provenant du bassin abandonné et de la mine étaient plus élevés que ceux de l'eau provenant des secteurs du bassin hydrographique non encore touchés par l'homme.

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SUMMARY

A baseline study was undertaken by the Environmental Protection Service of the watershed near Venus mine (site of a former mining and milling operation) in the Yukon, and Venus mill in British Columbia in 1980 before their planned development and start of operation in June 1981. Water quality parameters, bottom fauna characteristics and concentrations of cyanide and metals in sediment were evaluated. Sample stations included streams and the lake adjacent to an abandoned tailings pond from which Venus plans to recover the tailings, mine water, a creek into which mill tailings ponds will discharge, a control creek and the southern end of Windy Arm (Tagish Lake) into which the creek receiving tailings pond discharge flows.

The environmental characteristics of the predevelopment part of the watershed were found to be similiar to other unpolluted lakes and creeks in the Yukon River drainage basin. The softness of the water and its low mineral content make the aquatic environment particularly sensitive to discharge of metals.

High arsenic concentrations were found in mine water and abandoned tailings pond drainage. Arsenic removal from mine water may be required in the water licence from the Yukon Territorial Water Board and is planned by the company. Arsenic removal may also be required under the terms of the water licence in tailings pond water during recovery of the tailings for reprocessing at the Venus mill.

The continuing effects of the former milling operation were shown by the significantly higher concnetrations of cadmium, lead and zinc in sediment samples taken in the lake offshore from the abandoned tailings pond than found in sediment samples from the unaltered part of the watershed.

Future monitoring of water quality, bottom fauna and sediment characteristics of this watershed during the operation of Venus mine and mill can be compared to values documented by this study.

1 INTRODUCTION

Early in 1980 United Keno Hill Mines Ltd. announced their plan to reopen Venus Mine by June 1981 and submitted applications to the British Columbia Waste Management Branch for construction and operation of a mill in British Columbia and to the Yukon Territorial Water Board for a water use licence at the mine site in the Yukon. The water bodies affected by the mine and mill activity are part of the Yukon River system upstream of the communities of Tagish and Whitehorse. The location of the study area is shown in Figure 1. Windy Arm (elevation 656 m) is not classed as a commercial fishing lake and in 1980 there were no domestic fishing licences issued. However, Windy Arm is used as a recreational fishing lake. The Environmental Protection Service undertook a baseline study of the watershed in the vicinity of the mine and mill. This baseline study documents existing chemical parameters in water and sediment and gives a quantitative and qualitative analysis of the existing bottom fauna communities.

Mining first started in this area during the second decade of this century. More recent activity began in the mid sixties and culminated in the construction of a 272 tonne (300 ton) per day capacity mill which operated from September 1970 until June 1971. The tailings from this operation will be remilled by Venus Mines Ltd. The 46,000 tonne (50,000 ton) of tailings contain 2.80 gm/t gold, 40.74 gm/t silver, 0.37% zinc (UKHM Ltd. 1980). The Venus Mine property was re-examined in 1979 and earlier ore estimates were confirmed. It was decided in April 1980 to bring the Venus Mine back into production. Ore reserves have been calculated at 109,000 tonnes (120,000 tons) containing 8.84 gm/t (0.22 oz/ton) gold, 205.3 gm/t (6.60 oz/ton) silver, 1.89% lead, and 1.37% zinc. The ore is associated with 8% iron pyrite, 10% arsenopyrite and quartz.

The country rock in the mine workings consists primarily of pale green to green, competent, cherty andesite breccia, alternating with dark green andesite flows and possibly minor tuff (UKHM Ltd. 1980).

The Venus mine site is located in the Yukon 24 km from

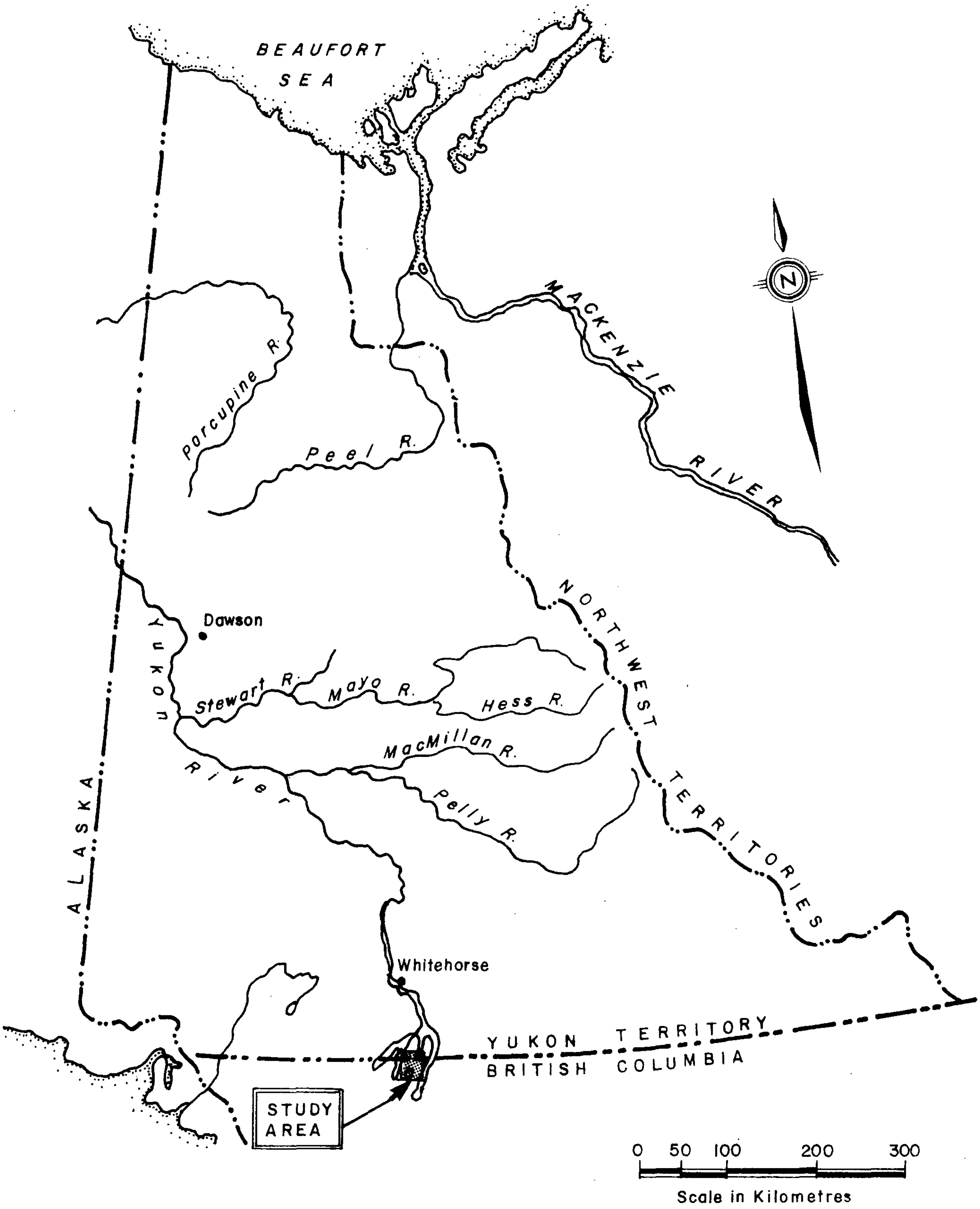

FIGURE I MAP OF THE YUKON TERRITORY SHOWING THE LOCATION OF THE STUDY AREA

Carcross on the Skagway road (96 km from Whitehorse). Approximately 1,800 litres per minute (400 IGPM) of water is generated in the mine from underground outflow and will be discharged to Windy Arm after treatment of the contaminated portion estimated to be about 900 litres per minute (200 IGPM). The surface facilities for the mine will be on the eastern side of the Skagway road below the mine at Pooly Point. Water from Pooly Creek is used in the surface facilities. It is treated in a septic tank system. The mine will be operated 1 shift per day, 5 days per week and will produce 127 tonne (140 ton)per day. Two years of ore reserves have been fully developed. It is expected that additional reserves will be developed during mine operation.

The abandoned tailings, 22.4 km from Carcross on the Skagway road, will be dewatered and trucked to the mill in the summer for reprocessing. At present there is a discharge to Windy Arm from these tailings through an asbestos culvert. The disturbance of the tailings during reclamation may change the discharge flow and chemical characteristics.

The Venus mill site is in British Columbia, 33.6 km from Carcross on the Skagway road which connects Carcross, Yukon with Skagway, Alaska. The mill site is at 59°57'N latitude and 134°40'W longitude. This is 105.6 km from Whitehorse, Yukon. The tailings ponds will drain into the southern end of Windy Arm. It is estimated that 273 litres per minute (60 IGPM) of water will be discharged from the mill, 24 hours per day, 7 days per week. The mill will process 91 tonne (100 ton) of ore per day.

2 METHODS

2.1 Sampling Station Location and Description

Sample station locations are shown in Figures 2 and 3. A description of each location is given in Table 1.

2.2 Water Quality

The water quality sampling schedule is given in Table 2. Table 1, Appendix I lists collection, preservation and analysis methods for all water quality parameters.

Temperature, pH, depth and conductivity were measured in the field. Dissolved oxygen was measured in the Environmental Protection Service Whitehorse laboratory. All other water quality analyses were done by Laboratory Services, Environmental Protection Service, 4195 Marine Drive, West Vancouver, British Columbia.

Water samples were analyzed for color, turbidity, non-filterable residue, filterable residue, total alkalinity, total hardness, total phosphate, nitrite, nitrate, sulfate, chlorine and silica. Separate water samples were taken and analyzed for total organic carbon/total inorganic carbon, total mercury and cyanide.

Water samples were analyzed for the following extractable metals:

Silver (Ag)
Aluminum (Al)
Arsenic (As)
Barium (Ba)
Calcium (Ca)
Cadmium (Cd)
Cobalt (Co)
Chromium (Cr)
Copper (Cu)
Iron (Fe)
Vanadium (V)
Manganese (Mn)
Molybdenum (Mo)
Sodium (Na)
Nickel (Ni)
Lead (Pb)
Antimony (Sb)
Selenium (Se)
Tin (Sn)
Strontium (Sr)
Titanium (Ti)
Zinc (Zn)

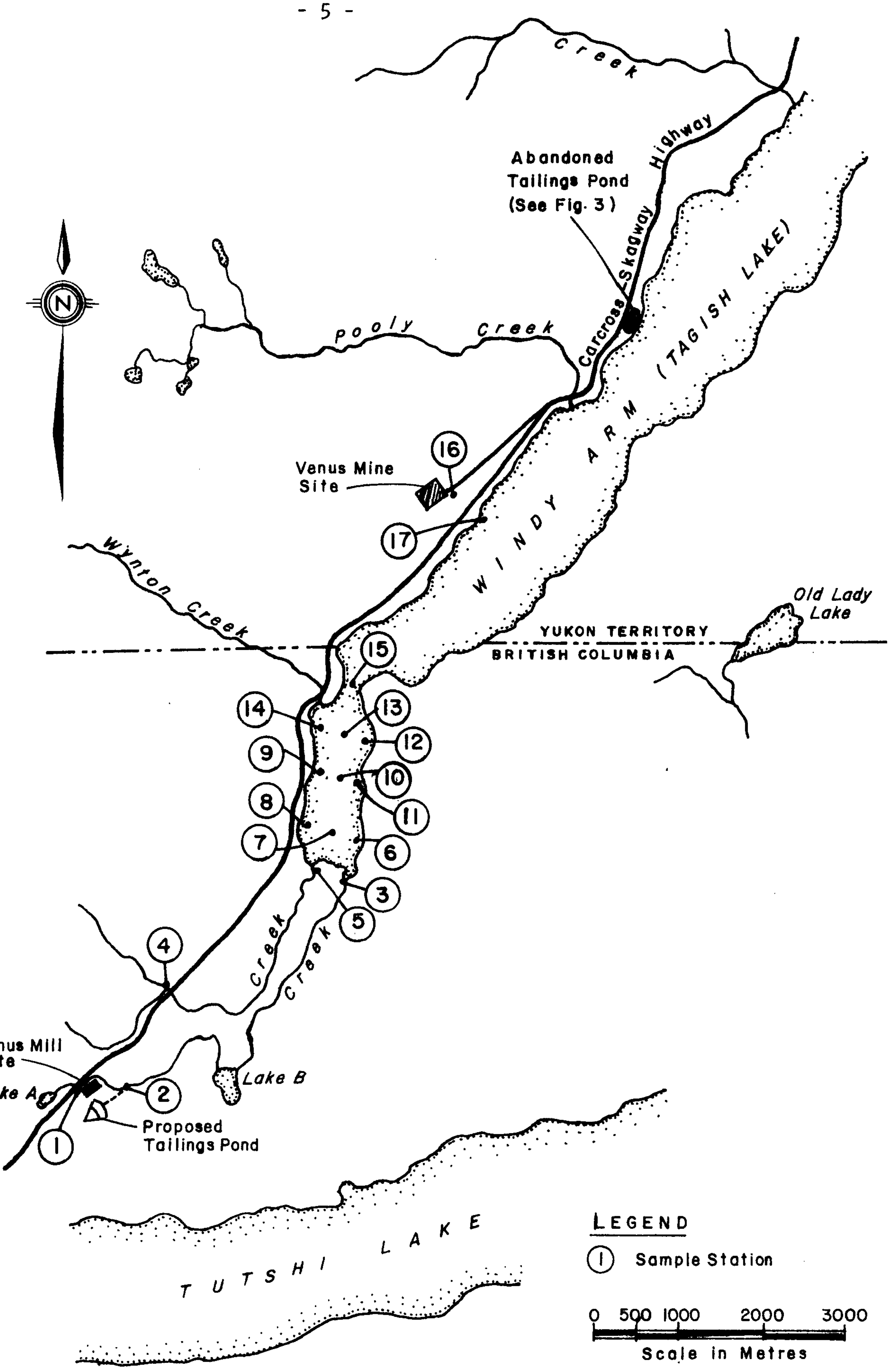

FIGURE 2 SAMPLE STATION LOCATIONS IN STUDY AREA
(See Figure 3 for detail)

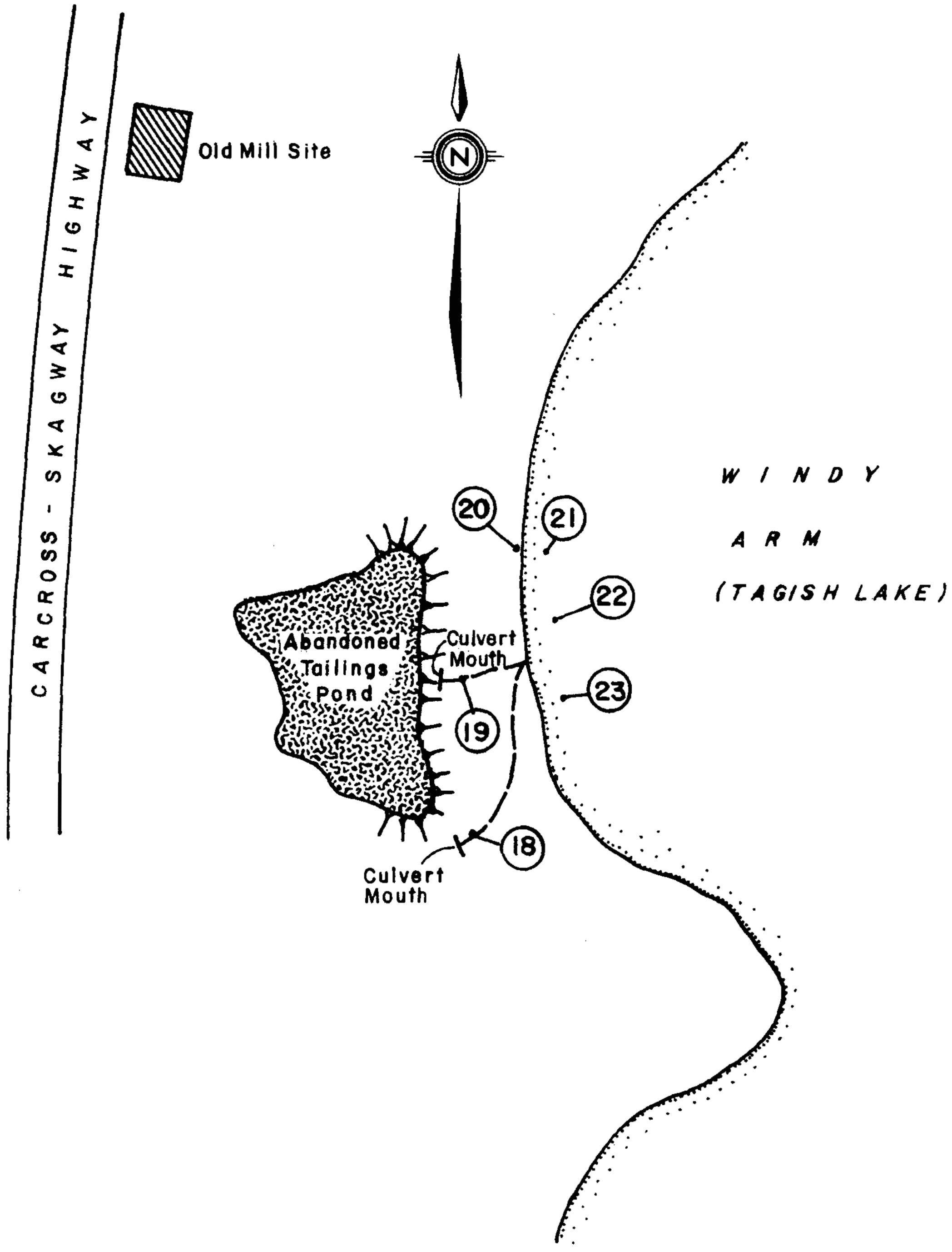

FIGURE 3 DETAIL SKETCH OF ABANDONED TAILINGS POND SHOWING LOCATIONS OF STATIONS 18 TO 23 (Not to Scale)

TABLE 1 STATION LOCATION AND DESCRIPTION

STATION NUMBER	STATION LOCATION AND DESCRIPTION
1	Samples were taken from a creek draining Lake A. The sampling location was upstream of the new proposed mill site at the downstream side of the Skagway road crossing. The company proposed to obtain all or a portion of its 273 litres per minute (60 IGPM) requirement for the mill from Lake A.
2	Station 2 was located on the creek draining Lake A, downstream of Station 1 and upstream of the proposed second dam site. Downstream, beyond the mill site, this creek empties into a larger creek prior to draining into Windy Arm at Station 3.
3	Station 3 was located downstream of the mill site at the mouth of the creek entering the east side of the south end of Windy Arm. Stream drainage from the mill site and effluent from the treatment ponds will enter this creek.
4	Station 4 was located at a creek crossing the Skagway road approximately 1 km north of the mill site. The creek was chosen as a control site and will be unaffected by the mill operations.
5	Station 5 was located downstream of Station 4 at the mouth of the creek entering the west side of the south end of Windy Arm near the Skagway road.
6-15	The next series of stations, 6-15 inclusive, are located in the south end of Windy Arm of Tagish Lake. Three transects running east to west were chosen on this arm, with 3 stations on each transect. See Figure 2 for these station locations. The water in Windy Arm flows from south to north.

TABLE 1 STATION LOCATION AND DESCRIPTION (continued)

STATION NUMBER	LOCATION AND DESCRIPTION
16	Station 16 was at the 792 m adit of Venus mine which is located 9.6 km north of the new mill site. The sampling location was at a site where adit water flowed down beneath mining waste rock and surfaced. This was approximately 30 m below the main adit water pipe and 120 m above the Skagway road.
17	Station 17 was located in Windy Arm approximately 20 m offshore from the Venus mine site.
18	Station 18 was located on a creek that discharges from a metal culvert. The culvert is situated beside the abandoned Venus Mine tailings pond. Station 18 was at the discharge end of the culvert and before the tailings drainage joined up with the creek.
19	Station 19 was located at the discharge end of an asbestos culvert draining the tailings pond. This culvert is about 6 m below the tailings pond (vertical measure) and approximately 40 m away (horizontal measure).
20	Station 20 was located at the base of a rock knoll (5-7 m high), which borders a corner of the abandoned Venus Mine tailings pond. Seepage is indicated by discoloration of the rock face and surrounding ground. The lake surface is 2-3 m (horizontal measure) away.
21-23	Stations 21, 22, and 23 were located in an arc 20-30 m offshore from the abandoned Venus Mine tailings pond. See Figure 3 for exact locations.

TABLE 2 SAMPLING SCHEDULE FOR WATER QUALITY, BOTTOM FAUNA AND SEDIMENT

DATE	TYPE OF SAMPLE	STATIONS
June 26/80	Surface water	1, 2, 3, 4, 5, 6A, 7A, 8A, 9A, 10A, 11A, 12A, 13A, 14A, 15A, 16, 17A, 18, 19, 20, 21A, 22A, 23A
July 3/80	Water - 2 m above bottom	6B, 7B, 8B, 9B, 10B, 11B, 12B, 13B, 14B, 15B, 17B, 21B, 22B, 23B
June 26/80	Bottom fauna	1, 2, 4, 5, 16, 18, 21, 22, 23
July 3/80	Bottom fauna	7, 8, 9, 10, 13, 15
July 3/80	Sediment	1, 2, 3, 5, 6, 7, 8, 9, 10, 13, 14, 15, 18, 19, 21, 22, 23

The percent dissolved oxygen saturation was calculated by first determining the dissolved oxygen saturation concentration from the formula:

$$S' = S \frac{P}{760}$$ (APHA et al 1975)

where: S' = Dissolved Oxygen (D.O.) saturation concentration at the in situ temperature and atmospheric pressure

S = D.O. saturation concentration at sea level for in situ temperature

P = Atmospheric pressure in mm of mercury at site elevation

Then the ratio of D.O. measured /S', times 100 was calculated to obtain percent dissolved oxygen saturation.

2.3 Bottom Fauna

The bottom fauna sampling schedule is given in Table 2. The bottom fauna collection, preservation and identification methods are given in Appendix I, Table 2. The date of collection, type of sampler, number of samples and total area sampled is given in Table 3. Bottom fauna samples at Stations 11, 12, and 17 were not obtained because the lake bottom at these stations was composed of rock. Bottom fauna data from Stations 3, 6, 14, 19, and 20 also were not obtained.

2.4 Sediment

The sampling schedule for sediment is given in Table 2. Sediment samples at Stations 4, 11, 12, 16, and 17 were not collected because the lake or creek bottom was rocky. No sediment sample from Station 20 was collected. Three sediment samples were taken at each station except Stations 15 and 23 where wind problems resulted in 1 and 2 samples, respectively, being collected.

Sediment samples were shipped to Vancouver for analysis at Laboratory Services, Environmental Protection Service, 4195 Marine Drive, West Vancouver.

A description of sediment collection, preparation and analysis methods is given in Appendix I, Table 3.

Samples 18, 19, 21, 22, and 23 were analyzed for cyanide. All samples were analyzed for:

Aluminum (Al)
Barium (Ba)
Calcium (Ca)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Iron (Fe)
Mercury (Hg)
Magnesium (Mg)
Manganese (Mn)
Molybdenum (Mo)
Sodium (Na)
Nickel (Ni)
Phosphorus (P)
Lead (Pb)
Silicon (Si)
Tin (Sn)
Strontium (Sr)
Titanium (Ti)
Vanadium (V)
Zinc (Zn)

All sediment samples are being retained for analyses of arsenic at a later date pending the refinement of the analytical methodology now employed by the West Vancouver laboratory.

All samples were analyzed for particle size distribution.

3 RESULTS AND DISCUSSION

3.1 Water Quality

The water quality results are given in Appendix I, Tables 1, 2, 3.

The results of the water quality analyses are compared with acceptable concentration limits for raw drinking water supply and concentration limits for healthy aquatic life. Table 4 in Appendix II lists these water quality criteria and their references. The upper concentration limits for healthy aquatic life are usually lower than raw drinking water concentration limits because aquatic life may be more susceptible to harmful effects because of lower tolerance or biomagnification of the substance in the food chain.

3.1.1 Water Quality Parameters Excluding Metals

3.1.1.1 Predevelopment creeks stations: 1 to 5. All measurements were similiar to those found in other unaffected creeks in the Yukon by Burns (1980). All measurements met the acceptable concentration limits for raw drinking water supply and concentration limits for healthy aquatic life for the parameters discussed in this section. Conductivity and filterable residue levels were low although they were within the range for healthy aquatic life. Total hardness at the creek stations was an average of 112 mg/l as $CaCO_3$ which is relatively soft. Some metals such as lead and nickel are more toxic to aquatic life in soft water (Appendix II, Table 4).

Higher values for conductivity, filterable residue, total alkalinity, total hardness, total inorganic carbon and sulfate were measured at the creek stations than were measured at the lake stations. Flow from these creeks must be diluted by the receiving lake which also receives glacial melt which has very low concentrations of salts.

3.1.1.2 Predevelopment lake stations: 6 to 15. Depths for the midpoints of the transects of the southern part of Windy Arm were 32 to

46m. Since the depth at the neck, Station 15, was 38 m, the southern end of Windy Arm and the neck it discharges through are of uniform depth. It is not known whether this southern part of Windy Arm will act as a sink for metals discharged by the Venus mill.

All measurements were similar to those found in Windy Arm by Robson et al (1978) and in Tagish Lake by Baker (1979a). All measurements met the acceptable concentration limits for raw drinking water supply for the parameters discussed in this section. Both conductivity and filterable residue levels were lower than the lower limit for healthy aquatic life. Total hardness measurements indicated that the lake water was soft.

The low concentration of salts as indicated by the low conductivity and low filterable residue levels are characteristic of a low productivity or oligotrophic lake.

3.1.1.3 Stations affected by past mining and milling operations: 16 to 23. With the exception of dissolved oxygen, all measurements met the acceptable concentration limits for raw drinking water and concentration limits for healthy aquatic life discussed in this section. Station 16, mine water, did not meet the drinking water standard of 100% of dissolved oxygen concentration but met the lower limit for healthy aquatic life of $\geq$54%. Station 20, tailings pond seepage, had a concentration of 47% of dissolved oxygen concentration which did not meet either criteria. The mine water may not have had time to become saturated with oxygen.

The temperature at Station 18 was much lower than the other stations and this indicates it was ground water.

The levels of parameters discussed in this section at Station 19, abandoned tailings pond drainage, are similiar to those reported for this station in 1975 and 1976 by Robson et al (1978) except for cyanide. A cyanide concentration of 0.94 mg/l CN was measured in 1975 but during this study the cyanide concentration was below the detection limit of 0.03 mg/l CN. This may indicate that overall cyanide levels have decreased since 1975.

Higher values for conductivity, filterable residue, total alkalinity, total hardness, total inorganic carbon, total phosphate, nitrate and sulfate were found at Stations 16, 18, 19 and 20 than in unaffected creek or lake station samples. These higher values are caused by the higher dissolved salts in the mine water at Station 16, the ground water at Station 18 and the abandoned tailings pond drainage and seepage at Stations 19 and 20 respectively. The higher concentrations of sulfates at these stations are believed to reflect the presence of 8% iron pyrite and 10% arsenopyrite in the Venus ore body. The concentrations of these parameters were not elevated at Station 17, offshore from the mine, or Stations 21, 22 and 23 offshore from the abandoned tailings pond. In respect to these parameters, sampling did not show a influence of the mine or abandoned tailings pond on the lake.

3.1.1.4 General comments. Lab pH levels were consistently lower and lab conductivity measurements were consistently higher than those taken in situ. This was the result of changes which occurred in the sample between collection and lab analysis and for conductivity was also the result of the change in temperature between in situ and lab measurement.

3.1.2 Water Quality Parameters - Metals. This was a baseline study and the concentrations of metals were low at the creek and lake stations which were unaffected by past activities but they were higher at stations affected by past mining and milling activities.

3.1.2.1 Predevelopment creek stations: 1 to 5. All metal concentrations in unaffected creek samples met the acceptable concentration limits for raw drinking water supply and concentration limits for healthy aquatic life with the exception of iron and mercury (N.B. See section 3.1.2.4). The drinking water limit for iron was exceeded slightly at station 5. The mercury concentrations for all stations were higher than the upper limit for healthy aquatic life of 0.0001 mg/l. Mercury concentrations at creek stations ranged from

0.00020 to 0.00032 mg/l Hg. Mercury concentrations will be discussed more fully under section 3.1.2.2 on lake stations. The source of iron in the creeks is likely iron pyrite since it is present in Venus mine ore and likely occurs in other mineral outcroppings in the watershed drained by the creeks.

The concentrations of barium, calcium, magnesium, sodium, silica, strontium and zinc were higher in the creek samples than in the lake samples. This is consistent with the higher conductivity, filterable residue and total hardness found in unaffected creek samples as compared to lake samples.

3.1.2.2 Predevelopment lake stations: 6 to 15. Metal concentrations in unaffected lake station samples met the acceptable concentration limits for raw drinking water supply and healthy aquatic life with the exception of iron, manganese and mercury (N.B. See section 3.1.2.4). The concentration of iron (Fe) was higher than the drinking water limit of 0.3 mg/l but lower than the aquatic life limit of 1.0 mg/l in one sample taken 2m off the bottom. All other samples taken 2 m off the lake bottom and all the lake surface water samples had concentrations below 0.3 mg/l. One lake surface water sample was slightly above the upper drinking water limit of 0.05 mg/l manganese (Mn) but was well below the healthy aquatic limit of 1.0 mg/l Mn.

The concentrations of mercury (Hg) at all unaffected lake stations were in the range 0.0020 to 0.0064 mg/l Hg. This concentration is well below the drinking water limit of 0.002 mg/l Hg but is higher than the 0.0001 mg/l Hg recommended to protect consumers of fish grown in these waters. Mercury is biomagnified in the food chain and accumulates in fish and man. Past data on mercury concentrations in Windy Arm and Tagish Lake was studied. Robson et al (1978) reported that 1975 Windy Arm lake samples had less than 0.00018 mg/l Hg at lake stations unaffected by past mining operations and Baker (1979a) reported that 1977 Tagish lake samples had 0.00020 mg/l Hg. It appears that mercury concentrations have increased in this lake. To check whether mercury concentrations in fish reflected this increase, lake trout mercury concentrations from samples taken in 1976 (Robson et al 1978) were compared to lake trout samples taken in 1980 (UKHM 1981). The average concentration in six lake trout in 1976 was 0.11 mg/kg Hg wet weight and the average concentration in two lake trout in 1980 was 0.27 mg/kg Hg wet weight. This data suggests mercury concentrations in lake trout have also increased but more data on fish should be obtained to confirm this. Although all concentrations were below the 0.5 mg/kg Hg wet weight guideline of Health and Welfare Canada, if the concentrations of mercury in fish are rising, the guideline may be exceeded within the next few years.

3.1.2.3 Stations affected by past mining and milling operations: 16 - 23. The mine water (Station 16), the abandoned tailings pond drainage (Station 19) and the abandoned tailings pond seepage (Station 20) had higher concentrations of some metals than the creek and lake stations that were not affected by past mining activities. Concentrations of arsenic (As), calcium (Ca), iron (Fe), magnesium (Mg), sodium (Na), silicon (Si), strontium (Sr) and zinc (Zn) were higher. Only the concentration of barium (Ba) was lower than at unaffected creek and lake stations. Only iron concentrations were higher than unaffected lake stations in the lake stations offshore from the abandoned tailing pond. It is possible that arsenic, lead and zinc were higher too but the detection limits of the analytical methods used for these metals were not low enough to show this (N.B. See section 3.1.2.4).

Arsenic concentrations exceeded the upper limit for drinking water and the limit for healthy aquatic life in the minewater (Station 16), the abandoned tailings pond drainage (Station 19) and the abandoned tailings pond seepage (Station 20). The source of this is the 10% arsenopyrite in Venus Mine ore and the previously processed arsenopyrite in the abandoned tailings.

The iron concentration exceeded the upper drinking water limit of 0.3 mg/l Fe but was less than the limit for healthy aquatic life of 1.0 mg/l Fe in the abandoned tailings pond drainage (Station 19). The source of this iron is believed to be iron pyrite in Venus Mine ore and in the abandoned tailings.

The manganese concentration was slightly higher than the upper drinking water limit of 0.05 mg/l Mn but lower than the limit for healthy aquatic life of 1.0 mg/l Mn in the drainage from the abandoned tailings pond (Station 19).

The lead concentration was three times the upper drinking water limit of 0.05 mg/l Pb and fifteen times the limit for healthy aquatic life of 0.030 mg/l Zn in the drainage from the abandoned tailings pond (Station 19).

The mercury concentration exceeded the upper limit for healthy aquatic life of 0.0001 mg/l Hg at all stations affected by past mining operations but only to the same extent as other samples taken from the unaffected creeks and lake in this study.

Although both silver and cadmium concentrations were under the upper limit for drinking water for these stations affected by past mining operations, the detection limit of the analytical methods used were not low enough to show if their concentrations exceeded the upper limits for healthy aquatic life. Both metals are present in the abandoned tailings. Silver is a major constituent of the ore and cadmium occurs as a trace element with its concentration linked to the concentration of zinc which is also a major constituent of the ore. Both metals are considered to be very toxic to aquatic life and an upper limit of 0.001 mg/l Ag and 0.0002 mg/l Cd have been recommended.

The drainage from the abandoned tailings pond (Station 19) was compared to the 1975 metals data for this station as reported in Robson et al (1978). The concentrations of arsenic, cadmium, iron, lead and zinc have stayed approximately the same. The concentration of barium appears to have decreased by a factor of ten and the mercury concentration appears to have increased by a factor of ten. Even allowing for likely differences in analytical techniques the drainage from the abandoned tailings pond has maintained similar metal concentrations for five years and been a continuing source of metals to Windy Arm.

3.1.2.4 General comments. The detection limits of the analyses used were not low enough to determine whether arsenic, lead and selenium concentrations exceeded the raw drinking water criteria or if arsenic, cadmium, lead, nickel, selenium, and silver concentrations exceeded healthy aquatic life limits. For example the detection limits for arsenic, lead and selenium were 0.15 mg/ As, 0.080 mg/ Pb, and 0.080 mg/l Se and the drinking water limits were 0.05 mg/l As, 0.05 mg/l Pb and 0.01 mg/l Se. All lake and unaffected creek samples had concentrations below detection limit for these metals. In addition the analyses detection limits for cadmium, nickel and silver were 0.010 mg/l Cd, 0.080 mg/l Ni and 0.030 mg/l Ag and the healthy aquatic life upper concentrations of arsenic, cadmium, silver, nickel, selenium and silver were 0.05 mg/l As, 0.0002 mg/l Cd, 0.005 mg/l Pb, 0.025 mg/l Ni, 0.01 mg/l Se and 0.0001 mg/l Ag. Since concentrations of arsenic, lead and selenium in the unaffected watershed were low, these metals are not a health problem. However since this was a baseline study, documentation of arsenic, cadmium, lead, nickel, selenium and silver concentrations would have aided in the evaluation of this watershed and provided better baseline information for the purpose of identifying future changes in concentrations.

3.2 Bottom Fauna

A list of bottom fauna taxonomic groups found in this study is given in Table 1, Appendix III. A list of identified bottom fauna and the numbers of individuals in each taxonomic group at each station is given in Table 2, Appendix III.

A diversity index based on classification to the genus level was calculated for the bottom fauna collected, using the following formula:

$$\text{Diversity } (H') = - \sum_{i=1}^{g} P_i \log_{10} P_i$$

where $P_i = n_i/N$

n_i = the total number of individuals in the i^{th} genus

N = the total number of individuals identified to genus level

g = the total number of genera sampled

This formula is a modification to using individuals identified to the genus level of Pielou's (1975) formula for individuals identified to the species level. As shown in Hughes (1978), this results in a slightly lower diversity index value than using numbers of individuals identified at the species level. Most bottom fauna were identified only to the genus level in this study so this modification was necessary.

The diversity index value increases with more genera and with more evenness of distribution of individuals among genera. The lowest diversity index value possible is 0 when there is only one genus present because $\log_{10}1 = 0$. The diversity indices were calculated for each of the two or three samples taken at a station and for the sum of the samples taken at a station. Both diversities are given in Table 2, Appendix III. The diversity indices for the sum of the samples taken at a station are given in Table 3. Table 3 also shows the area sampled, number of samples, sampling method, date and whether it was a creek or lake sample.

3.2.1 Predevelopment Creek Stations: 1 to 15. Numbers of bottom fauna at unaffected creek stations were similar to those found July 18, 1980 at control stations on seven placer mining streams in the Yukon as reported by Burns (1980). Diversity indices were lower than those found by Burns (1980). The total numbers of individuals at the creek stations 1 and 4 were higher than at the downstream stream stations of these creeks at Station 2 and Station 5 respectively. The low number of individuals at Stations 2 and 5 were probably due to an unfavorable physical environment since water quality was similar to that of upstream station samples. Station 1 had the largest number of Simulidae larvae (blackfly larvae). Station 4 had the highest number of Ephemeroptera.

3.2.2 Predevelopment Lake Stations: 6 to 15. Numbers of individuals and diversity indices were similar in this study to those reported by Robson et al (1978) for Windy Arm lake samples. Diversity indices at unaffected lake stations were also similar to those reported for Tagish lake samples by Baker (1979a). Since bottom fauna numbers and species composition change over the season (Hughes 1978), only a

TABLE 3 BOTTOM FAUNA SAMPLING INFORMATION

STATION	DATE SAMPLED	CREEK OR LAKE BOTTOM	SAMPLER	NUMBER OF SAMPLES	TOTAL AREA SAMPLED	DIVERSITY INDEX
1	June 26/80	Creek	Surber	3	3 ft^2	0.89
2	June 26/80	Creek	Surber	2	2 ft^2	0.57
4	June 26/80	Creek	Surber	2	2 ft^2	0.57
5	June 26/80	Creek	Ekman Dredge	3	3/4 ft^2	0.66
7	July 3/80	Lake	Ekman Dredge	3	3/4 ft^2	0.62
8	July 3/80	Lake	Ekman Dredge	1*	3/4 ft^2	0.89
9	July 3/80	Lake	Ekman Dredge	1*	3/4 ft^2	0.90
10	July 3/80	Lake	Ekman Dredge	3	3/4 ft^2	0.42
13	July 3/80	Lake	Ekman Dredge	2	1/2 ft^2	0.58
15	July 3/80	Lake	Ekman Dredge	3	3/4 ft^2	0.65
16	June 26/80	Creek	Surber	1	1 ft^2	0.60
18	June 26/80	Creek	Surber	3	3 ft^2	0.30
21	June 26/80	Lake	Ekman Dredge	3	3/4 ft^2	0.91
22	June 26/80	Lake	Ekman Dredge	3	3/4 ft^2	0.47
23	June 26/80	Lake	Ekman Dredge	3	3/4 ft^2	0.60

* Although 3 Ekman Dredge samples were taken, they were combined into one sample for identification and enumeration.

very general conclusion of similarity of data can be drawn for this study compared to those of Robson et al (1978) and Baker (1979a). The bottom fauna sampling for this study was done June 26 and July 3rd 1980. The sampling was done on September 4, 1975 and August 4, 1976 in Robson et al (1978) and on August 11 and September 12, 1977 in Baker (1979a). This is a significant difference in time of year.

Lake stations 7, 10, 13 and 15 were taken at depths of 48, 32, 38 and 38 meters respectively. The low number of individuals and lower diversity indices at these stations in comparison to the other shallower lake stations may be a result of fewer bottom fauna being adapted to live at these depths.

3.2.3 Stations Affected by Past Mining and Milling Operations: 16 to 23.

The numbers of bottom fauna in mine water (Station 16) and in the sample from a stream draining the area beside the abandoned tailings pond (Station 18) were low. Mine water contained 0.3 mg/l As which exceeds the upper limit for healthy aquatic life and this probably caused the low number of bottom fauna. The data was not conclusive however because lower numbers of bottom fauna were found in an unaffected creek (Station 2). The low numbers of bottom fauna at Station 18 were probably caused by high concentrations of cadmium, lead, and zinc and the presence of cyanide in the sediment at this station. The lowest diversity index was also found at Station 18. This reflects the fact that there were a large proportion of the Psectrocladius genus of family Chironomidae at Station 18.

The lake stations offshore from the abandoned tailings pond (Stations 21, 22, 23) were at 5 meters depth and the diversity indices at stations 22 and 23 were much lower than those found by Baker (1979a) at similar depths in Tagish Lake. This is probably the result of proximity to the abandoned tailings pond and the high concentrations of cadmium, lead and zinc in the sediments at these stations.

In conclusion, the bottom fauna data show some effects of the water quality in mine water and in water draining the area of the abandoned tailings pond. As well, the bottom fauna at lake stations offshore from the abandoned tailings pond show the effects of the high metal content in the sediment.

3.3 Sediment

3.3.1 Sediment Metal Concentrations. The concentrations of metals analyzed in the portion of the sediments that was smaller than 150 um are given in Appendix IV, Table 1 for all stations sampled. Concentrations are for dry weight (d/w) except for cyanide.

The concentrations of cyanide (CN^-) were 4.72, 1.58, 13.0, 53.2, and 7.02 mg/kg wet weight for Stations 18, 19, 21, 22, and 23 respectively. The concentration of cyanide was highest offshore from the abandoned tailings pond. The concentrations at Station 19, drainage from the abandoned tailings pond, was the lowest. Since Station 18 also had cyanide present it must be influenced by the abandoned tailings pond. It is surprising that these cyanides have not been oxidized into other compounds in the 9 years since the mill and tailings pond was used. A persistent slow leaching of cyanide into the water could have a continuous deleterious effect on fish.

The concentrations of cadmium, lead and zinc were higher at stations near the abandoned tailings pond and at lake stations just off shore from it than they were in either unaffected creek or lake stations. Concentrations of iron were similar at most stations except for a much higher value in the drainage from the abandoned tailings pond (Station 19). Venus mine ore contained iron, lead, zinc and trace amounts of cadmium and these metals have been deposited near the abandoned tailings pond in higher concentrations than they appear in other unaffected parts of the watershed.

The concentrations of lead and zinc found in sediments near the abandoned tailings pond confirm those found in 1975 and 1976 by Robson et al (1978).

Sediment in the drainage from the abandoned tailings pond (Station 19), had the highest concentrations of iron, mercury and lead in sediment but it also had the lowest concentrations of aluminum, barium, chromium, magnesium, manganese, sodium, phosphorus, silicon, strontium, titanium and vanadium.

3.3.2 Sediment Particle Size Analysis. The results of the sediment particle size analysis are given in Table 2 of Appendix IV.

The portion smaller than 63 um would be included in the sediments metal analysis which is done on all particles smaller than 150 um. By correlating the concentration of metal and the portion of the sediment it approximately represents, it can be seen that a high concentration and a large portion smaller than 63 um would have a large effect on the aquatic environment. Lead and zinc concentrations are high at Station 22 and the portion smaller than 63 um is 35.1% so this sediment would have a large effect on the aquatic environment. The cyanide concentration, wet weight - total sample, is also highest at this station which is offshore from the abandoned tailings pond.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Baseline Environmental Characteristics of Predevelopment Creek and Lake Stations

The water quality, bottom fauna, and sediment data from the southern end of Windy Arm (Tagish Lake) and the two creeks that drain into it were similar to other unaltered lakes and creeks in the Yukon. It was noted that creek samples contined more dissolved salts and had higher total hardness than the lake samples. The low dissolved salts and soft water in the lake are characteristic of a low productivity or oligotrophic lake. Since some metals such as lead, nickel and zinc are more toxic to aquatic life in soft water the lake would be particularly sensitive to the addition of metals to an extent which would increase the present concentrations.

There were only two areas of concern:

- There were two iron concentrations slightly elevated over drinking water criteria. These are not of serious concern and serve as baseline information.
- The mercury concentrations in water were all higher than the upper limit of 0.0001 mg/l Hg recommended to protect consumers of fish and mercury concentrations in both water and fish appear to have risen since 1975 and 1976 respectively.

4.2 Environmental Characteristics of Stations Affected by Past Mining and Milling Operations

The continuing effects of past mining and milling operations were shown in water quality, bottom fauna and sediment data of stations close to these locations. The arsenic and iron concentrations in water were elevated in the mine water (Station 16) and arsenic, iron, and lead concentrations in water were elevated in the abandoned tailings pond drainage (Station 19). Compared to other lake and stream sediment, significantly higher cadmium, lead and zinc concentrations occurred in the streambed near the abandoned tailings pond (Station 18), in the sediment of the drainage from the abandoned tailings pond (Station 19), and in lake sediments at two stations offshore from the abandoned tailings pond (Stations 22 and 23). Significant concentrations of cyanide were also found in sediment from the streambed near the abandoned tailings pond (Station 18), in the sediment of the drainage from the abandoned tailings pond (Station 19), and in lake sediment from the three stations offshore from the abandoned tailings pond (Stations 21, 22, 23). The bottom fauna from mine water (Station 16) were low in number, probably because of the high concentration of arsenic in the water. However the data were not conclusive because low numbers of bottom fauna were also found in an unaffected creek (Station 2). The bottom fauna in the stream originating near the abandoned tailing pond (Station 18) had a low diversity index probably because of the presence of cyanide and the high concentrations of cadmium, mercury, lead and zinc in the sediment at this station. There were two main areas of concern:

- Arsenic concentrations were elevated in the mine water (Station 16) and the drainage and seepage from the abandoned tailings pond (Stations 19 and 20 respectively). Treatment of mine water to remove arsenic during operation is planned by the company when the mine re-opens. The company also plans to recover the tailings from the abandoned tailings pond for reprocessing at their new mill site. Since the arsenic concentration was higher in the abandoned tailings pond drainage than it was in the mine water and the tailings are saturated with water it may also be necessary to treat tailings water to remove arsenic.
- Cyanide was found in the sediments of the stream originating near the abandoned tailings pond (Station 18), the drainage from the abandoned tailings pond (Station 19) and the lake stations offshore from the abandoned tailings pond (Stations 21, 22, 23). It is likely that cyanide is still present in the tailings even though drainage from the abandoned tailings (Station 19) contained no detectable cyanide. Consideration must be given in removing tailings so that cyanide does not become resolubilized into the water from the tailings.

4.3 Recommendations

1. That water quality, bottom fauna and the concentration of cyanide and metals in sediment be monitored for changes during and after Venus mill and mine operation in the watershed they affected,
2. That water samples at Stations 1 and 15 be collected in 1981 and analyzed by methods having detection limits at or below 0.01 mg/l for arsenic, 0.05 mg/l for manganese, 0.05 mg/l for lead and 0.01 mg/l for selenium since these are the recommended upper limits for drinking water (Anon. 1977). If possible, these water samples should also be analyzed by methods having detection limits at or below 0.0001 mg/l for silver, 0.0002 mg/l for cadmium, 0.0001 mg/l for mercury and 0.005 mg/l for lead since these are recommended upper limits for healthy aquatic life (Taylor 1980, Reeder 1979a, 1979b, Demayo 1980).
3. That concentrations of mercury in fish be routinely monitored in Windy Arm since mercury concentrations have possibly increased over those found in 1976 (Robson 1978) and if these increases show a continuing trend they may exceed the Health and Welfare recommended guideline of 0.5 mg/kg Hg wet weight.

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ACKNOWLEDGEMENTS

The author would like to thank I. Soroka for writing the methods chapter and for collating all the data. The author would also like to thank all the Environmental Protection Service regular and summer staff for their involvement in project planning, sample collection, lab analyses, drafting of figures, typing and manuscript review.

APPENDICES

APPENDIX I

COLLECTION, PRESERVATION AND ANALYSIS OR IDENTIFICATION METHODS

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Depth		Depth for sampling was determined using a TSK depth meter, model #89628, attached to a winch line.		
Temperature		In-situ temperature reading.	A thermometer or Y.S.I. Model 33 salinity, conductivity, temperature meter was used.	
Dissolved Oxygen (D.O.)	1.0 mg/l	Duplicate samples were collected at each station in 300 ml glass BOD bottles. The BOD bottle was rinsed 3 times with sample before filling. Subsurface samples were collected with a 3 litre van Dorn vessel. The D.O. samples were each preserved with 2 ml of manganese sulfate solution and 2 ml of alkali-iodide-azide solution. The samples were mixed by inverting them 15 times. A water seal was maintained and D.O. analysis was done within 7 days.	Iodometric Azide Modification Winkler Titration Method.	048
pH		Small aliquots of sample were taken and read soon after collection at field camp. No preservatives were required, however, temperature was noted. Lab measurements were taken as well.	Potentiometric. pH meter determines the difference in e.m.f. developed by a reference electrode and the e.m.f. from the precision or calomel electrode. A change in 1 pH unit requires an electrical change of 59.1 mV at 25°C.	080

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Conductivity	0.2 umhos/cm	In situ measurements, as well as lab measurements, were taken. The measurement was taken from the same sample as described in NH_3 below.	Conductivity Cell. This cell measures the solution's capacity for transmitting electricity. A Yellow Springs Instrument (Y.S.I.) Model 33, salinity, conductivity, temperature meter was used.	044
Ammonia NH_3-N	0.0050 mg/l	Single samples were collected in a 2 litre linear polyethylene container. The container was rinsed 3 times with sample before it was filled. Sub-surface samples were collected with a 3 litre van Dorn collecting vessel. No preservatives required. Stored at 4°C.	Phenol hypochlorite-colorimetric-automated. Under basic conditions ammonia reacts with phenol and is oxidized by sodium hypochlorite to form an organic complex, indolphenol blue. The intensity of indolphenol blue is measured at a wavelength of 630 nm. Reported as mg/l nitrogen. (1 mg/l N = 1.22 mg/l NH_3).	058
Color	5	Same sample as NH_3.	Platinum - Cobalt - Visual Comparison Method. Reported as color units.	040
Turbidity	1.0 FTU	Same sample as NH_3.	Nephelometric Turbidity. This is an empirical measurement of the light scattered by the sample compared to the intensity of the light scattered by a standard reference suspension. Light is directed through a tube containing the sample and the relative intensity of the scattered light at 90° to the light source is measured by photocells. Results are given in FTU's.	130

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Filterable Residue (F.R.)	10 mg/l	Same sample as NH_3.	A well mixed known volume of sample is filtered through a standard glass fibre filter paper. The filtrate is then evaporated and dried at 103°C. This dry filtrate, when weighed, gives filterable residue (FR) in mg/l.	100
Non-filterable Residue (N.F.R.)	5 mg/l	Same sample as NH_3.	A known volume of sample is filtered through a pre-weighed, dried, standard glass fibre filter paper. The paper is then dried and weighed again. The difference in weight represents the non-filterable residue (NFR) in mg/l.	104
Total Alkalinity	1.0 mg/l as $CaCO_3$	Same sample as NH_3.	Potentiometric Titration. Total alkalinity is determined by titration with sulfuric acid which has been standardized with sodium carbonate.	006
Total Organic Carbon (TOC)	1.0 mg/l	One sample was collected at each station using a 120 ml glass jar. The jar was rinsed 3 times with sample before it was filled. Stored at 4°C.	Carbon infra red analyzer measures total and inorganic carbon. The difference of these two measurements is taken to get organic carbon.	016
Total Inorganic Carbon (TIC)	1.0 mg/l	Same sample as TOC.		

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Total Phosphate T PO_4-P	0.0050 mg/l	Same sample as NH_3.	Acid-persulfate, Autoclave Digestion. Total phosphate (T PO_4) is measured by converting all phosphorus compounds to orthophosphates by using an acid-persulfate digestion. Then the measurement of total phosphate is based on a reaction between phosphate and molybdate ion to form complex heteropoly-acids. This is then reduced with ascorbic acid to form a blue molybdophosphoric acid color and the absorbance is measured at a wavelength of 885 nm. A technicon automated system is used.	086
Nitrite NO_2-N	0.0050 mg/l	Same sample as NH_3.	Diazotization-Colorimetric-Automated. Under acidic conditions nitrite ions react with sulfanilic acid to form a diazo compound. This compound, coupled with d-napthylamine, forms intense red azo dye which exhibits maximum absorbance at a wavelength of 520 nm. Reported as mg/l nitrogen. 3.29 mg/l NO_2^- = 1 mg/l N.	070
Nitrate NO_3-N	0.010 mg/l	Same sample as NH_3.	Cadmium-Copper Reduction-Colorimetric Automated. The sample was passed through a column containing cadmium granules coated with a porous layer of copper. The nitrate in the sample was reduced to nitrite. The sample was then	072

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
			analyzed using the nitrite method listed above and the total nitrite/nitrate-N concentration was determined. The nitrate concentration was found by difference and reported in mg/l Nitrogen. (4.43 mg/l NO_3^- = 1 mg/l N)	
Sulfate SO_4	1.0 mg/l	Same sample as NH_3.	Barium chloranilate - UV Spectrophotometric. In an aqueous solvent system containing 80% isopropyl alcohol the sulfate ion reacts with solid barium chloranilate to form a precipitate of barium sulfate and chloranilic acid. After centrifugation the absorbance of chloranilic acid is read at a wavelength of 310 nm. The absorbance is then compared to a standard plot.	122
Cyanide CN	0.03 mg/l	The sample was collected in a 1 litre nalgene wide mouth bottle, which was rinsed 3 times before filling. The sample was preserved with NaOH pellets to pH >12 and stored at 4°C.	Tetracyanonickelate (II) - UV - Colorimetric. Sample is refluxed with the addition of H_2SO_4. The simple and complex cyanides in the sample are converted to HCN gas which is then absorbed in an ammonium-nickelate trapping solution. The resulting solution of the nickel-tetracyanodianion may then be quantitatively measured on a UV Spectrophotometer at wavelengths 267 nm and 284 nm.	032

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Chloride Cl	0.50 mg/l	Same sample as NH_3.	Thiocyanate - Combined Reagent - Colorimetric - Automated. This method is based on the displacement of SCN ion from mercuric thiocyanate by Cl^- ion. The liberated SCN reacts with the ferric ion to form the colored complex, ferric thiocyanate. This complex is proportional to original Cl^- concentration and its absorbance is measured at a wavelength of 465 nm.	024
Extractable Metals		Single samples were collected at each station using a 200 ml linear polyethylene bottle. The sample bottle was rinsed 3 times with sample before filling. Subsurface samples were collected using a 3 litre van Dorn vessel. Each bottle was then preserved to a pH of <1.5 using 2.0 ml of concentrated nitric acid. The extractable method used measures the dissolved metals in addition to those (inorganic, organic, adsorbed, precipitated and particulate) which will be brought into solution by the addition of nitric acid.	An excitation source called the Inductively Coupled Argon Plasma (ICAP) combined with a computer controlled Optical Emission Spectrometer (OES) was used to measure the metal concentration.	210 592
Al	0.090			
As	0.15			
Ba	0.0030			
Ca	0.025			
Cd	0.010			
Co	0.015			
Cr	0.015			
Cu	0.010			
Fe	0.010			
Mg	0.025			
Mn	0.0040			
Mo	0.15			
Na	0.030			
Ni	0.08			
Pb	0.080			
Sb	0.080			
Se	0.15			

APPENDIX I   TABLE 1   WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
Sn	0.20			
Sr	0.0040			
Ti	0.0085			
V	0.050			
Zn	0.020			
Total Hardness			Total hardness is calculated from the ICAP concentrations of magnesium and calcium. 1 mg/l Mg = 4.116 mg/l $CaCO_3$. 1 mg/l Ca = 2.497 mg/l $CaCO_3$.	
Silica Si	0.5 mg/l	Same sample as NH_3.	Ascorbic Acid Reduction - Colorimetric - Automated. This reaction is based upon the reduction by ascorbic acid of silicomolybdate in acidic solution to molybdenum blue. The color is measured at a wavelength of 660 nm.	118
Mercury Hg (Total)	0.00020 mg/l	Samples were collected at each station using a 200 ml linear polyethylene bottle. Each bottle was rinsed 3 times with sample before being filled. Each sample was then preserved by the addition of 10 ml of 5% nitric dichromate solution.	Open Flameless System for Hg - AAS Determination. Organo mercury compounds in the sample are oxidized to inorganic mercury compounds by the use of sulfuric and nitric acid and potassium persulfate. The mercury is swept with argon from the solution and passed through an absorption cell which is situated in the light path of a mercury lamp. Mercury absorption	211 224 284 411

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	FIELD COLLECTION, SAMPLING PROCEDURES, PRESERVATION	ANALYTICAL PROCEDURE	METHOD SECTION[1]
			is determined at a wavelength of 253.7 nm with a background absorbance measured at a wavelength of 254.7 nm, using a tin hollow cathode lamp.	
Silver Ag	0.030 mg/l	Same sample as metals.	Flame Atomic Absorption Spectrophotometry.	210 290
Potassium K	0.010 mg/l	Same sample as metals.	Flame Atomic Emission Spectrophotometry.	210 423

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[1] Department of the Environment, Department of Fisheries and Oceans, Laboratory Manual, Environmental Protection Service, Fisheries and Marine Service, (1979).

APPENDIX I TABLE 2 BOTTOM FAUNA COLLECTION, PRESERVATION AND IDENTIFICATION METHODS

FIELD COLLECTION, SAMPLING PROCEDURES AND PRESERVATION	LABORATORY PROCEDURES	IDENTIFICATION AND ENUMERATION
Ekman Dredge: Lake bottom fauna samples were taken using a small boat, a winch and depth meter and an Ekman dredge - sample area - 225 cm^2 (.25 ft^2). Samples were washed using a .75 mm mesh screen and lake water to remove clay particles. Large rocks were washed and removed. The sample remaining was washed into a Surber net, shaken into a labelled glass jar and preserved with 10% formalin. Three samples were taken at each station, if possible. Surber Sampler: Creek samples were taken using a Surber sampler with a 60 cm long net-mesh size-1 mm. Area sampled was 900 cm^2 (1 ft^2). Surber samples were washed into the cup at the bottom of a plankton net (.75 mm mesh size) and put in separate, labelled glass jars and preserved with 10% formalin. Three samples were taken at each station.	Bottom fauna was removed from other material and placed in a labelled vial containing 70% methanol.	Bottom fauna were sent to Dr. Charles Low, Consulting Invertebrate Biologist, Nanaimo, B.C. for identification to genus, species if possible, and enumeration.

APPENDIX I TABLE 3 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS

PARAMETER	PREPARATION	ANALYSIS	METHOD CODE[1]
All parameters	Creek Stations: Sediment samples were scooped into Whirl Pack plastic bags. Lake Stations: The top layer of each Ekman dredge sample was transferred to a Whirl Pack bag. Three samples were taken at each station. Samples were frozen (-19°C) at the end of the day.		
Cyanide CN	Some distilled water was added to a known weight of sediment sample before starting the digestion step in the analytical procedure.	Tetracyanonickelate (11) - UV - Colorimetric Method. The sample was analyzed using this method as it was discussed in Table 3 for water. The concentration of cyanide is reported in mg/kg wet weight (w/w).	032
Hg (total)	Sample was freeze-dried for 48 hours to remove water. Sample was seived through a size 100 mesh (.15 mm) stainless steel sieve. The portion passing through was analyzed for mercury. Sample was completely oxidized by digestion with H_2SO_4 and H_2O_2.	Atomic Absorption Spectrophotometer - Open Flameless System. The oxidized mercury was reduced with stannous chloride, swept by argon into an absorption cell mounted in the beam path of an atomic absorption spectrophotometer and measured at a wavelength of 253.7 nm. The concentration of mercury was reported in mg/kg dry weight (d/w).	231, 236, 238, 275, 284, 411

APPENDIX I TABLE 3 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS (continued)

PARAMETER	PREPARATION	ANALYSIS	METHOD CODE[1]
Metals (Leachable) Al Ba Ca Cd Cr Cu Fe Mg Mn Mo Na Ni P Pb Si Sn Sr Si Sn Sr Ti V Zn	Sample was freeze-dried for 48 hours to remove water. Sample was seived through a size 100 mesh (.15 mm) stainless steel seive. Only the portion passing through was analyzed for metals. Sample was leached with HCl and HNO_3. The sample was heated for 3 hours.	An excitation source called the Inductively coupled Argon Plasma (ICAP) combined with a computer controlled Optical Emission Spectrometer (OES) was used to measure the concentrations of the metals listed on the left. Concentrations were reported in mg/kg dry weight (d/w).	231, 236, 238, 242

APPENDIX I TABLE 3 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS (continued)

PARAMETER	PREPARATION	ANALYSIS	METHOD CODE[1]
Particle Size	The sample was freeze-dried.	*Standard Sieving Operation*. A known weight of sediment was put into a series of sieves of the following US Standard Sizes: 35 (500 um), 60 (250 um), 230 (62.5 um) and a pan for <230 (<62.5 um). The set of sieves was shaken for 10 minutes. The amount in each sieve was weighed and the percentage of the initial weight was calculated.	078

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[1] Department of Environment, Department of Fisheries and Oceans, *Laboratory Manual*, Environmental Protection Service, Fisheries and Marine Service (1979).

APPENDIX II

WATER QUALITY DATA

APPENDIX II TABLE 1 WATER QUALITY DATA (EXCLUDING METALS)

STATION	DEPTH (m)	TEMP (°C)	D.O. (mg/l)	% D.O. SATUR-ATION (%)	IN SITU pH	LAB pH	IN SITU CONDUCT-IVITY (umhos/cm)	LAB CONDUCT-IVITY (umhos/cm)	COLOR (COLOR UNITS)	TURB-IDITY (FTU)	N.F. RESIDUE (mg/l)	F. RESIDUE (mg/l)
1	0	8.0	9.05	83	7.70	7.8	170	287	10	<1.0	<5	182
2	0	7.9	10.25	93	7.60	7.8	175	281	10	<1.0	<5	184
3	0	10.1	10.10	97	8.21	7.9	432	286	5	1.1	<5	175
4	0	7.8	11.00	98	8.00	7.8	60	113	10	<1.0	<5	73
5	0	8.9	10.20	95	8.27	7.9	239	187	5	<1.0	<5	115
6A	0	7.8	11.80	104	8.20	7.7	58	92.0	5	<1.0	<5	53
6B	26	6.1	-	-	-	7.8	58	86.5	5	<1.0	<5	62
7A	0	7.1	11.80	104	8.10	7.7	57	87.8	5	<1.0	<5	49
7B	46	7.0	-	-	-	7.7	60	87.0	5	<1.0	<5	54
8A	0	6.5	11.90	103	8.10	7.6	52	86.2	5	<1.0	<5	48
8B	16	6.1	-	-	-	7.7	59	86.2	5	<1.0	<5	57
9A	0	7.3	11.45	103	7.90	7.6	62	87.0	5	1.2	<5	53
9B	10	6.0	-	-	-	7.7	65	86.8	5	1.2	<5	55
10A	0	7.3	11.60	104	7.98	7.6	59	87.8	5	1.1	<5	52
10B	32	7.5	-	-	-	7.9	59	86.5	5	4.1	<5	58
11A	0	7.3	11.25	101	7.90	7.7	60	88.5	5	<1.0	<5	51
11B	10	7.1	-	-	-	7.8	65	86.0	5	<1.0	<5	57
12A	0	8.0	11.85	108	8.38	7.7	59	87.5	5	<1.0	<5	52
12B	8	7.1	11.50	102	-	7.8	62	86.2	5	<1.0	<5	57

APPENDIX II TABLE 1 WATER QUALITY DATA (EXCLUDING METALS) (continued)

STATION	DEPTH (m)	TEMP (°C)	D.O. (mg/l)	% D.O. SATURATION (%)	IN SITU pH	LAB pH	IN SITU CONDUCTIVITY (umhos/cm)	LAB CONDUCTIVITY (umhos/cm)	COLOR (COLOR UNITS)	TURBIDITY (FTU)	N.F. RESIDUE (mg/l)	F. RESIDUE (mg/l)
13A	0	7.5	11.65	104	8.00	7.7	68	86.0	5	<1.0	<5	54
13B	38	7.1	-	-	-	7.7	60	87.8	5	<1.0	<5	57
14A	0	7.1	11.55	102	7.92	7.7	59	85.8	5	<1.0	<5	52
14B	8	7.1	-	-	-	7.7	60	86.5	5	<1.0	<5	57
15A	0	8.5	11.60	106	8.10	7.7	59	89.0	5	<1.0	<5	53
15B	38	7.0	-	-	-	7.7	60	86.4	5	<1.0	<5	60
16	0	6.0	9.05	79	8.40	8.3	240	438	5	<1.0	5	281
17A	0	7.0	11.8	104	7.80	7.6	60	81.5	5	2.3	<5	47
17B	13	8.0	-	-	-	7.8	59	85.6	5	<1.0	<5	53
18	0	4.3	12.40	103	8.20	8.0	242	440	5	<1.0	<5	289
19	0	15.1	9.85	105	8.60	8.2	282	493	5	2.7	17	327
20	0	9.5	4.95	47	7.80	7.8	420	620	5	1.5	7	436
21A	0	9.0	12.85	111	7.80	7.5	49	82.0	5	6.8	11	49
21B	5	8.9	-	-	7.80	7.7	53	81.8	5	1.1	<5	53
22A	0	8.0	11.10	93	7.40	7.5	52	80.2	5	1.9	<5	51
22B	5	8.9	-	-	-	7.8	55	82.0	5	<1.0	<5	54
23A	0	7.9	11.65	98	7.80	7.6	51	83.5	5	<1.0	<5	50
23B	5	8.5	-	-	-	7.7	52	82.0	5	<1.0	<5	54

APPENDIX II TABLE 1 WATER QUALITY DATA (EXCLUDING METALS) (Continued)

STATION	DEPTH (m)	TOTAL ALKAL-INITY (mg/l CaCO$_3$)	TOTAL HARDNESS (mg/l CaCO$_3$)	T.O.C. (mg/l)	T.I.C. (mg/l)	TOTAL PO$_4$-P (mg/l)	NO$_2$-N (mg/l)	NO$_3$-N (mg/l)	NH$_3$-N (mg/l)	SO$_4$ (mg/l)	CN (mg/l)	Cl (mg/l)
1	0	109	142.0	2.0	25.0	0.0065	<0.0050	<0.010	<0.0050	35.1	<.03	<0.50
2	0	107	136.0	4.0	22.0	<0.0050	<0.0050	<0.010	<0.0050	34.8	<.03	<0.50
3	0	119	139.0	1.0	24.0	<0.0050	<0.0050	<0.010	<0.0050	26.3	<.03	0.53
4	0	43.7	52.2	2.0	9.0	<0.0050	<0.0050	<0.010	<0.0050	9.20	<.03	<0.50
5	0	76.5	90.1	2.0	15.0	0.0055	<0.0050	0.0106	0.0108	16.4	<.03	<0.50
6A	0	36.5	40.6	1.0	7.0	0.0055	<0.0050	0.0301	<0.0050	7.40	<.03	<0.50
6B	26	35.0	38.8	1.0	7.0	<0.0050	<0.0050	0.0250	<0.0050	6.75	<.03	<0.50
7A	0	35.3	40.0	1.0	7.0	0.0074	<0.0050	0.0267	0.0089	6.80	<.03	<0.50
7B	46	35.0	39.7	1.0	7.0	0.0052	<0.0050	0.0279	0.0070	6.80	<.03	<0.50
8A	0	34.5	39.4	1.0	7.0	0.0065	<0.0050	0.0272	0.0088	6.65	<.03	<0.50
8B	16	35.7	39.6	1.0	7.0	<0.0050	<0.0050	0.0246	<0.0050	6.70	<.03	<0.50
9A	0	35.3	39.4	1.0	7.0	0.0078	<0.0050	0.0403	0.0238	7.95	<.03	<0.50
9B	10	35.0	39.1	1.0	7.0	<0.0050	<0.0050	0.0241	0.0050	6.70	<.03	<0.50
10A	0	35.1	39.5	<1.0	7.0	0.0078	<0.0050	0.0343	0.0070	7.20	<.03	0.64
10B	32	35.0	39.9	<1.0	7.0	0.0088	<0.0050	0.0270	<0.0050	6.65	<.03	<0.50
11A	0	35.5	41.3	1.0	8.0	0.0063	<0.0050	0.0303	<0.0050	6.90	-	<0.50
11B	10	35.0	39.5	<1.0	7.0	<0.0050	<0.0050	0.0239	<0.0050	6.75	<.03	<0.50
12A	0	35.1	40.1	1.0	7.0	<0.0050	<0.0050	0.0263	<0.0050	6.90	<.03	<0.50
12B	8	35.0	39.0	<1.0	7.0	<0.0050	<0.0050	0.0246	<0.0050	7.90	<.03	<0.50

APPENDIX II TABLE 1 WATER QUALITY DATA (EXCLUDING METALS) (continued)

STATION	DEPTH (m)	TOTAL ALKAL-INITY (mg/l $CaCO_3$)	TOTAL HARDNESS (mg/l $CaCO_3$)	T.O.C. (mg/l)	T.I.C. (mg/l)	TOTAL PO_4-P (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	NH_3-N (mg/l)	SO_4 (mg/l)	CN (mg/l)	Cl (mg/l)
13A	0	34.5	38.9	1.0	7.0	<0.0050	<0.0050	0.0260	<0.0050	6.85	<.03	<0.50
13B	38	35.3	40.2	1.0	7.0	0.0058	<0.0050	0.0291	0.0120	6.75	<.03	<0.50
14A	0	34.3	38.9	1.0	6.0	0.0057	<0.0050	0.0258	<0.0050	7.55	<.03	<0.50
14B	8	35.1	39.9	<1.0	7.0	<0.0050	<0.0050	0.0244	<0.0050	6.80	<.03	<0.50
15A	0	36.0	39.8	1.0	7.0	<0.0050	<0.0050	0.0260	<0.0050	7.95	<.03	<0.50
15B	38	35.0	39.3	1.0	7.0	0.0057	<0.0050	0.0263	0.0054	6.70	<.03	<0.50
16	0	171	214.0	<1.0	34.0	0.0073	<0.0050	0.0260	<0.0050	56.7	<.03	0.82
17A	0	32.6	38.5	1.0	7.0	0.0053	<0.0050	<0.010	<0.0050	6.80	<.03	<0.50
17B	13	33.5	38.7	<1.0	7.0	<0.0050	<0.0050	0.0255	0.0104	6.35	<.03	<0.50
18	0	140	223.0	1.0	29.0	<0.0050	<0.0050	0.3720	<0.0050	82.4	<.03	0.53
19	0	157	251.0	1.0	31.0	0.0196	<0.0050	0.0759	<0.0050	95.0	<.03	0.81
20	0	170	315.0	<1.0	35.0	0.0343	<0.0050	0.0590	<0.0050	142	<.03	0.77
21A	0	32.4	35.6	<1.0	7.0	0.0143	<0.0050	0.0338	<0.0050	6.95	<.03	<0.50
21B	5	32.8	37.3	1.0	7.0	0.0052	<0.0050	0.0234	0.0070	6.00	<.03	<0.50
22A	0	32.5	36.6	1.0	6.0	0.0054	<0.0050	0.0244	<0.0050	6.05	<.03	<0.50
22B	5	33.5	39.1	1.0	7.0	0.0055	<0.0050	0.0250	0.0072	6.20	<.03	<0.50
23A	0	33.5	36.4	2.0	6.0	<0.0050	<0.0050	0.0248	<0.0050	6.35	<.03	<0.50
23B	5	33.5	37.2	<1.0	7.0	<0.0050	<0.0050	0.0274	0.0097	6.10	<.03	<0.50

APPENDIX II TABLE 2 WATER QUALITY DATA - EXTRACTABLE METALS - Ag TO Mg (all units in mg/l)

STATION	DEPTH (m)	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Mg
1	0	<0.030	<0.09	<0.15	0.0405	45.4	<0.01	<0.015	<0.015	<0.01	0.018	0.00020	0.443	6.93
2	0	<0.030	<0.09	<0.15	0.0367	43.6	<0.01	<0.015	<0.015	0.012	0.024	0.00025	0.469	6.59
3	0	<0.030	<0.09	<0.15	0.0351	45.5	<0.01	<0.015	<0.015	<0.01	0.035	0.00025	0.861	6.22
4	0	<0.030	<0.09	<0.15	0.0152	17.5	<0.01	<0.015	<0.015	<0.01	0.025	0.00025	0.314	2.06
5	0	<0.030	<0.09	<0.15	0.0241	29.7	<0.01	<0.015	<0.015	<0.01	0.123	0.00032	0.477	3.87
6A	0	<0.030	<0.09	<0.15	0.0185	13.3	<0.01	<0.015	<0.015	<0.01	0.027	0.00051	0.486	1.8
6B	26	<0.030	<0.09	<0.15	0.0177	12.7	<0.01	<0.015	<0.015	<0.01	0.013	0.00045	0.463	1.72
7A	0	<0.030	<0.09	<0.15	0.0183	13.1	<0.01	<0.015	<0.015	<0.01	0.022	0.00051	0.466	1.78
7B	46	<0.030	<0.09	<0.15	0.0181	13.0	<0.01	<0.015	<0.015	<0.01	0.022	0.00032	0.456	1.76
8A	0	<0.030	<0.09	<0.15	0.0179	12.9	<0.01	<0.015	<0.015	<0.01	0.018	0.00051	0.453	1.75
8B	16	<0.030	<0.09	<0.15	0.018	13.0	<0.01	<0.015	<0.015	<0.01	0.017	0.00032	0.457	1.74
9A	0	<0.030	<0.09	<0.15	0.0184	12.9	<0.01	<0.015	<0.015	<0.01	0.017	0.00020	0.441	1.75
9B	10	<0.030	<0.09	<0.15	0.0172	12.8	<0.01	<0.015	<0.015	<0.01	<0.01	0.00032	0.448	1.73
10A	0	<0.030	0.123	<0.15	0.0199	12.9	<0.01	<0.015	<0.015	<0.01	0.081	0.00020	0.601	1.78
10B	32	<0.030	<0.09	<0.15	0.0176	13.1	<0.01	<0.015	<0.015	<0.01	0.018	0.00032	0.455	1.75
11A	0	<0.030	<0.09	<0.15	0.0212	13.5	<0.01	<0.015	<0.015	<0.01	0.118	0.00032	0.788	1.85
11B	10	<0.030	<0.09	<0.15	0.0181	13.0	<0.01	<0.015	<0.015	<0.01	0.012	0.00032	0.446	1.72
12A	0	<0.030	<0.09	<0.15	0.0181	13.1	<0.01	<0.015	<0.015	<0.01	0.059	0.00032	0.525	1.79
12B	8	<0.030	<0.09	<0.15	0.0176	12.8	<0.01	<0.015	<0.015	<0.01	0.012	0.00020	0.448	1.71

APPENDIX II TABLE 2 WATER QUALITY DATA - EXTRACTABLE METALS - Ag TO Mg (all units in mg/l) (continued)

STATION	DEPTH (m)	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Mg
13A	0	<0.030	<0.09	<0.15	0.0179	12.7	<0.01	<0.015	<0.015	<0.01	0.039	0.00020	0.470	1.75
13B	38	<0.030	<0.09	<0.15	0.0175	13.2	<0.01	<0.015	<0.015	<0.01	0.016	0.00032	0.458	1.76
14A	0	<0.030	<0.09	<0.15	0.018	12.7	<0.01	<0.015	<0.015	<0.01	0.035	0.00025	0.469	1.75
14B	8	<0.030	0.213	<0.15	0.0235	13.0	<0.01	<0.015	<0.015	<0.01	0.365	0.00025	0.488	1.81
15A	0	<0.030	<0.09	<0.15	0.0177	13.0	<0.01	<0.015	<0.015	<0.01	0.021	0.00064	0.449	1.78
15B	38	<0.030	<0.09	<0.15	0.0174	12.9	<0.01	<0.015	<0.015	<0.01	0.028	0.00032	0.465	1.73
16	0	<0.030	<0.09	0.3	0.0338	43.2	<0.01	<0.015	<0.015	<0.01	0.049	0.00025	0.468	25.8
17A	0	<0.030	<0.09	<0.15	0.0168	12.5	<0.01	<0.015	<0.015	<0.01	0.017	0.00057	0.444	1.76
17B	13	<0.030	<0.09	<0.15	0.0174	12.6	<0.01	<0.015	<0.015	<0.01	0.014	0.00032	0.443	1.75
18	0	<0.030	0.108	<0.15	<.003	39.5	<0.01	<0.015	<0.015	<0.01	0.218	0.00038	0.334	30.2
19	0	<0.030	<0.09	1.2	0.0088	47.0	<0.01	<0.015	<0.015	<0.01	0.855	0.00045	0.788	32.5
20	0	<0.030	<0.09	0.74	0.0167	73.9	<0.01	<0.015	<0.015	<0.01	0.173	0.00032	4.77	31.8
21A	0	<0.030	<0.09	<0.15	0.0166	11.6	<0.01	<0.015	<0.015	<0.01	0.024	0.00025	0.454	1.62
21B	5	<0.030	<0.09	<0.15	0.0177	12.2	<0.01	<0.015	<0.015	<0.01	0.038	0.00032	0.446	1.65
22A	0	<0.030	0.116	<0.15	0.0182	11.9	<0.01	<0.015	<0.015	<0.01	0.144	0.00025	0.490	1.66
22B	5	<0.030	<0.09	<0.15	0.0172	12.6	<0.01	<0.015	<0.015	<0.01	0.028	0.00032	0.450	1.85
23A	0	<0.030	<0.09	<0.15	0.0172	11.9	<0.01	<0.015	<0.015	<0.01	0.05	0.00025	0.456	1.62
23B	5	<0.030	<0.09	<0.15	0.0172	12.2	<0.01	<0.015	<0.015	<0.01	0.023	0.00032	0.450	1.63

APPENDIX II TABLE 3 WATER QUALITY DATA - METALS Mn TO Zn (all units in mg/l)

STATION	DEPTH (m)	Mn	Mo	Na	Ni	Pb	Sb	Se	Si	Sn	Sr	Ti	V	Zn
1	0	0.0158	<0.15	2.63	<0.08	<0.08	<0.08	<0.15	3.52	<0.2	0.489	<0.0085	<0.05	0.041
2	0	<0.003	<0.15	2.64	<0.08	<0.08	<0.08	<0.15	3.97	<0.2	0.454	<0.0085	<0.05	0.024
3	0	0.0072	<0.15	4.01	<0.08	<0.08	<0.08	<0.15	3.16	<0.2	0.412	<0.0085	<0.05	<0.02
4	0	<0.003	<0.15	1.79	<0.08	<0.08	<0.08	<0.15	3.08	<0.2	0.14	<0.0085	<0.05	<0.02
5	0	0.0136	<0.15	3.08	<0.08	<0.08	<0.08	<0.15	3.45	<0.2	0.27	<0.0085	<0.05	<0.02
6A	0	0.0153	<0.15	1.73	<0.08	<0.08	<0.08	<0.15	1.89	<0.2	0.0954	<0.0085	<0.05	<0.02
6B	26	<0.003	<0.15	1.17	<0.08	<0.08	<0.08	<0.15	1.89	<0.2	0.0851	<0.0085	<0.05	<0.02
7A	0	0.0047	<0.15	1.69	<0.08	<0.08	<0.08	<0.15	1.89	<0.2	0.0934	<0.0085	<0.05	<0.02
7B	46	<0.003	<0.15	1.18	<0.08	<0.08	<0.08	<0.15	2.05	<0.2	0.0872	<0.0085	<0.05	<0.02
8A	0	0.0032	<0.15	1.69	<0.08	<0.08	<0.08	<0.15	1.86	<0.2	0.0912	<0.0085	<0.05	<0.02
8B	16	<0.003	<0.15	1.27	<0.08	<0.08	<0.08	<0.15	1.88	<0.2	0.0875	<0.0085	<0.05	<0.02
9A	0	<0.003	<0.15	1.7	<0.08	<0.08	<0.08	<0.15	1.85	<0.2	0.0912	<0.0085	<0.05	<0.02
9B	10	<0.003	<0.15	1.2	<0.08	<0.08	<0.08	<0.15	1.89	<0.2	0.0856	<0.0085	<0.05	<0.02
10A	0	0.0416	<0.15	1.71	<0.08	<0.08	<0.08	<0.15	1.88	<0.2	0.0914	<0.0085	<0.05	<0.02
10B	32	<0.003	<0.15	1.3	<0.08	<0.08	<0.08	<0.15	1.91	<0.2	0.0880	<0.0085	<0.05	<0.02
11A	0	0.0637	<0.15	1.9	<0.08	<0.08	<0.08	<0.15	1.88	<0.2	0.0958	<0.0085	<0.05	0.026
11B	10	<0.003	<0.15	1.29	<0.08	<0.08	<0.08	<0.15	1.89	<0.2	0.0869	<0.0085	<0.05	<0.02
12A	0	0.0195	<0.15	1.58	<0.08	<0.08	<0.08	<0.15	1.87	<0.2	0.0922	<0.0085	<0.05	0.055
12B	8	<0.003	<0.15	1.21	<0.08	<0.08	<0.08	<0.15	1.88	<0.2	0.0851	<0.0085	<0.05	<0.02

APPENDIX II TABLE 3 WATER QUALITY DATA - METALS Mn TO Zn (all units in mg/l) (continued)

STATION	DEPTH (m)	Mn	Mo	Na	Ni	Pb	Sb	Se	Si	Sn	Sr	Ti	V	Zn
13A	0	0.0073	<0.15	1.55	<0.08	<0.08	<0.08	<0.15	1.86	<0.2	0.0896	<0.0085	<0.05	<0.02
13B	38	<0.003	<0.15	1.27	<0.08	<0.08	<0.08	<0.15	2.02	<0.2	0.0889	<0.0085	<0.05	<0.02
14A	0	0.0087	<0.15	1.6	<0.08	<0.08	<0.08	<0.15	1.85	<0.2	0.0896	<0.0085	<0.05	<0.02
14B	8	0.015	<0.15	1.18	<0.08	<0.08	<0.08	<0.15	1.90	<0.2	0.0866	<0.0085	<0.05	<0.02
15A	0	<0.003	<0.15	1.56	<0.08	<0.08	<0.08	<0.15	1.89	<0.2	0.093	<0.0085	<0.05	<0.02
15B	38	<0.003	<0.15	1.18	<0.08	<0.08	<0.08	<0.15	1.90	<0.2	0.087	<0.0085	<0.05	<0.02
16	0	0.0059	<0.15	9.82	<0.08	<0.08	<0.08	<0.15	4.20	<0.2	1.32	<0.0085	<0.05	0.065
17A	0	<0.003	<0.15	1.62	<0.08	<0.08	<0.08	<0.15	1.83	<0.2	0.0883	<0.0085	<0.05	<0.02
17B	13	<0.003	<0.15	1.21	<0.08	<0.08	<0.08	<0.15	1.87	<0.2	0.0846	<0.0085	<0.05	<0.02
18	0	0.0084	<0.15	3.67	<0.08	<0.08	<0.08	<0.15	3.20	<0.2	0.203	<0.0085	<0.05	0.038
19	0	0.0617	<0.15	4.04	<0.08	0.159	<0.08	<0.15	3.37	<0.2	0.257	<0.0085	<0.05	0.181
20	0	0.0046	<0.15	6.27	<0.08	<0.08	<0.08	<0.15	4.20	<0.2	0.684	<0.0085	<0.05	<0.02
21A	0	0.0057	<0.15	1.29	<0.08	<0.08	<0.08	<0.15	1.86	<0.2	0.0783	<0.0085	<0.05	0.027
21B	5	<0.003	<0.15	1.16	<0.08	<0.08	<0.08	<0.15	1.84	<0.2	0.0786	<0.0085	<0.05	<0.02
22A	0	0.0086	<0.15	1.57	<0.08	<0.08	<0.08	<0.15	1.83	<0.2	0.08	<0.0085	<0.05	<0.02
22B	5	<0.003	<0.15	1.25	<0.08	<0.08	<0.08	<0.15	1.85	<0.2	0.0801	<0.0085	<0.05	<0.02
23A	0	0.0042	<0.15	1.51	<0.08	<0.08	<0.08	<0.15	1.85	<0.2	0.0805	<0.0085	<0.05	0.03
23B	5	<0.003	<0.15	1.16	<0.08	<0.08	<0.08	<0.15	1.84	<0.2	0.0782	<0.0085	<0.05	<0.02

APPENDIX II TABLE 4 WATER QUALITY CRITERIA

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)
Physical				
Color Pt. Counts	25-75	1	No increase in natural waters	7
Odor and taste	Not noticeable	1		
Turbidity J.T.U.	5	1		
Chemical				
Alkalinity mg/l (Total)	Not considered a public health problem 30-500 mg/l $CaCO_3$	1 7	>100 (relates to pH)	4
Aluminum (Al) mg/l	Not considered a public health problem	5	0.1	2
Ammonia (NH_3-N) mg/l	0.5	1	0.02	2
Antimony (Sb) mg/l				
Arsenic (As) mg/l	0.01-0.05	1	0.05	6
Barium (Ba) mg/l	1.0	1	5.0	5
Boron (Bo) mg/l	1.0	1		
Cadmium (Cd) mg/l	0.01	1	0.0002	6

APPENDIX II TABLE 4 WATER QUALITY CRITERIA (continued)

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)
Calcium (Ca) mg/l	75-200	5		
Chloride (Cl) mg/l	250	1		
Chromium (Cr) mg/l	0.05	1	0.04	6
Cobalt (Co) mg/l				
Conductivity @ 25°C (umhos/cm)	Depends on dissolved salts	5	150-500	4
Copper (Cu) mg/l	1.0	1	0.005	2
Cyanide (CN) mg/l	0.2	1	0.005	2
Dissolved oxygen (% saturation)	Near 100%	1	$\geq$54%	2
Fluoride (F) mg/l	1.6	1	1.5	5
Hardness (as $CaCO_3$) (Total) mg/l	100-350	1		
Iron (Fe) mg/l	0.3	1	1.0	3
Lead (Pb) mg/l	0.05	1	0.005 (soft H_2O*) 0.01 (hard H_2O*)	6 6
Magnesium (Mg) mg/l	50	1		
Manganese (Mn) mg/l	0.05	1	1.0	5
Mercury (Hg) mg/l	0.002	1	0.0001-0.0002	6
Molybdenum (Mo)				
Nickel (Ni) mg/l	0.25	6	0.025 (soft H_2O*) 0.25 (hard H_2O*)	6 6

APPENDIX II TABLE 4 WATER QUALITY CRITERIA (continued)

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)
Nitrate (NO_3-N) mg/l	10	1		
Nitrite (NO_2-N) mg/l	1	1		
pH units	8.3-9.0, 5.0-9.6	1, 1	6.5-9.0	3
Phosphorus (P) (Total) mg/l	0.2 (as PO_4)	7	0.020 to prevent algae	2
Potassium (K) mg/l				
Residue: Filterable mg/l (total dissolved solids)	1000	1	70-400 with a maximum of 2000	4
Non-filterable mg/l	80	7		
Selenium (Se) mg/l	0.01	1	0.01	6
Silica (Si) mg/l				
Silver (Ag) mg/l	0.05	1	0.0001	6
Sodium (Na) mg/l	20	1		
Strontium (Sr) mg/l				
Sulfate (SO_4) mg/l	150-250	1		
Tin (Sn) mg/l	Not present in natural waters	5		
Titanium (Ti) mg/l				
Total Inorganic Carbon (TIC)				

APPENDIX II TABLE 4 WATER QUALITY CRITERIA (continued)

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)
Total Organic Carbon (TOC) mg/l	5.0	2		
Vanadium (V)				
Zinc (Zn) mg/l	5.0	1	0.030	2

* Soft water has a total hardness less than 95 mg/l as $CaCO_3$. Hard water has a total hardness of more than 95 mg/l as $CaCO_3$ (Reference 6).

APPENDIX II TABLE 4 WATER QUALITY CRITERIA (continued)

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APPENDIX III

BOTTOM FAUNA DATA

APPENDIX III TABLE 1 BOTTOM FAUNA TAXANOMIC GROUPS FOUND IN THE VENUS MINES WATERSHED

1	Phylum:	Nematoda
	Phylum:	Annelida
	Class:	Oligochaeta
	Order:	Plesiopora
	Family:	Naididae
2		*Nais communis* or *variabilis*
3	Family:	Enchytraeidae
	Family:	Tubificidae
4		*Tubifex* sp.
5		*Limnodrilus* sp.
6		*Telmatodrilus* sp.
7		*Rhyacodrilus coccineus*
	Phylum:	Arthropoda
	Class:	Crustacea
	Order:	Cladocera
	Family:	Chydoridae
8		*Eurycercus lamellatus*
	Class:	Arachnoidea
9	Order:	Arachnida (terr.)
10	Order:	Acari undet.
	Class:	Insecta
	Order:	Plecoptera

APPENDIX III TABLE 1 BOTTOM FAUNA TAXANOMIC GROUPS FOUND IN THE VENUS MINES WATERSHED (continued)

	Family:	Nemouridae
11		*Nemoura* *(Zapada)* sp.
12		*Prostoia* sp.
	Family:	Chloroperlinae
13		*Alloperla* sp.
	Family:	Perlodidae
14		*Cultus* sp.
15		*Kogotus* sp.
	Order:	Ephemeroptera
	Family:	Baetidae
16		*Ameletus* sp.
17		*Baetis* sp.
18		*Ephemerella* *doddsi*
	Family:	Heptageniidae
19		*Cinygmula* sp.
20		*Epeorus* sp.
21		*Rithrogena* sp.
22	Order:	Hemiptera (terr.)
	Order:	Trichoptera
	Family:	Rhyacophilidae
23		*Agapetus* sp.
24		*Rhyacophila* *tucula*

APPENDIX III TABLE 1 BOTTOM FAUNA TAXANOMIC GROUPS FOUND IN THE VENUS MINES WATERSHED (continued)

	Family:	Limnephilidae
25		*Drusinus* sp.
	Family:	Hydropsychidae
26		*Cheumatopsyche* sp.
27	Order:	Lepidoptera (terr. larvae)
28	Order:	Coleoptera, adult
29	Order:	Diptera, adult
	Family:	Tipulidae
30		*Tipula* sp.
31		*Pedicia* sp.
32	Family:	Simulidae, larvae
33	Family:	Chironomidae, pupa
34		*Cardiocladius* sp.
35		*Chironomus* sp.
36		*Cricotopus* sp.
37		*Cryptochironomus* sp.
38		*Endochironomus* sp.
39		*Eukiefferiella* sp.
40		*Glyptotendipes* sp.
41		*Heterotrissocladius* sp.
42		*Micropsectra* sp.
43		*Procladius* sp.

APPENDIX III TABLE 1 BOTTOM FAUNA TAXANOMIC GROUPS FOUND IN THE VENUS MINES WATERSHED (continued)

44		<u>Psectrocladius</u> sp.
45		<u>Trichocladius</u> sp.
	Family:	Empididae
46		<u>Chelifera</u> sp.
47		<u>Clinocera</u> sp.
48		<u>Hemerodromia</u> sp.
49	Order:	Hymenoptera, adult (terr.)
	Phylum:	Mollusca
	Class:	Gastropoda
	Order:	Cytenobranchiata
	Family:	Valvatidae
50		<u>Valvata</u> <u>sincera</u>
	Family:	Lymnaeidae
51		<u>Lymnaea</u> sp.
	Class:	Pelecypoda
	Family:	Sphaeriidae
52		<u>Pisidium</u> sp.

APPENDIX III TABLE 2 BOTTOM FAUNA DATA AT SAMPLING STATIONS

		STATION 1				STATION 2			STATION 4			STATION 5				STATION 7			
	TAXONOMIC GROUP	A	B	C	TOTAL A,B,C	A	B	TOTAL A,B	A	B	TOTAL A,B	A	B	C	TOTAL A,B,C	A	B	C	TOTAL A,B,C
1	Nematoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	*Nais communis* or *variabilis*	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	*Enchytraeidae*	6	1	-	7	2	-	2	-	-	-	-	-	-	-	-	-	-	-
4	*Tubifex* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	*Limnodrilus* sp.	3	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	*Telmatrodrilus* sp.	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	*Rhyacodrilus coccineus*	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	2	-	2
8	*Eurycercus lamellatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	*Arachnida* (terr.)	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-
10	Acari (undet.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	*Nemoura (Zapada)* sp.	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	*Prostoia* sp.	12	-	14	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	*Alloperla* sp.	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
14	*Cultus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	*Kogotus* sp.	-	17	-	17	-	-	-	-	1	1	-	-	-	-	-	-	-	-
16	*Ameletus* sp.	-	-	-	-	-	1	1	-	-	-	-	1	-	1	-	-	-	-
17	*Baetis* sp.	2	1	4	7	1	-	1	6	5	11	-	-	-	-	-	-	-	-
18	*Ephemerella doddsi*	-	-	-	-	-	-	-	1	2	3	-	-	-	-	-	-	-	-
19	*Cinygmula* sp.	4	3	7	14	4	1	5	27	31	58	6	-	-	6	-	-	-	-
20	*Epeorus* sp.	-	-	-	-	-	-	-	2	7	9	-	-	-	-	-	-	-	-
21	*Rithrogena* sp.	-	-	-	-	-	-	-	7	-	7	1	-	1	2	-	-	-	-
22	*Hemiptera* (terr.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	*Agapetus* sp.	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-
24	*Rhyacophilia tucula*	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
25	*Drusinus* sp.	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
26	*Cheumatopsyche* sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	Lepidoptera (terr. larvae)	-	-	-	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-

APPENDIX III TABLE 2 BOTTOM FAUNA DATA AT SAMPLING STATIONS (continued)

TAXONOMIC GROUP	STATION 1				STATION 2			STATION 4			STATION 5				STATION 7			
	A	B	C	TOTAL A,B,C	A	B	TOTAL A,B	A	B	TOTAL A,B	A	B	C	TOTAL A,B,C	A	B	C	TOTAL A,B,C
28 Coleoptera, adult	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29 Diptera, adult	-	-	1	1	-	-	-	1	-	1	-	-	-	-	-	-	-	-
30 *Tipula* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31 *Pedicia* sp.	-	2	1	3	-	-	-	-	1	1	-	-	-	-	-	-	-	-
32 Simulidae, larvae	29	22	91	142	-	1	1	-	-	-	-	-	-	-	1	-	-	1
33 Chironomidae pupa	4	-	1	5	-	1	1	-	-	-	-	-	-	-	-	-	-	-
34 *Cardiocladius* sp.	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35 *Chironomus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
36 *Cricotopus* sp.	1	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37 *Cryptochironomus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38 *Endochironomus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39 *Eukiefferiella* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
40 *Glyptotendipes* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41 *Heterotrissocladius* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	9	7	19
42 *Micropsectra* sp.	1	-	1	2	-	-	-	-	-	-	-	2	-	2	-	-	-	-
43 *Procladius* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	2	7
44 *Psectrocladius* sp.	7	1	7	15	-	-	-	-	1	1	-	-	-	-	-	-	-	-
45 *Trichocladius* sp.	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-
46 *Chelifera* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47 *Clinocera* sp.	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
48 *Hemerodromia* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49 Hymenoptera, adult (terr.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50 *Valvata sincera*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
51 *Lymnaea* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52 *Pisidium* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	5
Eggmass (undet.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2
Column Total	72	48	130	250	9	5	14	47	50	97	8	3	2	13	14	17	9	40
Total Number (N)	32	24	37	93	7	2	9	44	49	93	8	3	2	13	11	17	9	37
Diversity (H')	.76	.42	.75	.89	.50	.30	.57	.51	.54	.57	.32	.28	.30	.66	.46	.62	.23	.62

APPENDIX III TABLE 2 BOTTOM FAUNA DATA AT SAMPLING STATIONS (continued)

	TAXONOMIC GROUP	STN 8	STN 9	STATION 10				STATION 13			STATION 15				STN 16
		TOTAL A,B,C	TOTAL A,B,C	A	B	C	TOTAL A,B,C	A	B	TOTAL A,B	A	B	C	TOTAL A,B,C	A
1	Nematoda	-	-	2	1	-	3	-	1	1	-	-	-	-	-
2	Nais communis or variabilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Enchytraeidae	-	14	-	-	-	-	-	-	-	-	-	-	-	-
4	Tubifex sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Limnodrilus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Telmatrodrilus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Rhyacodrilus coccineus	6	14	-	-	-	-	2	9	11	8	-	1	9	-
8	Eurycercus lamellatus	-	1	-	-	-	-	-	-	-	-	-	-	-	-
9	Arachnida (terr.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	Acari (undet.)	1	1	-	-	1	1	-	-	-	-	-	-	-	-
11	Nemoura (Zapada) sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	Prostoia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	Alloperla sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	Cultus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1
15	Kogotus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	Ameletus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Baetis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	5
18	Ephemerella doddsi	-	-	-	-	-	-	-	-	-	-	-	-	-	2
19	Cinygmula sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	10
20	Epeorus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	Rithrogena sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	Hemiptera (terr.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	Agapetus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	Rhyacophilia tucula	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	Drusinus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	Cheumatopsyche sp	-	-	-	-	-	-	-	-	-	-	-	-	-	1
27	Lepidoptera (terr. larvae)	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX III TABLE 2 BOTTOM FAUNA DATA AT SAMPLING STATIONS (continued)

TAXONOMIC GROUP	STN 8	STN 9	STATION 10				STATION 13			STATION 15				STN 16
	TOTAL A,B,C	TOTAL A,B,C	A	B	C	TOTAL A,B,C	A	B	TOTAL A,B	A	B	C	TOTAL A,B,C	A
28 Coleoptera, adult	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29 Diptera, adult	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30 *Tipula* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31 *Pedicia* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32 *Simulidae*, larvae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33 Chironomidae pupa	-	1	-	-	2	2	1	-	1	-	1	-	1	-
34 *Cardiocladius* sp.	6	18	-	-	-	-	1	-	1	-	-	-	-	-
35 *Chironomus* sp.	1	-	-	-	-	-	1	-	1	-	-	-	-	-
36 *Cricotopus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37 *Cryptochironomus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38 *Endochironomus* sp.	1	7	-	-	-	-	-	-	-	3	-	-	3	-
39 *Eukiefferiella* sp.	13	2	-	-	-	-	-	-	-	-	-	-	-	-
40 *Glyptotendipes* sp.	-	-	-	-	-	-	-	-	-	-	-	1	1	-
41 *Heterotrissocladius* sp.	9	6	1	10	5	16	-	-	-	-	1	1	2	-
42 *Micropsectra* sp.	5	5	-	-	-	-	1	-	1	-	-	-	-	-
43 *Procladius* sp.	10	10	1	1	1	3	-	-	-	-	1	-	1	-
44 *Psectrocladius* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45 *Trichocladius* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46 *Chelifera* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47 *Clinocera* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1
48 *Hemerodromia* sp.	1	-	-	-	-	-	-	-	-	-	-	-	-	-
49 Hymenoptera, adult (terr.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50 *Valvata sincera*	1	5	-	-	1	1	-	4	4	-	-	-	-	-
51 *Lymnaea* sp.	1	-	-	-	-	-	-	-	-	-	-	-	-	-
52 *Pisidium* sp.	21	16	-	-	4	4	-	2	2	2	2	-	4	-
Eggmass (undet.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Column Total	76	100	4	12	14	30	6	16	22	13	5	3	21	20
Total Number (N)	75	84	2	11	11	24	5	15	20	13	4	3	20	20
Diversity (H')	.89	.90	.30	.13	.50	.42	.58	.40	.58	.40	.45	.48	.65	.60

APPENDIX III TABLE 2 BOTTOM FAUNA DATA AT SAMPLING STATIONS (continued)

TAXONOMIC GROUP	STATION 18				STATION 21				STATION 22				STATION 23			
	A	B	C	TOTAL A,B,C	A	B	C	TOTAL A,B,C	A	B	C	TOTAL A,B,C	A	B	C	TOTAL A,B,C
1 Nematoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 Nais communis or variabilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 Enchytraeidae	9	5	9	23	-	-	-	-	-	-	-	-	-	-	-	-
4 Tubifex sp.	-	-	-	-	1	1	-	2	-	-	-	-	-	-	1	1
5 Limnodrilus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6 Telmatrodrilus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7 Rhyacodrilus coccineus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8 Eurycercus lamellatus	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-
9 Arachnida (terr.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10 Acari (undet.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11 Nemoura (Zapada) sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12 Prostoia sp.	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
13 Alloperla sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14 Cultus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 Kogotus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16 Ameletus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17 Baetis sp.	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
18 Ephemerella doddsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19 Cinygmula sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20 Epeorus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21 Rithrogena sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22 Hemiptera (terr.)	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
23 Agapetus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24 Rhyacophilia tucula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25 Drusinus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26 Cheumatopsyche sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27 Lepidoptera (terr. larvae)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX III TABLE 2 BOTTOM FAUNA DATA AT SAMPLING STATIONS (continued)

TAXONOMIC GROUP	STATION 18				STATION 21				STATION 22				STATION 23			
	A	B	C	TOTAL A,B,C	A	B	C	TOTAL A,B,C	A	B	C	TOTAL A,B,C	A	B	C	TOTAL A,B,C
28 Coleoptera, adult	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29 Diptera, adult	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
30 Tipula sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31 Pedicia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32 Simulidae, larvae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33 Chironomidae pupa	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
34 Cardiocladius sp.	-	-	-	-	1	3	3	7	-	-	2	2	-	2	-	2
35 Chironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36 Cricotopus sp.	2	-	-	2	-	-	1	1	-	-	-	-	-	-	-	-
37 Cryptochironomus sp.	-	-	-	-	-	2	3	5	1	-	1	2	-	1	-	1
38 Endochironomus sp.	-	-	-	-	1	-	-	1	-	-	-	-	3	-	4	7
39 Eukiefferiella sp.	-	-	-	-	-	3	1	4	-	-	-	-	-	-	-	-
40 Glyptotendipes sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41 Heterotrissocladius sp.	2	-	-	2	1	-	2	3	-	-	-	-	-	-	-	-
42 Micropsectra sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
43 Procladius sp.	-	-	-	-	3	1	8	12	4	1	18	23	6	11	13	30
44 Psectrocladius sp.	9	14	5	28	-	-	-	-	-	-	-	-	-	-	-	-
45 Trichocladius sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46 Chelifera sp.	-	-	-	-	-	1	-	1	-	-	1	1	-	-	-	-
47 Clinocera sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48 Hemerodromia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49 Hymenoptera, adult (terr.)	-	2	-	2	-	1	-	1	-	-	-	-	-	-	-	-
50 Valvata sincera	-	-	-	-	1	3	1	5	1	1	3	5	2	1	10	13
51 Lymnaea sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52 Pisidium sp.	-	-	-	-	5	8	3	16	-	-	1	1	-	1	3	4
Eggmass (undet.)	-	-	-	-	-	-	-	-	1	-	-	1	1	2	-	3
Column Total	23	22	17	62	14	23	22	59	7	2	26	35	12	18	31	61
Total Number (N)	13	14	7	34	12	21	22	55	6	2	26	34	11	16	31	58
Diversity (H')	.36	.00	.35	.30	.79	.79	.79	.91	.38	.30	.47	.47	.43	.45	.58	.60

APPENDIX IV

SEDIMENT DATA

APPENDIX IV TABLE 1 SEDIMENT DATA FOR SAMPLING STATIONS (all measurements are in mg/kg dry weight unless otherwise noted)

STATION	DEPTH m	CN w/w[1]	Al	As	Ba	Ca	Cd	Cr	Cu	Fe	Hg	Mg
1	-		13050		107.0	11010	<1.63	12.4	38.2	19700	<0.099	6030
2	-		17200		201.0	13600	<1.24	28.7	33.4	21200	<0.133	5200
3	-		18300		187.0	8750	<1.23	37.7	51.0	23900	0.140	7750
5	-		18500		215.0	10200	<1.21	36.5	46.0	27100	0.109	7450
6	26		21600		183.0	6000	<1.25	41.1	44.4	25700	0.110	10600
7	48		25300		282.0	6150	<1.23	41.5	65.5	40800	0.106	10500
8	18.5		30100		207.0	3720	<1.22	57.5	68.5	36500	0.149	8350
9	12		30600		224.0	4540	<1.23	61.0	67.0	38700	0.131	10100
10	32		30600		505.0	6000	<1.25	54.5	77.0	57500	0.177	8550
13	38		25500		273.0	5300	1.38	40.4	84.5	44000	<0.097	9200
14	8		12800		120.0	5350	<1.25	20.5	34.4	14300	<0.101	8750
15	38		22000		266.0	7825	<1.87	29.0	65.9	48250	<0.097	15700
18	-	4.72	6200		61.0	11600	33.4	15.9	26.2	64000	0.160	7400
19	-	1.58	403.0		11.0	2640	46.8	<1.86	32.8	245000	0.201	9650
21	5	13.0	25500		367.0	13095	<1.86	56.3	56.6	34250	0.094	>18550
22	5	53.2	6700		79.0	12300	149.0	17.6	70.5	93000	0.163	4920
23	5	7.02	17600		211.0	6300	38.3	35.8	65.5	48700	0.098	7200

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[1] w/w means wet weight. All other concentrations in this table are given in dry weight for the portion passing a 150 um sieve.

APPENDIX IV TABLE 1 SEDIMENT DATA FOR SAMPLING STATIONS (all measurements are in mg/kg dry weight unless otherwise noted) (continued)

STATION	DEPTH m	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Sr	Ti	V	Zn
1	-	505.0	<24.1	366.0	28.2	519.0	46.9	1725	<32.0	85.3	628.0	39.7	214.0
2	-	1080	<18.7	380.0	17.6	820.0	54.0	1890	<24.9	169.0	352.0	38.3	90.0
3	-	352.0	<18.4	385.0	30.9	700.0	56.0	2160	<24.5	78.5	460.0	55.0	92.0
5	-	790	<18.3	387.0	27.0	880.0	54.5	2800	<24.4	99.5	379.0	51.5	92.5
6	26	349.0	<18.7	438.0	32.4	845.0	69.5	2710	<24.9	48.3	476.0	62.5	93.0
7	48	1120	<18.5	505.0	39.6	1060	73.5	2490	<24.6	53.5	990.0	75.5	127.0
8	18.5	412.0	<18.3	715.0	49.1	1410	84.0	3090	<24.4	58.0	680.0	83.5	166.0
9	12	445.0	<18.5	615.0	55.5	1140	85.0	4020	<24.6	50.5	800.0	92.0	166.0
10	32	1020	23.7	805.0	44.7	2410	180.0	3150	<24.9	90.0	565.0	79.0	180.0
13	38	740.0	<18.7	444.0	44.9	1040	90.0	2570	<24.9	52.0	416.0	68.0	134.0
14	8	163.0	<18.7	48.7	20.0	281.0	38.4	1090	<24.9	26.9	225.0	36.2	61.0
15	38	1960	<28.0	213.5	33.7	869.5	79.6	2355	37.3	44.10	630	60.9	124.5
18	-	354.0	<18.6	94.5	18.9	153.0	1230	1120	<24.8	36.3	177.0	17.5	840.0
19	-	85.0	<18.6	<3.71	21.2	<37.1	3510	550.0	<24.8	12.8	2.96	<6.2	955.0
21	5	549.0	27.8	731.0	63.5	687.0	81	2325	37.10	64.0	1070	84.8	94.6
22	5	715.0	<18.4	162.0	24.0	575.0	3450	2050	<24.5	70.5	127.0	12.4	3450
23	5	720.0	<18.5	555.0	29.2	725.0	1400	1890	<24.7	43.3	520.0	48.5	920.0

APPENDIX IV TABLE 2 SEDIMENT PARTICLE SIZE ANALYSIS

STATION NUMBER	% COMPOSITION			
	>500 um	250-500 um	63-250 um	<63 um
1	24.4	27.5	40.0	8.1
2	5.5	13.6	65.4	15.5
3	16.4	18.4	75.2	24.5
5	62.3	6.8	22.7	8.2
6	23.4	26.9	36.3	13.4
7	33.9	25.7	28.3	14.2
8	61.7	13.2	19.2	5.8
9	18.3	37.6	39.0	5.2
10	37.1	22.7	27.9	12.3
13	12.0	17.3	65.1	5.7
14	24.2	35.7	39.6	0.40
15	4.6	9.0	65.1	21.3
18	21.5	26.1	44.8	7.6
19	23.2	14.0	58.8	4.1
21	90.7	4.9	3.8	0.70
22	0.90	3.3	60.7	35.1
23	73.7	12.6	8.8	5.0