Environment Canada
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Pacific Region
Yukon Branch

A BIOLOGICAL AND WATER QUALITY ASSESSMENT AT A PLACER MINE ON LITTLE GOLD CREEK, YUKON TERRITORY

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by

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ABSTRACT

An assessment of water quality and biological conditions at a placer gold mine site on Little Gold Creek was carried out during the period June to September, 1982. The water quality, sediment and bottom fauna characteristics were documented at five sample stations.

Water quality parameters were seen to be dramatically influenced by activity at the placer mine. During periods of sluicing activity elevated values were observed at downstream stations for suspended sediments (NFR), settleable solids, filterable residue, turbidity, and the extractable heavy metals. Dissolved oxygen levels and pH values were lower at downstream locations during sluicing.

Sediment composition of the stream bottom was seen to increase in percent of fine sands, silts and at downstream locations during sluicing. These fine sediments were seen to have lower extractable heavy metal values than the more coarse sediments of the control station. This was attributed to the larger, and heavier metal bearing particles being deposited in the settling pond system. Stream bottom composition was observed to return to a composition more typical of the control station after extended periods of no sluicing activity.

Bottom fauna abundance and diversity was determined. Diversity indices indicate that stations subjected to the influence of the placer mine activity had lower diversity and fewer organisms than the control. The composition of benthic invertebrates changed from a community dominated by members of the Ephemeroptera and Plecoptera at the control station to a community dominated by members of the Diptera at stations subject to the influence of the placer mining activity.

RESUME

Une évaluation de la qualité et des conditions biologiques de l'eau d'une exploitation d'extraction d'or, a eu lieu sur le Little Gold Creek, Territoire du Yukon, durant la période de juin à septembre 1982. La qualité de l'eau, les caractéristiques des sédiments et de la faune benthique ont été analysées à cinq stations d'échantillonnage.

Les différents paramètres de qualité des eaux, semblent profondément influencés par l'activité de l'exploitation du "placer". Durant la période de "sluicing" des hausses de la quantité de solides en suspension, solides sédimentables, résidus filtrables, turbidité et métaux lourds extractables, ont été observées aux points d'échantillonnage en aval de l'exploitation. Les niveaux d'oxygène dissous et de pH furent plus bas, à ces même points, à la même période.

Il semble y avoir une augumentation du pourcentage de sable fins et de silts dans la composition des sédiments en aval des opérations minières. Ces sédiments fins semblement avoir une plus faible valeur en métaux lourds extractables que les sédiments plus grossiers de la station de contrôle. Ceci s'explique par la sédimentation des particules plus grosses et porteuses de métaux lourds lors de leur passage dans le bassin de décantation. Il a été observé que la composition du fond du ruisseau tend à retourner à une composition plus typique, ressemblant à la station de contrôle, après une période prolongée exempte d'activités minières.

L'abondance et la diversité de la faune benthique ont été déterminées. Les stations sujettes à l'influence des activités d'extraction d'or présentant des indices de diversité plus faibles et une abondance réduite comparativement à la station de contrôle. La composition des organismes benthiques change d'une communauté dominée par des Ephéméroptères et Plécoptères, à la station de contrôle, pour un communauté dominée par des Diptères aux stations sujettes à l'influence des activités de l'exploitation du "placer".

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1 INTRODUCTION

The Environmental Protection Service conducted a study of water quality, sediment composition and bottom fauna in the watershed of Little Gold Creek in the Sixty Mile River area (Figure 1) The information derived from the study enables the assessment of the quality of the stream in the vicinity of a placer mining operation. Sampling occurred on six separate dates in 1982: June 26, July 7, July 20, August 10, September 2 and September 23.

1.1 Background

Gold was discovered in the Sixty Mile River district in 1892, four years before the Klondike Gold Rush. The major discovery was found by C. Miller on Miller Creek, and subsequent discoveries were made at Glacier Creek and Big Gold Creek (Sabina 1979). Aside from the Forty Mile River district gold rush, the Sixty Mile River goldfields were the second major gold discovery in the Yukon at this time.

In the early days, Little Gold Creek was extensively prospected but was generally considered too poor to work. The gold was distributed uniformly in a narrow and continuous streak, which was nowhere very rich. Heavy boulders made successful mining there difficult (Cockfield 1921).

According to mining records for the Sixty Mile River district, some of the individuals who staked and worked various claims on the property of Little Gold Creek were: D.W. McLeod 1920-1923, F. Hurst 1919-1920, J.J. Biebold 1920-1921, William A. Williams 1933, J.E. Clark representing Terra Mines Ltd. 1953-1956. Most recently, however, was a company with an extensive operation on Little Gold Creek, downstream of the present study, during the 1980-1981 season.

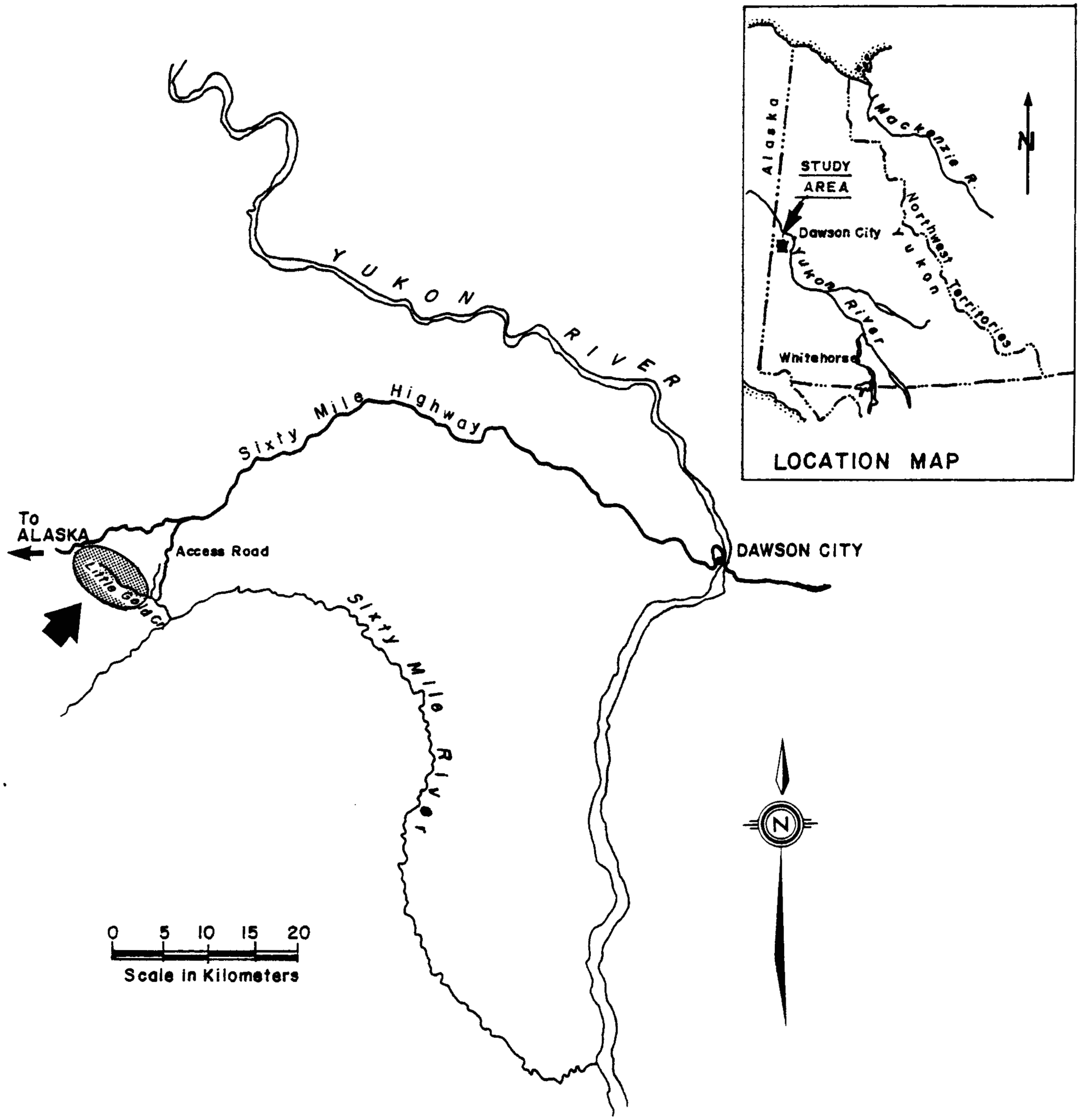


FIGURE 1 LOCATION OF LITTLE GOLD CREEK STUDY AREA

2 STUDY AREA

The mining operation on Little Gold Creek is located 40 air miles west of Dawson City at 64°05'N, 140°50'W. It is connected by an access road which leaves the Sixty Mile Highway at km 84 west of Dawson City (see Figure 1).

The access road, much of which is above tree line lies on the crest of a long flat-topped ridge which separates the Yukon River and Forty Mile River to the north from Swede Creek and the Sixty Mile River to the south. The ridges are of fairly uniform elevation and are dissected into a maze of deep, gently curved, V-shaped valleys whose floors are 450-900 m below the crests (Sabina 1979).

Little Gold Creek is a 9.5 km long tributary of Big Gold Creek, which in turn is a tributary of the Sixty Mile River (Figure 2). The elevation of the property ranges from 810 m at the bottom to 860 m at the top of the study area.

Sampling stations were selected to include; an upstream control, sluice box effluent , final settling pond effluent, and two sites several hundred metres downstream, (see Figure 2). The sample sites are described in Table 1 and illustrated in photographs, Figures 3 to 12.

2.1 Description

During the period of study, a three-man placer mining operation was working the upper reaches of Little Gold Creek on claims 13800-13820. In 1982 the company operated with a Water Use Authorization under the Northern Inland Waters Act (NIWA). The Authorization was for 200-450 litres per day (45-100 IGPD) for the camp and 9000 litres per minute (2000 IGPM) for the mining operation during sluicing hours. Water used for sluicing operations was discharged to two settling ponds and eventually to Little Gold Creek.

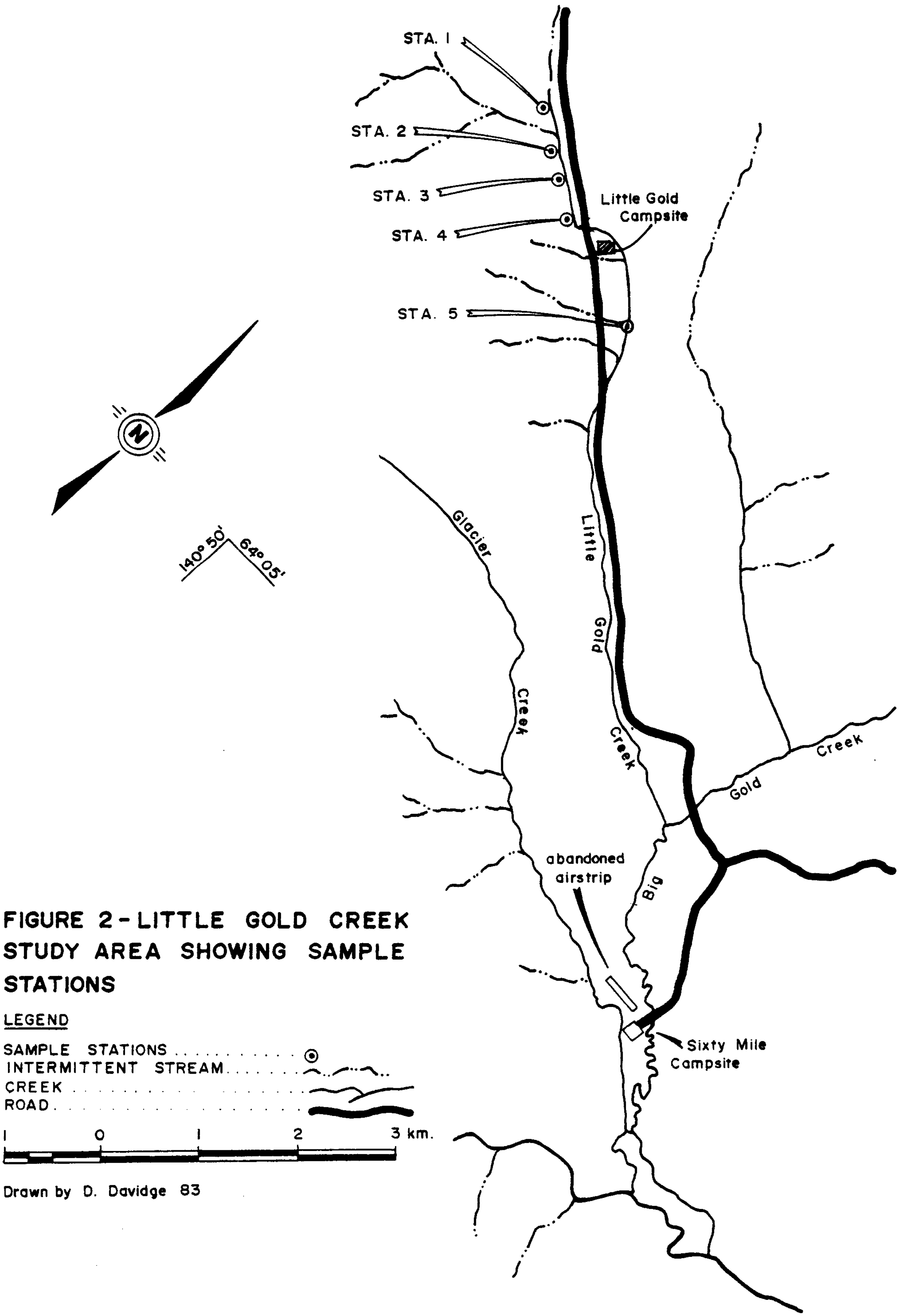


FIGURE 2 - LITTLE GOLD CREEK STUDY AREA SHOWING SAMPLE STATIONS

TABLE 1 DESCRIPTION OF SAMPLE SITES IN THE STUDY AREA

STATION	LOCATION	STREAM BOTTOM	REMARKS
1	64°04'N 141°54'W on Little Gold Creek 0.8 km upstream from the mining operation and 7.7 km upstream of its confluence with Big Gold Creek. Elevation 860 m (2820 ft).	Gravel and coarse sand. Patches of rust and brown colour in some places.	Stable banks. Vegetation consists of black spruce, willows and grasses. No fish were obtained from electrofishing. 50% shade.
2	64°04'N 141°54'W. Sluice box effluent. Ground seepage and direct run off from sluicing operation. 0.9 km downstream of Station 1. Elevation 850 m (2790 ft).	N/A	Water is very turbid during sluicing hours.
3	64°04'N 141°53'W. Located in the effluent discharge channel of the second settling pond. Elevation 845 m (2775 ft).	N/A	Mine effluent decant from tailings pond. Plastic overlay on spill way below tailings pond. Stream disturbed by mining operation. 0% shade.
4	64°04'N 141°52'W on Little Gold Creek 300 m below the second tailings pond (Station 3). Elevation 840 m (2756 ft).	Large boulders and cobbles interspersed with gravel and sediment.	Stable banks. Vegetation consists of buckbrush and grasses. No fish were obtained from electrofishing. 0% shade.
5	64°03'N 141°51'W on Little Gold Creek 1.1 km downstream of Station 4. Elevation 810 m (2657 ft).	Small cobbles with gravel, sand and sediment cemented together. Some bedrock showing.	Stable banks. Vegetation consists of willows, grasses and moss. No fish were obtained from electrofishing. 0% shade.

FIGURE 3 OVERVIEW OF PLACER MINING OPERATION AT LITTLE GOLD CREEK. JUNE 25, 1982.

FIGURE 4 FIRST SETTLING POND. NOTE CREEK DIVERSION ON THE EXTREME UPPER LEFT SIDE OF PHOTO.

FIGURE 5 DOWNSTREAM VIEW OF LITTLE GOLD CREEK VALLEY. NOTE STRIPPED AREA WITH PAYDIRT IN THE CENTRE OF THE PHOTO READY TO BE SLUICED. JULY 7, 1982.

FIGURE 6 DOWNSTREAM VIEW OF LITTLE GOLD CREEK. OVERVIEW OF THE VALLEY NEAR THE END OF THE OPERATING SEASON. SEPTEMBER 2, 1982.

FIGURE 7 STATION 1. CONTROL STATION, LOCATED IN AN UNDISTURBED SECTION OF LITTLE GOLD CREEK. UPSTREAM OF THE PLACER MINING OPERATION. SEPTEMBER 2, 1982.

FIGURE 8 STATION 1. RELOCATED 70 m UPSTREAM FROM THE ORIGINAL STATION SITE DUE TO DISTURBANCE TO THE STREAM BED. SEPTEMBER 23, 1982.

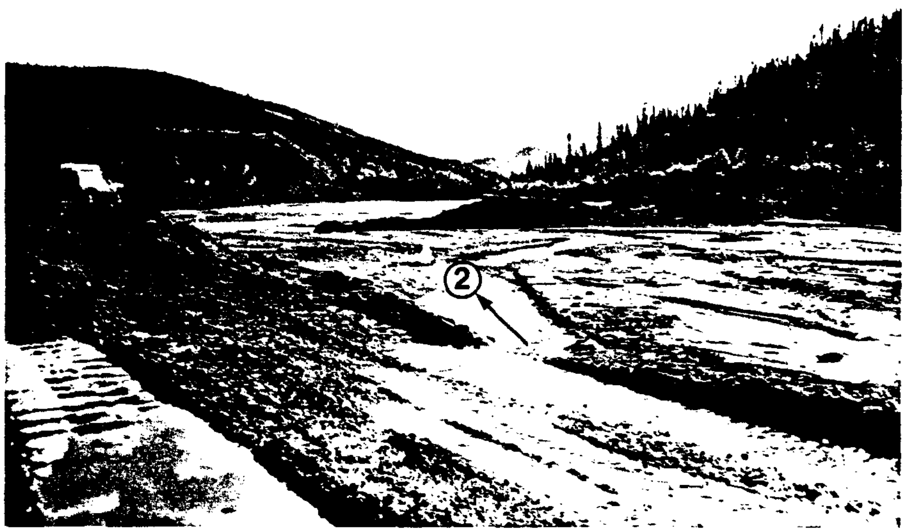


FIGURE 9 STATION 2. SAMPLING MINING EFFLUENT BEFORE REACHING THE FIRST SETTLING POND. VIEW DOWNSTREAM.

FIGURE 10 STATION 3. LOCATED IN THE EFFLUENT DISCHARGE CHANNEL OF THE SECOND SETTLING POND.

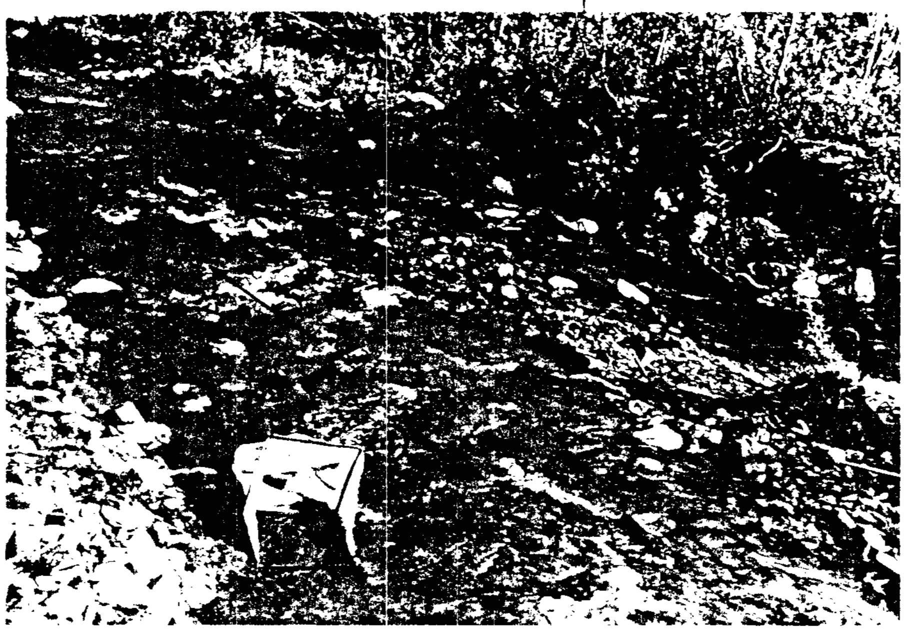


FIGURE 11 STATION 4. LITTLE GOLD CREEK, 300 m DOWNSTREAM FROM STATION 3.

FIGURE 12 STATION 5. LITTLE GOLD CREEK, 1.1 km DOWNSTREAM FROM STATION 4. VIEW DOWNSTREAM.

The method of mining involved stripping overburden and storing it along the edge of the valley, removing and stockpiling paydirt for sluicing and feeding the paydirt through the sluice box. The equipment on site consisted of a crawler tractor (D8 Cat), a front end loader (John Deere Model A 448), a three channel Ross sluice box (Model 200) and a 150 h.p. pump. The volume of material stripped and mined for 1982 was estimated by the operators to be 95,569 m^3 (125,000 yd^3).

The method for handling the tailings involved moving the coarse tailings materials to the side of the site for disposal or possible rewash. The effluent was routed to settling ponds to settle out some of the finer sediment particles. The coarse gravel tailings piles were flattened and fanned out along the base of the valley slope as the operation progressed upstream. During the course of the operation Little Gold Creek was relocated to one side of the valley to by pass the operation, re-entering the main channel below the second settling pond. Water for sluicing was diverted from the stream into a storage pond and during sluicing this was supplemented by makeup water recirculated from the first settling pond. Water for sluicing was pumped upstream from the storage pond through an approximate 10" pipe to the sluice box.

2.2 Mineralization Description

Little Gold Creek originates about two miles east of the Alaska Boundary. It originates in a number of steep walled, narrow gulches and near its head the grade is steep but in the lower reaches it gradually flattens out, approximately 1.4 cm per m (1.4% gradient).

Metamorphic rock is dominant at Little Gold Creek and forms what is known as the Yukon Group. These are the oldest rocks in the district and from evidence are referred to as Precambrian. They have been subdivided into a number of series, the oldest being composed of sheared and metamorphosed clastics now represented by gneissoid quartzites, quartz-mica, mica and graphitic schists, sheared and mashed conglomerates and crystalline limestone (Cockfield 1921).

Quartz veins are abundant in the metamorphic rocks of the Yukon Group but are nearly always small and non-persistent. They follow very closely the planes of foliation of the schists, and in the majority of cases are apparently barren of minerals but in some cases iron minerals, galena (PbS) and zinc blend are found. Pyrite (FeS_2) is generally absent and the amount of sulphides (SO_2) is very small (Cockfield 1921).

3 METHODS

Each station was sampled six times over the period of the summer. The sampling dates were June 25, July 7, July 20, August 10, September 2 and September 23, 1982.

3.1 Water Quality

Water samples were collected and preserved as described in Appendix 1, Table 1 at each of Stations 1, 3, 4 and 5. At Station 2, samples were collected for non-filterable residue (NFR) only.

Temperature, conductivity and pH were measured in the field using a Yellow Springs Instrument direct-reading salinity-conductivity-temperature meter and a Model 296 Radiometer pH meter. Stream discharge (flow) was measured by using a Price-type current meter. Dissolved oxygen was analyzed using the Winkler Azide modification. Settleable solids were collected as grab samples and analysed in the Environmental Protection Service Whitehorse Lab a few days later using an Imhoff cone and allowing one litre of well mixed sample to settle for one hour. Non-filterable residues were collected in duplicate. One sample was analyzed within a few days in the Whitehorse Lab and the second sample was sent to the E.P.S. Vancouver Lab, 4195 Marine Drive, West Vancouver, B.C. All other analyses were performed by the E.P.S. Vancouver Lab. These included turbidity, colour, total hardness, filterable residue, total alkalinity, total phosphates, nitrates, nitrites, ammonia, sulfate, chloride and the following extractable metals:

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

The percent dissolved oxygen saturation (% DO) was calculated by first determining the dissolved oxygen saturation concentration (S') from the formula:

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

where S' = dissolved oxygen (DO) saturation concentration at the in situ temperature and atmospheric pressure

S = dissolved oxygen (DO) saturation concentration at sea level for in situ temperature

P = atmospheric pressure in mm of mercury (mm Hg) at site elevation

The percent dissolved oxygen saturation was obtained by using the ratio of field dissolved oxygen and S' in the following formula:

$$\frac{\text{Field DO}}{S'} \times 100 = \text{\% DO Saturation}$$

where Field DO = Dissolved Oxygen concentration measured in the field

3.2 Sediments

Sediment samples were collected at the same time as water samples at Stations 1, 4 and 5. Sediment samples were collected on July 7, July 20, August 10, September 2 and September 23, 1982. Sediments were not collected at Stations 2 and 3 as Station 2 was a sluice box discharge station, and Station 3 was a settling pond effluent station. Three sediment samples were collected at each site using an aluminum shovel to scoop the samples into labelled Whirl Pak bags. A description of sediment collection, preparation and analysis methods is given in Appendix I, Table 2. All sediment samples were shipped to Vancouver by air for analysis at the E.P.S. Lab. Each of the three sediment samples collected at each station were analyzed for particle size and the following leachable metals:

Aluminum (Al)	Copper (Cu)	Potassium (K)
Arsenic (As)	Iron (Fe)	Silicon (Si)
Barium (Ba)	Lead (Pb)	Silver (Ag)
Beryllium (Be)	Magnesium (Mg)	Sodium (Na)
Boron (B)	Manganese (Mn)	Strontium (Sr)
Cadmium (Cd)	Mercury (Hg)	Tin (Sn)
Calcium (Ca)	Molybdenum (Mo)	Titanium (Ti)
Chromium (Cr)	Nickel (Ni)	Vanadium (V)
Cobalt (Co)	Phosphorus (P)	Zinc (Zn)

3.3 Bottom Fauna

Bottom fauna samples were collected at the same time as water and sediment samples at Stations 1, 4 and 5 on six separate sampling dates. Sluicing discharge and settling pond effluent, Stations 2 and 3 respectively, were not sampled for bottom fauna. Three samples were collected at each station using a 30 cm x 30 cm Surber sampler (900 cm^2 or 1 ft^2) with a mesh size of 0.76 mm. Bottom fauna collection, preservation and identification methods are given in Appendix 1, Table 3.

Diversity indices were calculated from the bottom fauna data collected, using the formula described by Pielou (1975) as follows:

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

where $P_i = n_i/N$

n_i = total number of individuals in the ith genus in one sample

N = total number of individuals identified to genus level.

g = total number of genera in one sample

The use of individuals identified to genus level instead of to species level results in slightly lower diversity indices (H') values (Hughes, 1978).

3.4 Fish

Electrofishing of the creek at Stations 1, 4 and 5 was conducted in order to obtain tissue samples for metal analysis, but no fish were found. Notes were made on whether sample streams looked suitable for fish habitat.

4. RESULTS AND DISCUSSION

The results for the different parameters measured generally are seen to be greatly influenced by the mining, particlarly sluicing, activity at the mine site. It is therefore important to note that sluicing activity was ocurring during the sampling periods on July 20 and September 23 only. During sampling on the other dates active sluicing was not underway and may not have been underway for several days preceding sampling.

4.1 Water Quality

Table 4 in Appendix 1 lists the accepted water quality criteria for drinking water and aquatic life with the appropriate reference sources. The water quality results are presented in their entirety in Appendix II whereas the following results and discussion with accompanying graphs concentrates on those parameters considered important to water quality and affected by the placer mining activity.

4.1.1 Heavy Metals

The following heavy metals, illustrated in Figures 13 and 14, are significantly affected downstream on Little Gold Creek by placer mining activity:

Arsenic (As)	Manganese (Mn)
Copper (Cu)	Nickel (Ni)
Iron (Fe)	Lead (Pb)
Mercury (Hg)	Zinc (Zn)

Water analysis for extractable heavy metals reveal significant increases due to sluicing on July 20 and September 23 when compared to non-sluicing times and the control station.

Arsenic levels ranged from 0.0095 mg/l and 0.0067 mg/l at Stations 4 and 5 on July 20 to 0.0075 mg/l and 0.0052 mg/l at Stations 4 and 5 on September 23. Although arsenic levels downstream increased

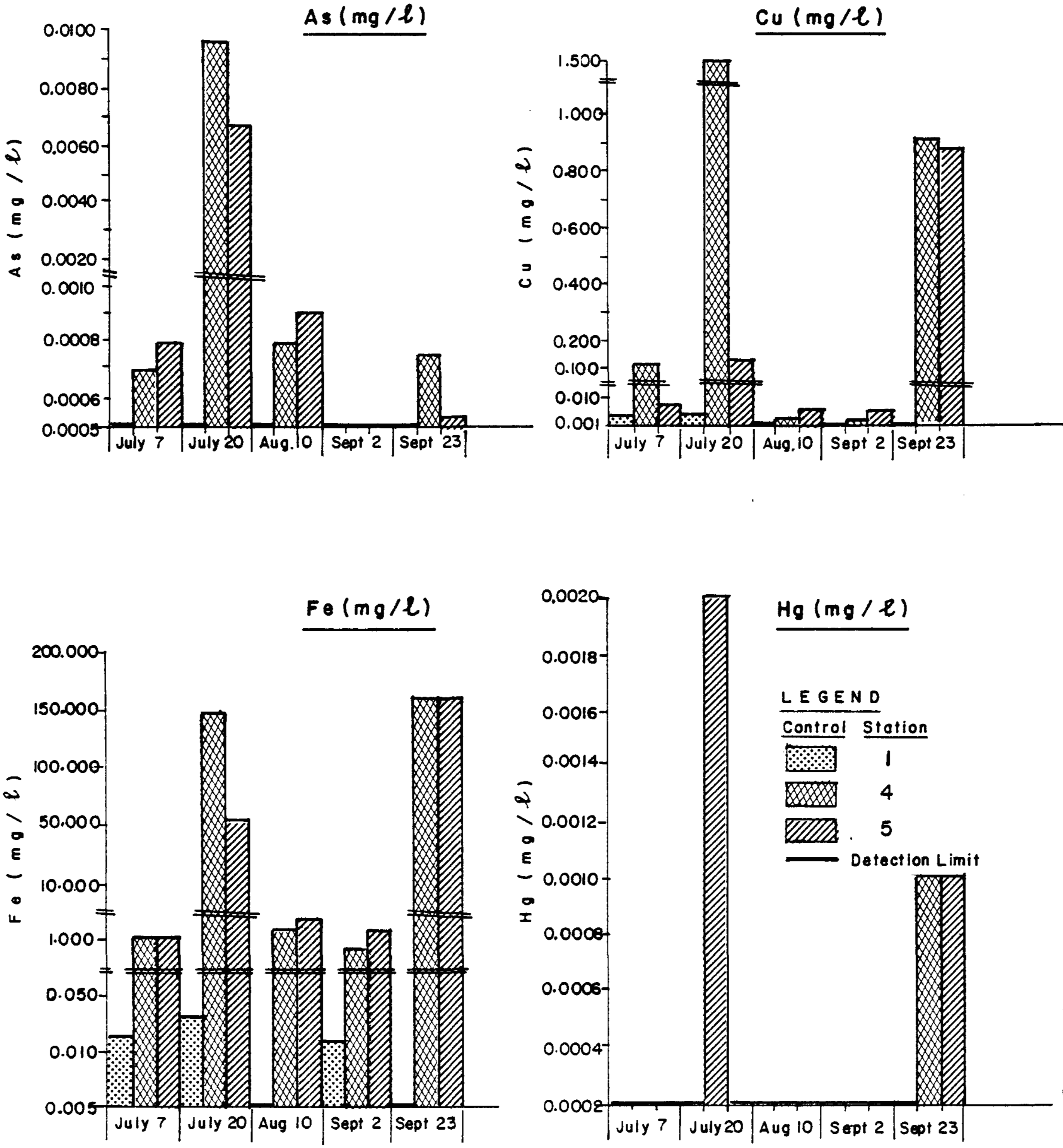


FIGURE 13 HEAVY METALS IN WATER
(Origin of Y-axis equals Detection Limit)

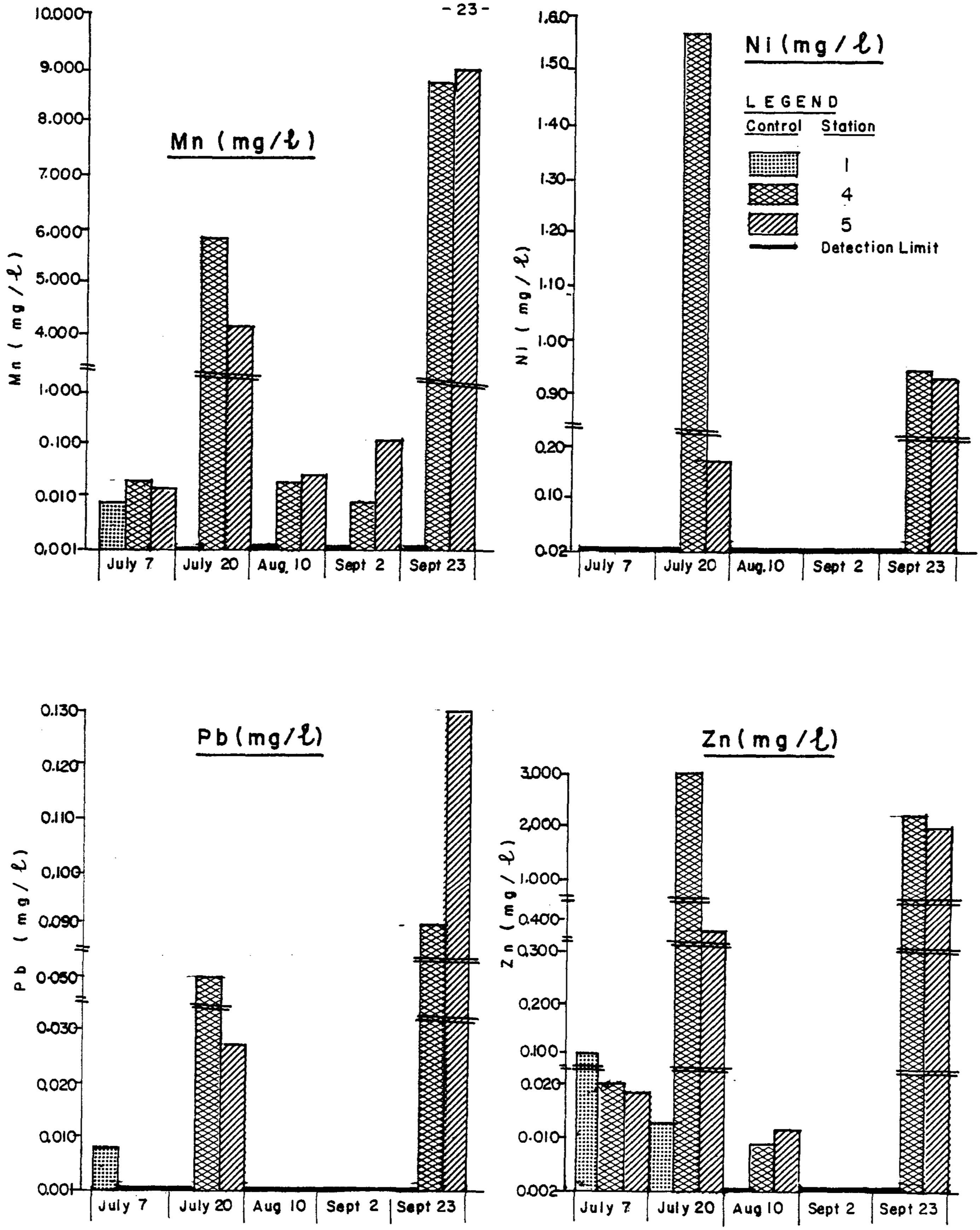


FIGURE 14 HEAVY METALS IN WATER
(Origin of Y-axis equals Detection Limit)

between 10 and 20 times from the upstream levels, they were still within recommended limits for drinking water and aquatic life.

Copper levels dramatically increased as a result of mining, and on both sluicing dates were above recommended limits for drinking water and aquatic life. This increase was as much as 370 times greater than upstream values.

Iron levels also exceeded both recommended limits at downstream stations. Levels of 148 mg/l and 51.3 mg/l were found at Stations 4 and 5 on July 20, and 167 mg/l at Stations 4 and 5 on September 23. High levels of iron found downstream were probably attributable to iron pyrite present in the ore body.

Mercury levels exceeded recommended limits for aquatic life (0.0001 - 0.0002 mg/l) at Station 4 on July 20, with a value of 0.0020 mg/l and at Stations 4 and 5 on September 23 with values of 0.0010 mg/l.

Levels for manganese were found to be dramatically increased at both downstream stations on July 20 and September 23. Values of 5.85 mg/l and 4.22 mg/l at Stations 4 and 5 exceeded the recommended limits for drinking water and aquatic life, as did values of 8.79 mg/l and 9.0 mg/l found at Stations 4 and 5 on September 23.

Nickel also exceeded both drinking water and aquatic life standards downstream of the mining operation. Levels of 1.5 mg/l and 0.17 mg/l were demonstrated at Stations 4 and 5 on July 20 and 0.94 mg/l and 0.93 mg/l at Stations 4 and 5 on September 23.

Lead levels of 0.050 mg/l and 0.027 mg/l were found at Stations 4 and 5 on July 20, and 0.090 mg/l and 0.130 mg/l at Stations 4 and 5 on September 23. These levels were noted to be approximately 50 - 100 times greater than at upstream stations and were also greater than recommended levels for drinking water and healthy aquatic life.

Zinc also demonstrated high values that exceeded both recommended limits. These values were 2.96 mg/l and 0.344 mg/l at Stations 4 and 5 on July 20 and 2.10 mg/l and 1.99 mg/l at Stations 4 and 5 on September 23. A zinc value of 0.110 mg/l was found at Station 1 (Control Station) on July 2, but values downstream were much lower, therefore the validity of this value was questionable. Other heavy metals that increased as a result of mining activity included Aluminum (Al), Cadmium (Cd), Magnesium (mg), Barium (Ba), and Chromium (Cr). These values are presented in Appendix II.

4.1.2 Suspended Sediments (Non-Filterable Residue - NFR)

All suspended sediments were collected by grab sample and analyzed at the E.P.S. Whitehorse Laboratory two to four days after collection. Duplicate samples were also analyzed at the EPS Laboratory in Vancouver as a cross reference for quality control and corresponded very closely with the results of the E.P.S. Whitehorse Laboratory. The results presented are those determined in the E.P.S. Whitehorse lab.

Suspended sediments can be defined as "any particulate matter suspended in water that is retained by a 0.45 micron filter or a filter of defined pore size. The term is also synonymous with non-filterable residue (NFR)" (Dept. of Environment, 1979). Suspended sediments are comprised of sand, silt, clay and detritus, and are usually the major cause of concern in water with regard to a placer mining operation. Griffiths and Walton (1978) summarize the direct and indirect effects of sediment on fish. The direct effects are: (1) mortality of adult fish as a result of mechanical and abrasive damage; (2) impairment of reproduction, growth and survival; and (3) increase of disease within a population. The indirect effects result from: (1) habitat modifications; (2) alterations in food sources and other biotic relationships; and (3) reduction of visibility.

Good discussions of the effects and potential effects of suspended sediments on fish, the aquatic habitat and bottom invertebrates have been presented by Pickral (1981), Griffiths and Walton (1978), Cordone and Kelley (1976), and Rosenberg and Snow (1975).

Water quality with regard to suspended sediments in the upper reaches of Little Gold Creek is relatively pristine and indicates low levels, less than 5 mg/l, of suspended sediments. On August 10, 1982, Station 1 exhibited a suspended sediment level of 20 mg/l but this is still regarded as being very low and could have been due to rainfall or bank sloughing. Very high values for suspended sediments were found at downstream stations on the two sluicing dates, July 20 and September 23.

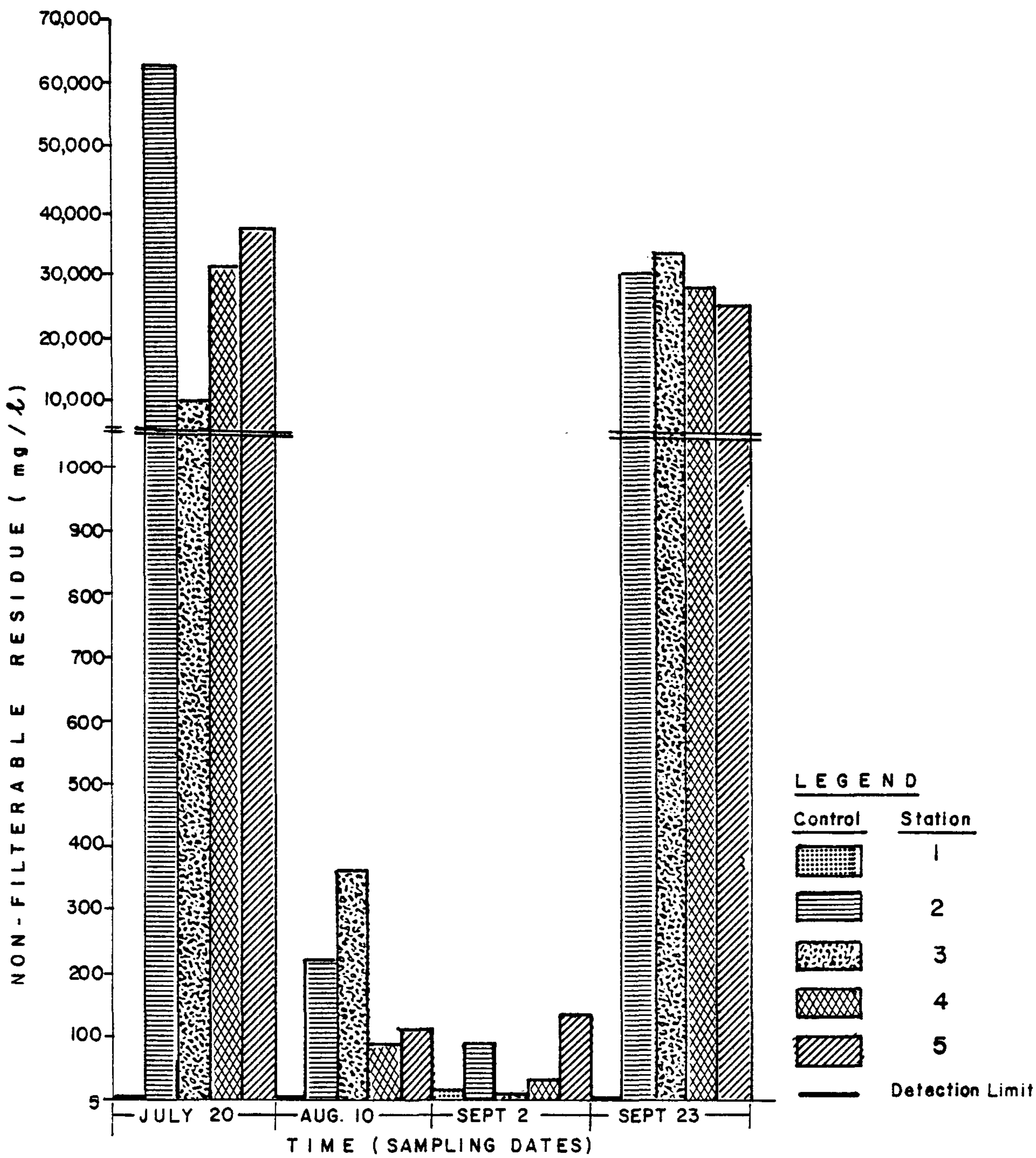


FIGURE 15 NON-FILTERABLE RESIDUES
(Origin of Y-axis equals Detection Limit)

Suspended sediments measured as high as 62,000 mg/l and 37,000 mg/l at Station 2 and Station 5 respectively on July 20 and 30,000 mg/l and 25,000 mg/l at Stations 2 and 5 on September 23 as shown in Figure 15. These results also show by comparing values at Station 2 and Stations 4 and 5 that the settling ponds were not functioning well on these dates.

During sampling times on August 10 and September 2 active sluicing was not occurring and the suspended sediment levels at downstream stations all exhibited greatly reduced values as compared to sluicing times, although values at all stations were higher on August 10 which corresponds with a period of high rainfall preceding this sampling time. The values at Stations 3, 4 and 5 in particular suggest these are the background levels that would be expected as a result of the terrain disturbance alone from "non-point source" erosion.

Suspended sediment levels influence or may influence other water quality parameters such as turbidity, colour, settleable solids, and dissolved oxygen. These parameters and others are described in the following section.

4.1.3 Other Water Quality Parameters

The results for other water quality parameters that were noticeably different between upstream and downstream stations and probably influenced by placer-mining are provided below. A groundwater source below the sampling area was noted and it is possible that undetected groundwater sources were entering the stream between upstream and downstream stations which could influence the values of the parameters analyzed. The values for these parameters, in many cases, exceeded drinking water standards or recommended levels for aquatic life. The parameters include dissolved oxygen saturation, settleable solids, filterable residues, colour, total hardness, phosphorus, nitrite (NO_2-N) and ammonia (NH_3-N). Results for these and other parameters are provided in Appendix II.

a) Temperature. The results show a general marked increase between Station 1 and Station 5 although there is no clear pattern in relation to sluicing versus non-sluicing times. The general downstream increase from 6.0°C to 11.0°C on July 7, and 4.7°C to 9.0°C on July 20 can be explained by the fact that the operation had a large storage pond to provide adequate water for prolonged sluicing and because during sluicing there was a high percentage of the sluicing water recirculated. The greatest temperature difference between upstream and downstream stations occurred in mid-season when the warming of ponded water would be greatest whereas at the beginning and end of the season the upstream and downstream temperature differences were greatly reduced.

b) pH. During sluicing the pH dropped slightly from 7.2 at Station 1 to 6.7 at Station 4 on July 20 and from 7.8 at Station 1 to 7.0 and 7.1 at Stations 4 and 5 on September 23.

c) Dissolved Oxygen (DO). Slight decreases in dissolved oxygen were noted at all downstream stations as compared to the Station 1 control. The most significant drop occurred during the sluicing period on July 20 at which time the DO ranged from 11.4 mg/l at Station 1 to 9.9 mg/l and 9.8 mg/l at Stations 4 and 5 respectively. The reduction in DO levels at downstream locations is not surprising because of the high organic content of the surface materials and resulting organic materials in the water from sluicing and runoff which create an oxygen demand. Ground water, if entering the stream in these areas, could also reduce DO levels. The DO levels however remained well above minimum levels recommended for aquatic life. The percent saturation for DO which is directly related to the actual concentration, is used as the reference standard for this parameter. Dissolved oxygen saturation did not meet the drinking water standard at any of the downstream stations except on July 7 which corresponds with the fact that mining activity did not influence these stations until after that date. It should also be noted that percent DO saturation was irregular at the control station during the season and was at 100% saturation on only two of the five sampling dates. Under the conditions present in this stream reach, the decrease in percent DO saturation is not great although it was detectable on sluicing dates, and could be influenced by ground water sources.

d) Turbidity. Increased turbidity generally exists in water when an increased surface area of silt and clay particles reflect more light than would larger sand particles (Talkema 1983). Because turbidity is directly related, though not necessarily linear, with suspended sediments it was found, as expected, to be greatly elevated at downstream stations on July 20 and September 23. Values as high as 32,500 FTU (Formazin Turbidity Units) and 650 FTU occurred at Stations 4 and 5 respectively on July 20 and 26,800 FTU and 26,000 FTU at Stations 4 and 5 on September 23. These values compare with values less than 1.0 and typically 0.1 at the Station 1 control. Downstream values at Stations 4 and 5 during non-sluicing times range between 4.7 and 28.0 FTU indicating turbidity resulting from non-point sources at the operation.

e) Settleable Solids. Settleable solids are commonly defined as "any particulate matter in suspension that will settle out of suspension in a standard unit of time" (Dept. of Environment, 1979). Settleable solids levels, as expected, followed the same pattern as suspended sediments and were found to be greatly increased at Stations 4 and 5 during sluicing times on July 20 and September 23. A value greater than 40 ml/l was found at Station 2 on June 25. This was not a sluicing time therefore the cause of this high level cannot be explained. All other values for settleable solids ranged from less than 0.1 ml/l to 0.5 ml/l.

f) Filterable Residue. Filterable residue (FR), also known as dissolved solids, was found to be within limits for drinking water and recommended levels for aquatic life except at Station 4 on September 23. On this date it was found to be 3040 mg/l. All other downstream values ranged from 132 mg/l to 168 mg/l FR, therefore it is questionable whether the one value is accurate or due to error.

g) Colour. Colour exceeded recommended levels for drinking water by demonstrating values greater than 100 colour units at Stations 4 and 5 on July 20. Colour measurements were not analyzed for September 23 due to high turbidity interferences. High values for colour were due to increased concentrations of organic matter introduced to water from the stripping process.

h) Hardness. Relatively low levels of total hardness were noted throughout the sampling period. Values ranged from 43-82 mg/l $CaCO_3$ at Station 1 to 108-149 mg/l $CaCO_3$ at Stations 4 and 5. There was however a pronounced increase at Stations 4 and 5 on July 20 and September 23 due to sluicing. Hardness concentrations as high as 2470 mg/l $CaCO_3$ and 466 mg/l $CaCO_3$ were found at Stations 4 and 5 on July 20, and levels of 1840 mg/l $CaCO_3$ and 1900 mg/l $CaCO_3$ at Stations 4 and 5 on September 23. These results clearly exceeded the criteria required for drinking water.

i) Phosphorous (as PO_4). High levels of phosphorus were observed at these same stations during sluicing. Levels of 72.6 mg/l and 3.20 mg/l at Stations 4 and 5 for July 20, and 37.2 mg/l and 33.0 mg/l for Stations 4 and 5 on September 23. On both of those dates values exceeded drinking water standards and recommended levels for aquatic life. Values at the control station were .01 mg/l or less while values at Stations 4 and 5 during non-sluicing times was in the range of 0.076 mg/l to 0.133 mg/l.

j) Nitrites and Ammonia. Nitrite and ammonia measurements also exceeded drinking water standards, and ammonia exceeded recommended levels for aquatic life. Nitrite values ranged from 0.025 mg/l at Stations 4 and 5 on July 20, to values of 0.042 mg/l and 0.039 mg/l at Stations 4 and 5 on September 23. The detection limit for nitrite (0.005 mg/l) is greater than the recommended drinking water limit (0.001 mg/l), but all stations except those affected during sluicing periods were less than the detection limit. Ammonia did not exceed recommended levels for drinking water, however it did exceed levels for aquatic life on both sluicing dates. These ranged from 0.040 mg/l and 0.036 mg/l at Stations 4 and 5 on July 20, to 0.145 mg/l and 0.125 mg/l at Stations 4 and 5 on September 23.

k) Conductivity, sulphate, nitrate and alkalinity were all within recommended levels for drinking water and aquatic life. It is worth noting that conductivity increased at downstream stations relative to the control on all sampling dates.

4.2 Sediments

Sediment samples were collected at Stations 1, 4 and 5 on each of the sampling dates and subsequently analyzed for particle size composition and leachable metals. No sediment samples were collected at Stations 2 and 3. When analyzing and discussing the results of sediment analysis it is necessary to be aware of the variability that can occur among replicate samples due to natural variations in stream bottom composition. Despite the limitations on interpretation the data shows the effects of sluicing on sediment composition and sediment chemistry at downstream stations compared to the control, and this can be related to the effectiveness of the settling ponds.

4.2.1 Sediment Particle Size Analysis.

Results of the sediment particle size analyses are given in Appendix III, Table 1. Illustrations of particle size in terms of percent composition can be found in Figures 16 and 17. It should be noted that Station 1 was relocated 70 m upstream on September 23 because the previous location was disturbed by mining activity. This accounts for the different particle size distribution for the control station on September 23.

Increased levels of silts and clays occurred downstream of the mining activity throughout the operating season. Sluicing time was estimated by the operator as 250 hours between June and September. Especially high concentrations of fine silts and sands were found at Stations 4 and 5 on two sampling dates when sluicing occurred, which were July 20 and September 23. During these two periods, percent composition of silts and fine sand (75 um to 350 um) exceeded 85% at downstream stations.

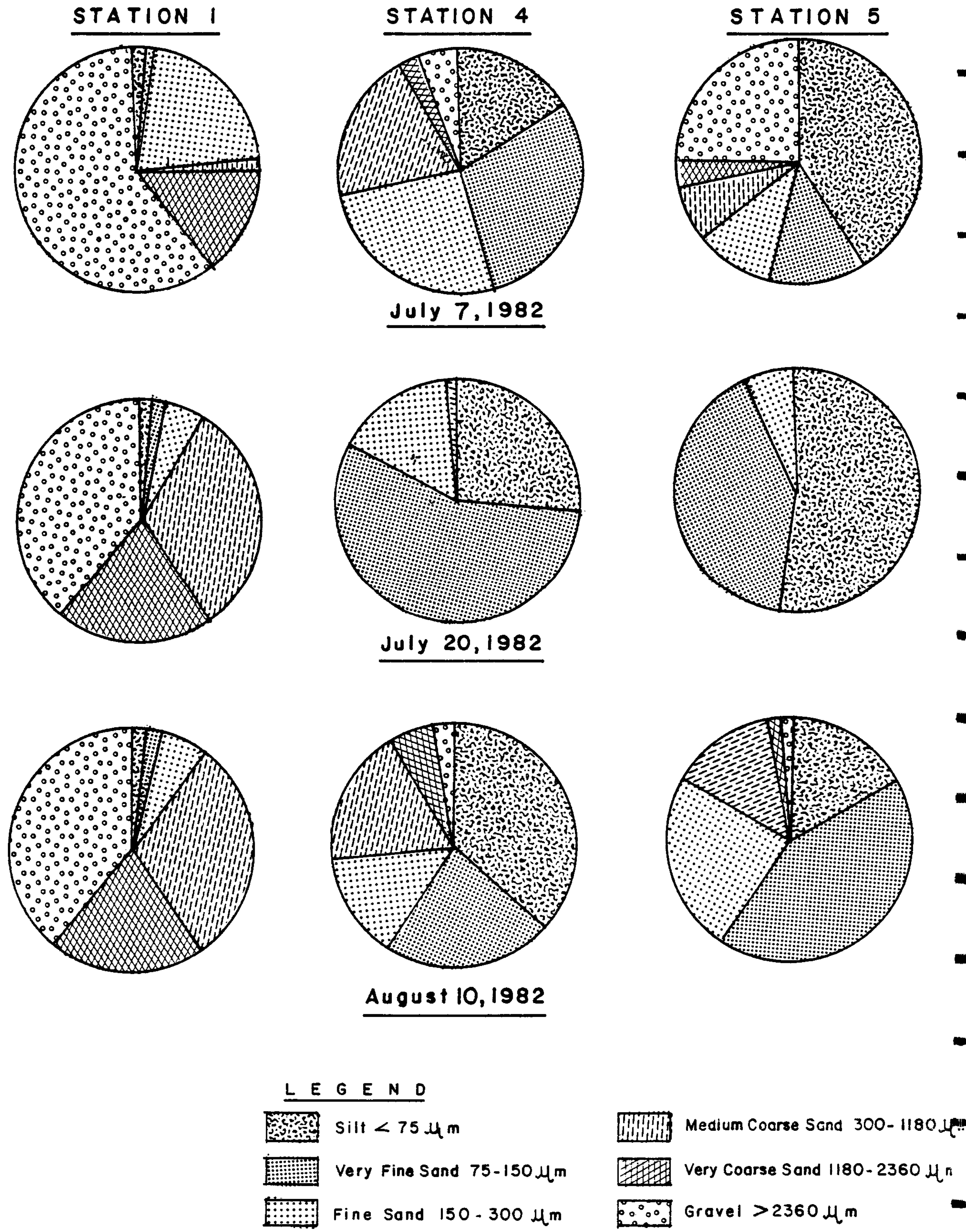


FIGURE 16 SEDIMENT PARTICLE SIZE ANALYSIS - PERCENT COMPOSITION

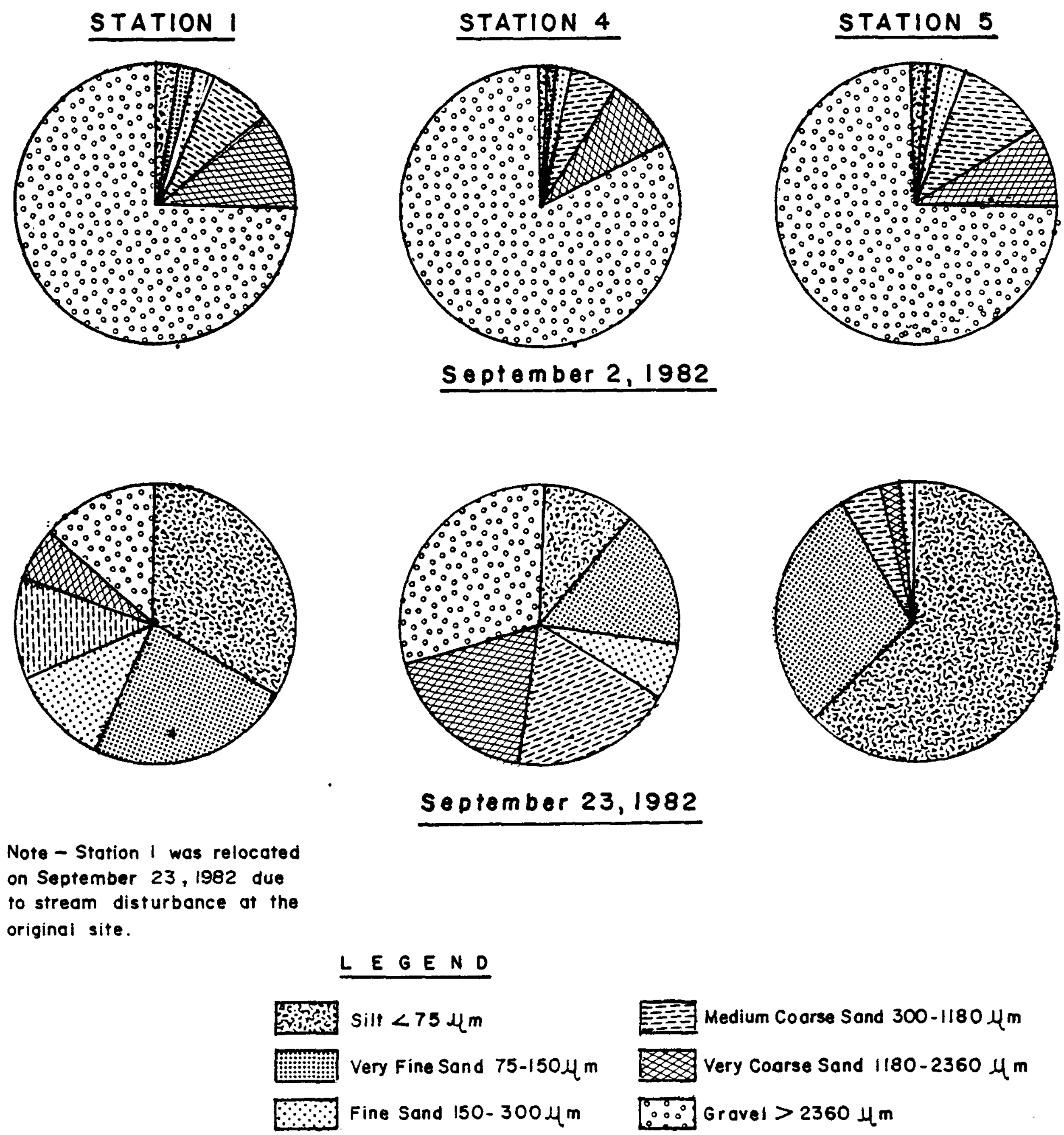


FIGURE 17 SEDIMENT PARTICLE SIZE ANALYSIS - PERCENT COMPOSITION

A one week shut down during the week preceeding September 2 resulted in decreased (less than 10%) concentrations of fine sediments at the downstream stations. The majority of the samples collected here were made up of particle sizes greater than 2360 um. The shutdown provided enough time for most fine particles to be resuspended and transported further downstream, allowing the streambed in the study area to recover. The effects of these sediments settling on the stream bottom have been referred to earlier in the discussion related to suspended sediments.

4.2.2 Sediment Metal Concentrations.

The concentrations of metals analyzed in the portion of sediments that was smaller than 150 um are given in Appendix III, Table 2 for the stations sampled. Table 2 on page 35 presents the mean values for sediment metal concentrations.

Table 2 reveals that during the sluicing periods sampled (July 20, September 23), the values for heavy metals in sediment were generally found to decrease at both downstream stations compared to Station 1 but particularly at Station 4. This general trend, was more apparent during sluicing on July 20 than it was on September 23. This can be partially explained by assuming that at the beginning of the operating season the settling pond worked efficiently at removing the heavier metal bearing particles, leaving the lighter particles, non-metal bearing silts and clays, (Paski, 1982) to be carried downstream. Evidence of this occurring is illustrated in Figures 16 and 17. At Stations 4 and 5 on July 20, for instance, more than 95% of the sediment collected contained fine sands and silts ranging in size from 75 um to 300 um. At Station 5 on September 23, 85% of the sediment collected consisted of the fine sands and silts. An example of contrast can be found on September 2 where only 5 - 10% of the samples collected at Stations 4 and 5 consisted of fine sands and silts. The remainder of the samples consisted of medium coarse sand to gravel ranging in size from 300 um to 2360 um and greater. This suggests that as the season progressed from July 20 to September 23 the settling ponds began to fill with sediments and thus lost the retention time necessary to settle fine sands and silts during sluicing which thus

TABLE 2 MEAN VALUES FOR SEDIMENT METAL CONCENTRATIONS
(All mean concentrations given in mg/kg dry weight unless otherwise noted)

DATE:	July 7, 1982			July 20, 1982			August 10, 1982			September 2, 1982			September 23, 1982		
STATIONS:	1	4	5	1	4	5	1	4	5	1	4	5	1	4	5
Ag	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Al	16933	9830	11633	11900	6530	9697	14900	16800	12133	18033	15000	13133	15300	13100	14967
As	16.1	10.8	13.8	14.2	7.6	9.3	14.6	17.5	10.8	12.9	10.7	11.3	9.7	8.7	9.4
B	3.5	3.7	6.8	6.6	7.8	6.6	4.4	5.8	6.9	5.8	20.4	11.2	---	---	---
Ba	255	282	249	168	131	153	217	330	231	242	301	372	200	218	228
Be	0.2	0.3	<0.2	0.2	<0.2	0.2	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.4
Ca	5156	4020	4090	3400	3050	3070	4133	4483	4057	5460	4297	4860	4520	5087	4447
Cd	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	3.3	9.3	<0.3	<0.3	<0.3	<0.3
Co	10.7	9.3	13.7	13.9	9.9	12.8	13.5	16.7	11.8	15.9	13.6	12.9	11.9	10.9	11.4
Cr	47.0	30.8	36.6	35.0	21.7	32.7	41.4	58.1	40.9	50.5	48.9	43.8	43.8	37.2	45.3
Cu	33.1	44.2	45.8	27.6	32.7	37.4	30.5	53.9	37.0	33.2	48.4	44.3	26.7	43.7	45.5
Fe	28133	26367	30067	24467	19600	24200	26333	36367	25833	29667	33367	30833	25433	30067	31333
Hg	0.15	0.12	0.16	0.22	0.09	0.07	0.19	0.14	0.16	0.14	0.16	0.17	0.12	0.17	0.14
K	987	1043	919	647	627	787	1207	1517	1283	1950	2067	1767	1387	1543	1793
Mg	6963	5260	6150	5077	3460	5677	5783	9490	6553	6393	6960	5993	5143	5640	7233
Mn	1213	982	1140	994	377	579	1293	1396	691	1131	908	882	870	692	704
Mo	2.1	3.3	2.5	5.1	3.6	4.7	5.3	8.3	5.5	8.1	9.5	7.4	13.0	16.0	16.6
Na	223	153	177	130	120	157	187	190	180	290	207	187	243	270	250
Ni	37	39	47	37	31	41	34	50	36	47	43	39	37	36	39
P	983	1094	942	923	985	795	1047	1067	1023	925	1093	1320	930	1105	914
Pb	4	4	5	6	4	5	5	5	4	10	8	8	8	8	6
Si	3527	2923	2907	2883	2400	2750	4183	3627	3620	3503	2707	3190	3813	4900	4660
Sn	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sr	29.4	20.5	24.2	18.1	13.8	16.1	25.1	25.8	23.5	35.3	26.2	30.3	31.8	31.8	27.7
Ti	483	250	283	276	176	257	492	440	469	864	689	893	766	934	796
V	52	39	43	41	29	40	50	66	49	60	60	58	54	57	59
Zn	122	117	131	104	92.5	112	104	136	108	133	136	122	112	121	131

remained suspended until they had passed through the settling ponds. Some of these particles subsequently settled out on the stream bottom at Stations 4 and 5. The results at Stations 4 and 5 for September 2 indicated that given time, one week in this case, when there is no sluicing the stream will resuspend these fine sands and silts and move them further downstream. It is not known if there was a flood event just prior to September 2 which would have assisted in flushing the finer materials downstream.

Because of their importance related to water quality and biological condition the same eight heavy metals as illustrated for water quality are selected and illustrated for sediment chemistry. Figures 18 and 19 show metal values in the sediments at each station on each sampling date for arsenic (As), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn).

It is interesting to note that for most heavy metals there was a pronounced decrease in values at Stations 4 and 5 during sluicing on July 20, and a recovery of those levels at the end of the summer, as seen on September 23. For instance, arsenic displayed a mean value of 14.2 mg/kg at the control station (Station 1) on July 20. This compares with values found at other sample times for arsenic at Station 1. Downstream, mean values for arsenic were 10.8 mg/kg and 13.8 mg/kg at Stations 4 and 5 on July 7, 7.6 mg/kg and 9.3 mg/kg on July 20, 17.5 mg/kg and 10.8 mg/kg on August 10, 10.7 mg/kg and 11.3 mg/kg on September 2, and 8.7 mg/kg and 9.4 mg/kg on September 23. As one can see, arsenic demonstrates decreased values on both sluicing dates. However differences in mean values are less dramatic at the end of the summer.

Copper values for sediment at downstream stations demonstrated a slight decrease on July 20 with mean values of 32.7 mg/kg at Station 4 and 37.4 mg/kg at Station 5. All other mean values found for copper including those found on the second sluicing period, September 23, ranged from 43.7 mg/kg to 53.9 mg/kg at Station 4 and from 37.0 mg/kg to 45.8 mg/kg at Station 5. These levels were all considered to be within normal limits for sediment (Paski, 1982).

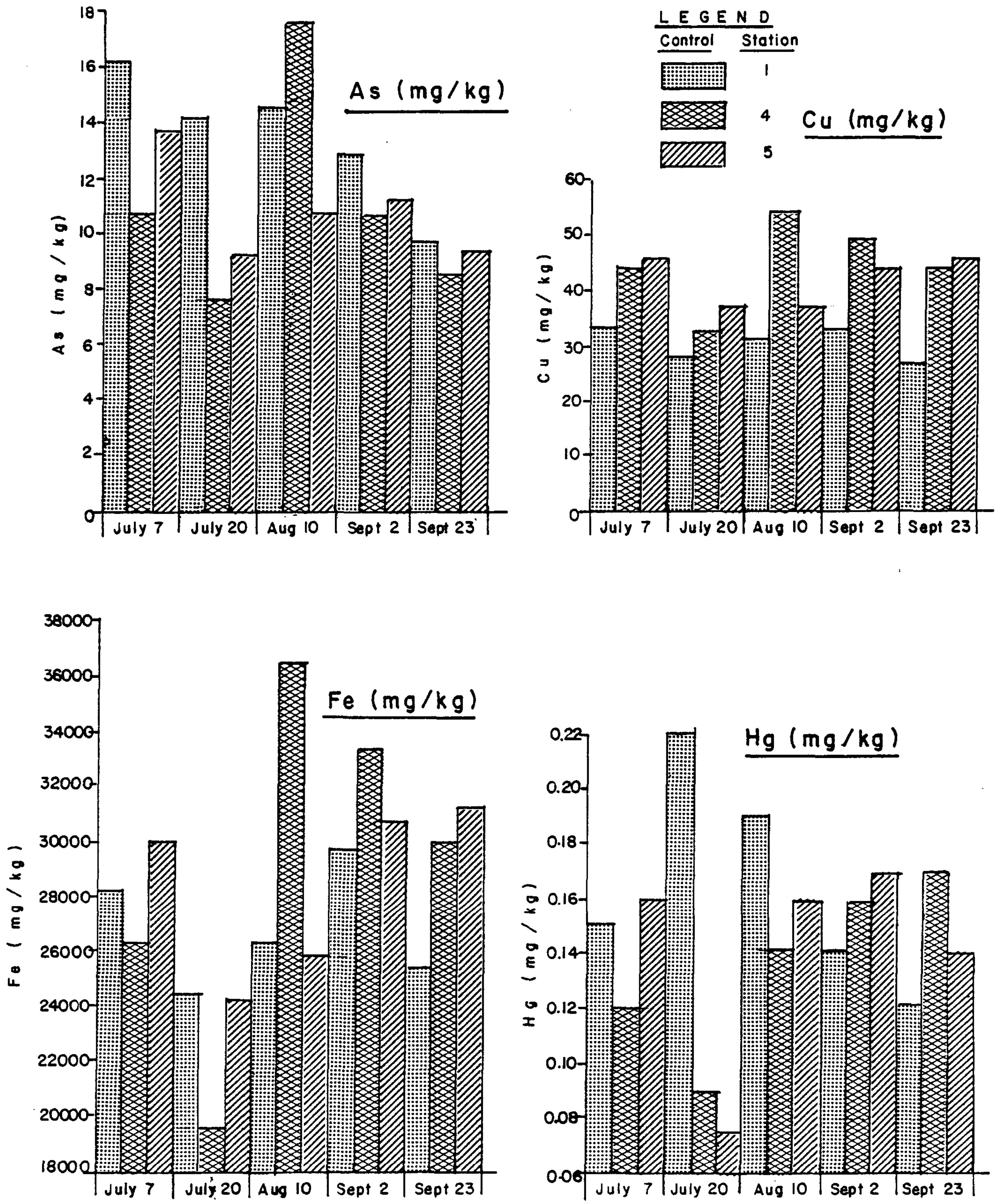


FIGURE 18 HEAVY METALS IN SEDIMENT - LITTLE GOLD CREEK

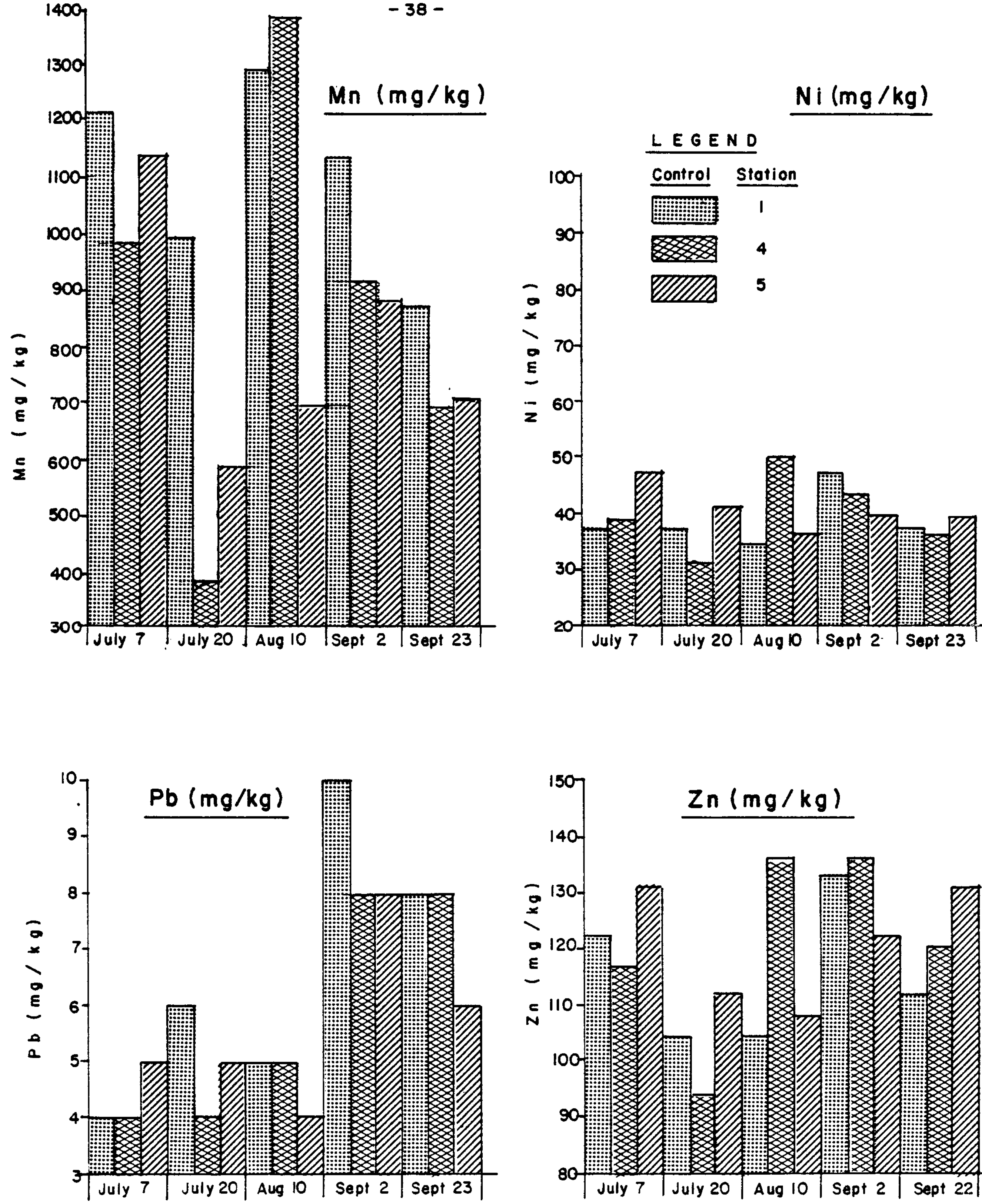


FIGURE 19 HEAVY METALS IN SEDIMENT - LITTLE GOLD CREEK

Iron values dramatically decreased on July 20. For example, mean values such as 19600 mg/kg and 24200 mg/kg were found at Stations 4 and 5 on July 20 and 30067 mg/kg and 31333 mg/kg at Stations 4 and 5 on September 23. Other values for iron found downstream ranged between 26367 mg/kg to 36367 mg/kg at Station 4 and between 25833 mg/kg to 30833 mg/kg at Station 5.

Mercury levels declined at downstream stations during the first sluicing period. However, they returned to previous levels on September 23. Mean values were found to range from 0.12 mg/kg and 0.16 mg/kg at Stations 4 and 5 on July 7 (a non-sluicing date) to mean values of 0.09 mg/kg and 0.07 mg/kg at Stations 4 and 5 on July 20. Mean values of 0.17 mg/kg and 0.14 mg/kg were found to exist for mercury on September 23. Mercury concentrations typical of sediments from placer mining streams in Yukon Territory (Mathers et al 1981) range between 0.10 mg/kg and 0.37 mg/kg.

Once again a sharp decrease was noted for manganese during sluicing periods. Levels ranged from 377 mg/kg and 579 mg/kg at Stations 4 and 5 on July 20 and 692 mg/kg and 704 mg/kg at Stations 4 and 5 on September 23. An example of common manganese values found downstream during non-sluicing periods were 982 mg/kg and 1140 mg/kg at Stations 4 and 5 on July 7, and 882 mg/kg and 908 mg/kg at Stations 4 and 5 on September 2. Normal sediment levels for manganese are in the area of 1,000 mg/kg (Paski 1982).

Nickel values generally did not demonstrate any significant changes. A small decrease was noted on July 20 but levels once again were back up to background levels by the end of the operating season. Mean values of 31 mg/kg and 41 mg/kg were found on July 20 and 36 mg/kg and 39 mg/kg on September 23.

Mean values found for lead throughout the sampling period varied between 4 and 10 mg/kg (see Table 2). Typical lead values may range between 20-30 mg/kg (Paski 1982).

Zinc was found to be slightly depressed at Station 4 on July 20 with a mean value of 92.5 mg/kg compared to 104 mg/kg found at Station 1; however it was back up to background levels at Station 5 on July 20 with a value of 112 mg/kg. Zinc was 112 mg/kg at Station 1 and 121 mg/kg and 131 mg/kg at Stations 4 and 5 on September 23.

Overall, downstream levels for heavy metals decreased significantly during the first sluicing period compared with levels found during the second sluicing period. Conversely a dramatic increase in heavy metals in water was found on those two dates (see Figures 13 and 14). All of this might suggest that the efficiency of the settling pond in terms of retention time was more effective at settling heavy metals at the beginning of the operating season than at the end.

4.3 Bottom Fauna

4.3.1 Bottom Fauna Numbers and Diversity Indices

A summary of Little Gold Creek bottom fauna numbers and diversity indices is given in Table 3. Stations 1, 4 and 5 were the only stations where bottom fauna were collected. Station 2 (sluice box discharge) and Station 3 (settling pond effluent) were unsuitable for collection. Appendix IV, Table 1 lists the bottom fauna taxonomic groups as in Pennak (1978), found in Little Gold Creek. Appendix IV, Table 2 lists the numbers of individuals in each taxonomic group and the diversity index for each sample.

Diversity values were calculated (Table 3) to assist further assessment of the impact that a placer mining operation would have on Little Gold Creek. Diversity is a calculated value which is used to express the "richness of a community, represented by the number of different taxonomic groups (genera in this case). Communities of high diversity are characterized by large numbers of species with no single species overwhelmingly abundant. Communities of low diversity contain few species, some of which are represented in disproportionately high numbers. Generally diversity values greater than 0.90 (in $\log_{10}$ or 3.0 in $\log_2$) are found in unpolluted, productive waters while heavily polluted waters have values less than 0.30 (in $\log_{10}$ or 1.0 in $\log_2$)" (Archibald, et al 1981). The diversity indices in this study area can be compared to those found in other unpolluted alpine streams in Yukon (Burns 1980). The low numbers of individuals found could be attributable to the high elevation and the cold climate of the study

TABLE 3 SUMMARY OF BOTTOM FAUNA DIVERSITY INDICES AND NUMBERS

STATION		DIVERSITY (H^1)	NUMBER PER FT^2 ($0.093m^2$)	CALCULATED NUMBER PER M^2	STATION		DIVERSITY (H^1)	NUMBER PER FT^2 ($0.093m^2$)	CALCULATED NUMBER PER M^2	STATION		DIVERSITY (H^1)	NUMBER PER FT^2 ($0.093m^2$)	CALCULATED NUMBER PER M^2
a	1 - 1	0.88	201	2,163	a	4 - 1	0.59	14	151	a	5 - 1	0.41	5	54
a	1 - 2	0.78	107	1,151	a	4 - 2	----	--	---	a	5 - 2	0.62	10	108
a	1 - 3	0.82	84	904	a	4 - 3	0.53	10	108	a	5 - 3	0.47	11	118
b	1 - 1	0.77	31	334	b	4 - 1	1.07	104	1,119	b	5 - 1	0.44	6	65
b	1 - 2	1.00	288	3,099	b	4 - 2	0.68	7	75	b	5 - 2	0.84	14	151
b	1 - 3	0.93	207	2,227	b	4 - 3	0.00	1	11	b	5 - 3	0.83	24	258
c	1 - 1	0.80	148	1,592	c	4 - 1	0.46	5	54	c	5 - 1	0.73	21	226
c	1 - 2	0.90	83	893	c	4 - 2	0.43	14	151	c	5 - 2	0.92	17	183
c	1 - 3	0.97	245	2,636	c	4 - 3	0.64	14	151	c	5 - 3	0.77	36	387
d	1 - 1	0.81	48	516	d	4 - 1	0.47	15	161	d	5 - 1	0.41	5	54
d	1 - 2	0.91	70	753	d	4 - 2	0.00	0	0	d	5 - 2	0.54	35	377
d	1 - 3	0.71	87	936	d	4 - 3	0.75	10	108	d	5 - 3	0.65	24	258
e	1 - 1	0.55	12	129	e	4 - 1	0.48	9	97	e	5 - 1	0.48	4	43
e	1 - 2	0.55	36	387	e	4 - 2	0.00	1	11	e	5 - 2	0.72	22	237
e	1 - 3	0.77	25	269	e	4 - 3	0.00	1	11	e	5 - 3	0.58	8	86
f	1 - 1	0.75	171	1,840	f	4 - 1	0.45	9	93	f	5 - 1	0.40	43	463
f	1 - 2	0.84	82	882	f	4 - 2	0.30	3	32	f	5 - 2	0.77	16	172
f	1 - 3	0.75	53	570	f	4 - 3	0.00	2	22	f	5 - 3	0.00	1	11

(a) June 25, 1982 (c) July 20,0,982 (e) September 2, 1982
(b) July 7, 1982 (d) August 1 1982 (f) September 23, 1982

site, low hardness and conductivity values. The bottom fauna productivity appears low, as a result of these environmental factors which thus affects the potential for fish habitat.

Diversity (H') values taken over six sampling periods for Station 1 (control) range from 0.55 to 0.97 and actual numbers of individuals collected by Surber Sampler ranged from 12-288 (per 0.093 m^2 or 1.0 ft^2). Downstream at Stations 4 and 5, however, diversities and numbers were much lower (see Table 3). On July 20 the diversity ranged from 0.43 - 0.64 to 0.73 - 0.93 at Station 4 and 5 respectively. Total numbers of bottom fauna found ranged from 5 - 14 at Station 4 and 17 - 36 at Station 5. On September 23 diversity ranged from 0.30 - 0.45 at Station 4 to 0.40 - 0.77 at Station 5 and actual total numbers collected ranged from 2 - 9 at Station 4 to 1 - 43 at Station 5.

It was clearly evident that diversity and numbers were decreased significantly at Station 4 compared to the control at Station 1 with some recovery indicated at Station 5. The three most abundant orders of bottom fauna found were Ephemeroptera, Diptera and Plecoptera which are further discussed in the following section.

4.3.2 Three Most Abundant Orders Found in Little Gold Creek

A list of the three most abundant orders and the component taxa found in Little Gold Creek is given in Table 4. The numbers found and percent abundance calculated for these orders is shown in Table 5. These values represent the total numbers obtained in 3 replicate samples (0.279 m^2) at each station. Graphs illustrating actual abundance and percent abundance for the three orders can be found in Figures 20, 21 and 22.

Because of their sensitivity to low-levels (10-15 mg/l) of suspended sediments (Rosenberg and Snow 1977), the invertebrate populations are important as monitoring agents of environmental changes resulting from siltation. Increased levels of supsended sediments may fill interstices in the gravel substrate thereby reducing the exchange of oxygenated water crucial to the survival of macroinvertebrates. In addition to this, increased siltation can alter substrate composition thus altering or completely changing the types of species that require

TABLE 4   THREE MOST ABUNDANT ORDERS AND THEIR TAXONOMIC GROUPS

Ephemeroptera:	*Ameletus* sp.	*Epeorus* sp.
	Baetis sp.	
	Cinygmula sp.	
Diptera:	Chironomidae adult	*Micropsectra* sp.
	Chironomidae pupae	*Orthocladius* sp.
	Brillia sp.	*Smittia* sp.
	Cardiocladius sp.	*Diamesa* sp.
	Cricotopus sp.	*Monodiamesa* sp.
	Corynoneura sp.	*Pseudodiamesa* sp.
	Epoicocladius sp.	*Prosimulium* sp.
	Eukiefferiella sp.	*Gymnopais* sp.
	Heterotrissocladius sp.	*Tipula* sp.
Plecoptera:	*Capnia* sp.	*Zapada* sp.
	Alloperla sp.	*Podmosta* sp.
	Paraleuctra sp.	Unid. dam.
	Utaperla sp.	

TABLE 5 TOTAL NUMBERS AND PERCENT CALCULATED FOR THE THREE MOST ABUNDANT ORDERS

SAMPLE DATE		June 25, 1982		July 7, 1982		July 20, 1982		August 10, 1982		September 2, 1982		September 23, 1982	
STATION		Total Number	Per-centage	Total Number	Per-centage	Total Number	Per-centage	Total Number	Per-centage	Total Number	Per-centage	Total Number	Per-centage
1	E	68	59	107	52	182	57	45	46	33	62	3	2
	D	32	28	91	44	119	37	34	34	17	32	131	94
	P	15	13	9	4	20	6	20	20	3	6	5	4
	Tot.	115		207		321		99		53		139	
4	E	15	65	6	7	1	3	3	33	1	50	0	0
	D	0	0	63	71	31	97	5	56	1	50	5	83
	P	8	35	20	22	0	0	1	11	0	0	1	17
	Tot.	23		89		32		9		2		6	
5	E	19	76	12	28	30	45	4	14	3	13	1	11
	D	1	4	26	60	19	28	15	52	16	67	6	67
	P	5	20	5	12	18	27	10	34	5	20	2	22
	Tot.	25		43		67		29		24		9	

E - Ephemeroptera D - Diptera P - Plecoptera

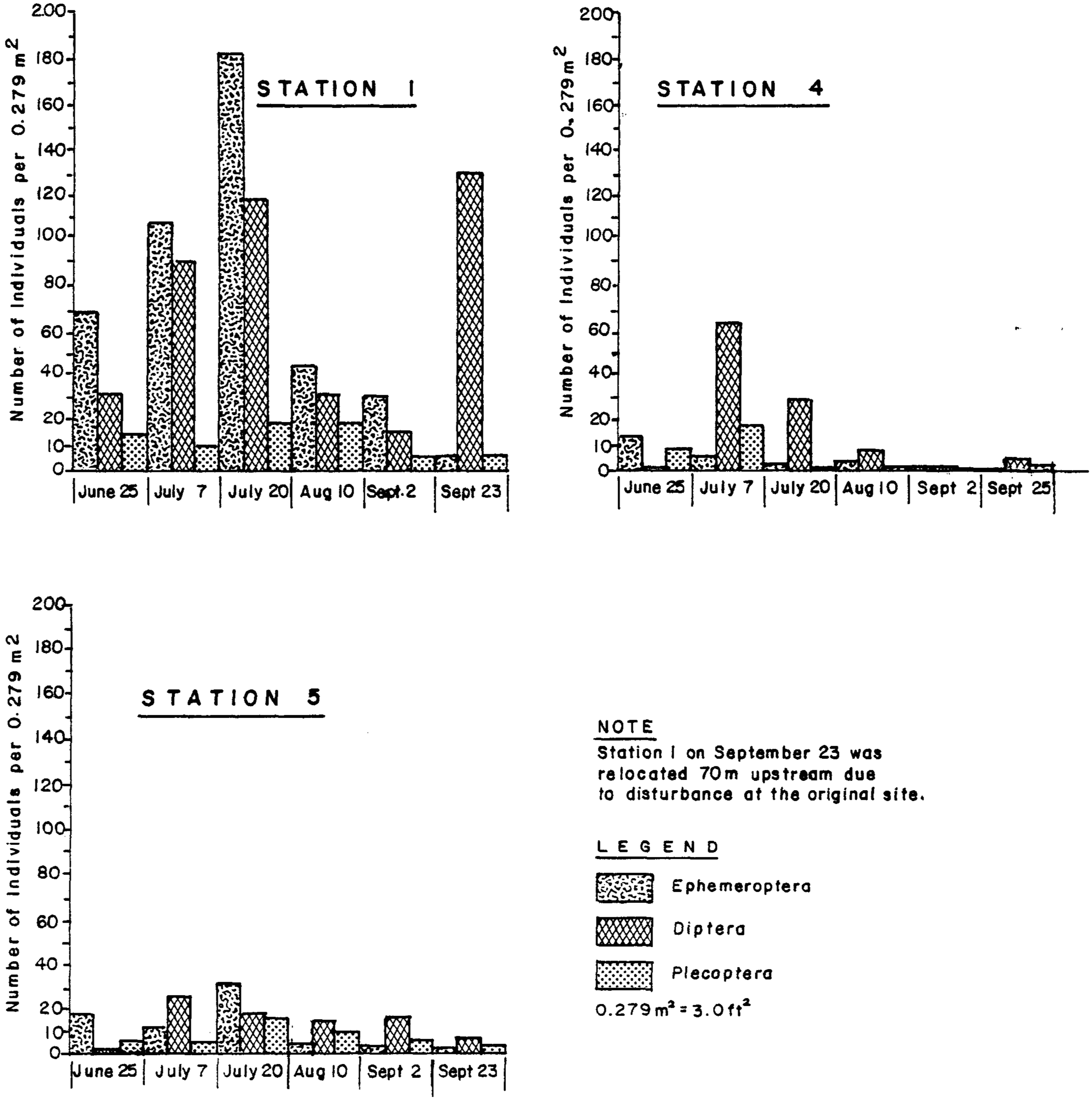


FIGURE 20 BOTTOM FAUNA DATA - ABUNDANCE

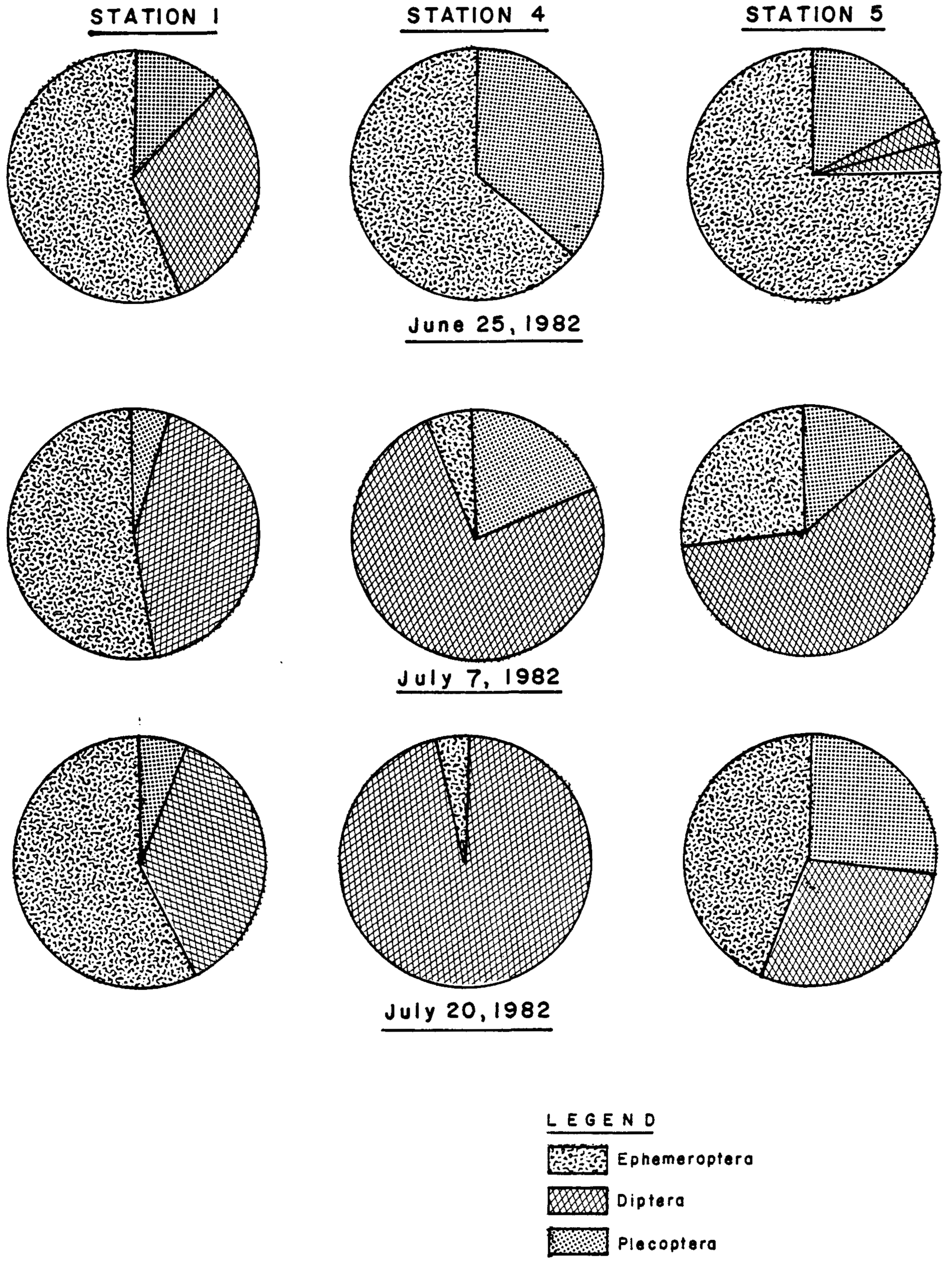
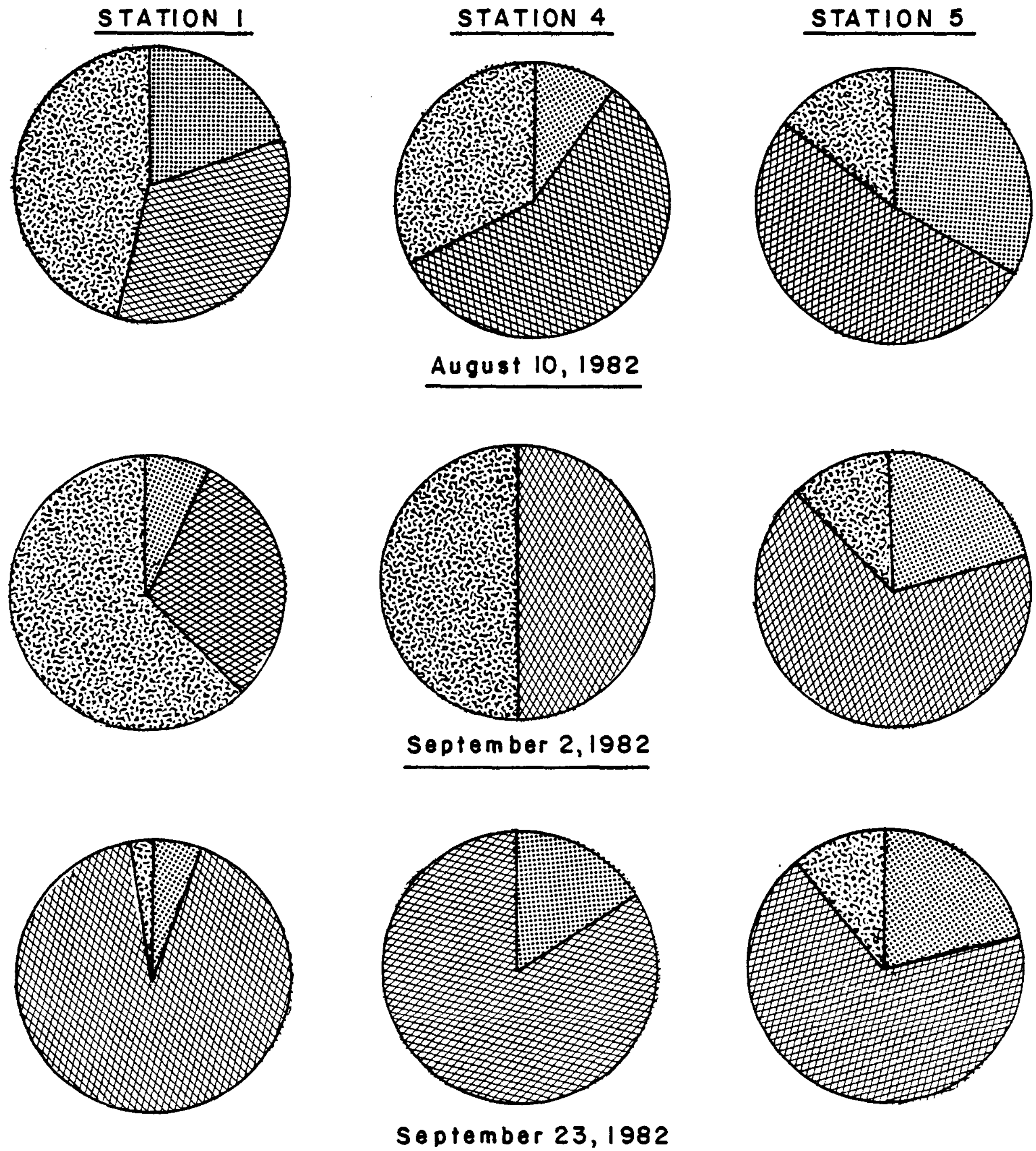


FIGURE 21 BOTTOM FAUNA DATA - PERCENT ABUNDANCE -



NOTE
Station 1 was relocated on September 23, 1982 due to stream disturbance at the original site

LEGEND
- Ephemeroptera
- Diptera
- Plecoptera

FIGURE 22 BOTTOM FAUNA DATA - PERCENT ABUNDANCE specific habitat and community structure. A change in habitat of flowing waters as a result of sedimentation usually results in a decline in important fish food organisms (Trichoptera, Ephemeroptera, Plecoptera) and the replacement with more tolerant species such as Chironomidae and Oligochaeta (Griffiths and Walton, 1978).

The three most abundant orders were chosen to determine if any general observations could be made with regard to their numbers as related to sluicing or non-sluicing conditions. The order Ephemeroptera appeared very abundant at Station 1 (See Figure 20) throughout the sampling period with the exception of September 23. Station 1 was relocated approximately 70 m upstream (see Figure 8) on this date as the original site was disturbed by mining activity. This station as illustrated in Figure 17 is comprised of approximately 65% silt and sands ranging in size from 75 to 300 um. This significant difference in stream bed composition from the previous control station could explain why the number of individuals of the order Diptera were increased compared to those of the order Ephemeroptera. Ephemeroptera, a clean water invertebrate group, known for its inability to survive high sediment levels (Langer 1980), appears to have been influenced by sluicing at Station 4 on July 20 and September 23 (see Figure 20). A reduction in numbers of almost 100% was demonstrated at Station 4 on both of these dates. Downstream at Station 5 individuals were reduced by 84% on July 20 and 67% on September 23.

Individuals of the order Diptera were less than 50% in abundance at the control stations on all dates except September 23, where they represented 94% abundance. Numbers of individuals downstream however were significantly affected by mining activity; but because of this order's variability in structure and habitat as described by Pennak (1978) and tolerance to change, compared to other more sensitive species, it represented 97% abundance at Station 4 on July 20 and 83% on September 23 (see Figures 21 and 22). At Station 5 on July 20, Diptera represented only 28% abundance and 67% on September 23. These figures may suggest that in comparison, a greater percentage of Diptera individuals survived the effects of sluicing than did individuals from the order Ephemeroptera although actual numbers were reduced as shown in Figure 20. Individuals of the order Plecoptera demonstrated characteristics of marked seasonal succession of emmergence as described by Merrit and Cummins (1978). This was evident at Station 1 by the increase in numbers toward the middle of the operating season offset by the gradual decrease in numbers towards the close of the summer season. Numbers at Station 4 on July 20 were decreased by 100% compared to Station 1 and by 10 % at Station 5. On September 23 individuals of the order Plecoptera were reduced 80% at Station 4 and 60% at Station 5. Similar characteristics of marked seasonal succession in emmergence was evident at Station 5, however significantly fewer numbers were involved (see Figure 20).

In summary some of the effects on benthic invertebrates from placer mining activity as shown by this study appear to be a reduction in abundance of individuals belonging to each of the three most dominant orders and the selective reduction or elimination of taxa sensitive to suspended sediments and substrate composition such as the Ephemeroptera and Plecoptera. Those taxa more tolerant of suspended sediments or fine textured substrate, such as the Diptera showed an increase in percent abundance compared to other orders however actual numbers were reduced. Despite the low numbers of individuals found and the complexity of aquatic systems the above results parallel results as described by other authors as noted previously.

REFERENCES

Anonymous, Guidelines for Establishing Water Quality Objective for the Territorial Waters of the Yukon and Northwest Territories. Report of the Working Group on Water Quality Objective to the Chairman, Water Boards, Yukon and Northwest Terrritories, July (1977).

APHA, AWWA, WPCF, Standard Methods for the Examination of Water and Wastewater. 14th Ed. (1975).

Archibald, P.L., Burns, B.E., A Baseline Survey of the Water Quality and Conditions in the Streams of the Howard's Pas Area, Yukon Territory. Environmental Protection Service, Yukon Branch, Pacific Regional No. 81-13 January (1981).

Burns, B.E., Water Quality Investigations of Placer Gold Mining Streams in the Yukon Territory. Contaminants Contract Fund. Contract No. 05SB. KE114-0-2308, Unpublished, 1980 data (1980).

California State Water Resources Control Board, Water Quality Criteria. Publication No. 3-A, Second Edition by McKee & Wolf (1963).

Cockfield, W.E., Sixty Mile and Ladue Rivers Area, Yukon. Geotechnical Survey of Canada, Memoir 123 (1921).

Cordone, A.J., and D.W. Kelley, 1961. The Influence of Inorganic Sediment on the Aquatic Life of Streams. Calif. Fish and Game. 47 (2): 189-228.

Department of Environment, Department of Fisheries and Oceans, Laboratory Manual. Environmental Protection Service, Fisheries and Marine Servie (1979).

Environment Canada, Pollution Sampling Handbook. Pacific Region Laboratory Services, Fisheries Operations and Environmental Protection Service, West Vancouver, B.C. (1976).

Griffiths, W.H. and B.D. Walton, 1978. The Effects of Sedimentation On The Aquatic Biota. Alberta Oil Sands, Environmental Research Program. A.F. 4.9.1, July 1978, Edmonton, Alberta. 86 pp.

Health and Welfare Canada, Guidelines for Canadian Drinking Water Quality 1978. Supply and Services, Canada (1979).

Hughes, B.D., "The Influence of Factors Other than Pollution on the Value of Shannon's Diversity Index for Benthic Macro-Invertebrates in Streams". Water Research Vol. 12, p. 359 (1978).

Hynes, H.B.N., The Ecology of Running Waters. University of Toronto Press (1972).

Inland Waters Directorate, Guidelines for Surface Water Quality, Vol.1, Inorganic Chemical Substances. Environment Canada, Ottawa (1979, 1980).

Langer, O.E., Effects of Sedimentation on Salmonid Stream Life. Paper presented at the Technical Workshop on Suspended Solids and the Aquatic Environment. June 17 & 18, 1980 Whitehorse, Y.T. Draft Proceedings prepared by Ken Weagle Environmental Consultants.

Mathers, J.S., N.O. West and B. Burns, Aquatic and Wildlife Resources of Seven Yukon Streams Subject to Placer Mining. Government of Canada, Department of Fisheries and Oceans, Pacific Region (1981).

Merritt, R.W. and K.W. Cummins, An Introduction to the Aquatic Insects of North America. Kendall Hunt Publishing Company, Dubuque, Iowa (1978).

Ontario Ministry of the Environment, Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of Environment (1978).

Paski, E., Personal Communication. Chemistry Technologist, Laboratory Services, Environmental Protection Service, West Vancouver (1982).

Pennak, R.W., Fresh-Water Invertebrates of the United States, 2nd Edition, John Wiley & Sons, Inc. Publisher (1978).

Pickral, J.C., Research Scientist. State of the Art Of Stream Monitoring. Virginia Highway and Transportation Research Council, VHTRC 81-R34, Charlottesville, Virginia. March 1981.

Pielou, E.C., Ecological Diversity, John Wiley and Sons Inc., Toronto, Chapter 1, Page 8 (1975).

Rosenberg, D.M. and N.B. Snow, 1975. Ecological Studies on Aquatic Organisms in the Mackenzie and Porcupine River Drainages in Relation to Sedimentation. Fish. Mar. Ser. Res. Dev. Technical Report 547. 86 pp.

Sabina, A.P., Rocks and Minerals for the Collector. Geological Survey of Canada, Department of Energy, Mines and Resources (1973).

Spurr, J.E., Geology of the Yukon Gold District. U.S. Geological Survey, 18th Annual Report (1898).

Taekema, B., Suspended Solids and Heavy Metals at an Atlin Placer Mine. Ministry of Environment - British Columbia, Waste Management Branch, Smithers (1983).

Thurston, R.V., R.C. Russo, C.M. Fetteroff, Jr., T.A. Edsall, and Y.M. Barber, Jr. (Eds.), A Review of the EPA Red Book: Quality Criteria for Water. Water Quality Section, American Fisheries Society, Bathesda, MD., 313p. (1979).

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APPENDICES

APPENDIX I

COLLECTION, PRESERVATION, ANALYSIS OR IDENTIFICATION METHODS AND WATER QUALITY CRITERIA

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

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Temperature		In situ temperature reading.	Standard Centigrade Thermometer	
Flow		In situ flow measurements using a Price-type current meter.	Cross-section of the stream was measured and the velocity of flow was calculated using the standard Price-type Current Meter Method[3].	
Dissolved Oxygen	1.00 mg/l	Duplicate samples collected in 300 ml glass BOD bottles. The BOD bottles were rinsed 3 times with sample before filling. Preserved with 2 ml manganese sulphate and 2 ml alkali-iodide-azide solution and shaken 15 times. A water seal was maintained and DO 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. No preservative.	Potentiometric	080
Conductivity	0.2 umhos/cm	In situ measurement. Laboratory measurement. No preservative. The measurement was taken from the same as NH_3 below.	YSI Conductivity Meter Model 33 Radiometer Conductivity Meter (CDMC) with radiometer conductivity cell.	044

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

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Ammonia NH_3-N	0.005 mg/l	Single samples collected in 2 litre linear polyethylene containers. Each container was rinsed 3 times with sample before it was filled. No preservatives. Stored at 4°C.	Phenol Hypochlorite-Colorimetric-Automated	058
Colour	5 (colour units)	Same sample as NH_3.	Platinum-Cobalt Visual Comparison	040
Turbidity	0.1 (FTU)	Same sample as NH_3.	Nephelometric Turbidity	130
Settleable Solids	0.1 mg/l	Same collection procedure as for NH_3.	Settleable Matter	112
Non-Filterable Residue (NFR)	5.0 mg/l	Same sample as NH_3.	Filtration, drying and weighing of residue on filter	104
Filterable Residue (FR)	10.0 mg/l	Same sample as NH_3.	Filtration, drying and weighing of filtrate	100
Total Alkalinity	1.0 mg/l as $CaCO_3$	Same sample as NH_3.	Potentiometric Titration	006
Total Phosphate T PO_4-P	0.005 mg/l	Same sample as NH_3.	Acid-persulphate, Autoclave Digestion	086
Nitrate NO_2-N	0.005 mg/l	Same sample as NH_3.	Diazotization-Colorimetric-Automated	070

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

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Nitrate NO_3-N	0.01 mg/l	Same sample as NH_3.	Cadmium Copper Reduction Colorimetric Automated	072
Sulphate SO_4	1.0 mg/l	Same sample as NH_3.	Barium Chloranilate -UV Spectrophotometric	122
Chloride Cl	0.5 mg/l	Same sample as NH_3.	Thiocyanate-Combined Reagent-Colorimetric	024
Silica Total Si	0.5 mg/l	Same sample as NH_3.	Ascorbic Acid Reduction - Colorimetric	118
Mercury Total Hg	0.0002 mg/l	Single samples were collected in a 200 ml linear polyethylene bottle. Preserved with a 10 ml 5% nitric dichromate solution.	Open Flameless System for Hg-AAS Determination	211 224 284 411
Extractable Metals	mg/l	Single samples collected in 200 ml linear polyethylene bottles. Each bottle was rinsed 3 times with sample before filling. Preserved to a pH <1.5 using 2.0 ml concentrated HNO_3.	Inductively Coupled Argon Plasma (ICAP) combined with Optical Emission Spectrometer (OES)	201 592
Al	0.05			
As	0.05			
Ba	0.0015			
Be	0.001			
Ca	0.050			
Cd	0.004			
Co	0.005			
Cr	0.005			
Cu	0.005			

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

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Extractable Metals (continued)	mg/l			
Fe	0.005			
Mg	0.10			
Mn	0.001			
Mo	0.005			
Na	0.5			
Ni	0.02			
Pb	0.04			
Sb	0.05			
Se	0.05			
Sn	0.01			
Sr	0.002			
Tl	0.002			
V	0.01			
Zn	0.005			
As	0.00050	Same sample as metals.	Hydride Generation - ICAP	
Cd	0.0005	Same as sample metals.	Graphite Atomic Absorption	Atomic
Cu	0.001	Same sample as metals.	Flameless Technique (AAS)	Absorption
Pb	0.001	Same sample as metals.		Jerrel-Ash
Zn	0.002	Same sample as metals.		850 Manual

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

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Ag	0.03 mg/l	Same sample as metals.	Flame Atomatic Absorption Spectrophotometry	210 290
K	0.01 mg/l	Same sample as metals.	Flame Atomic Emission Spectro-photometry	210 423
Total Hardness	0.030 mg/l as $CaCO_3$	Same sample as metals.	The sum of the ICAP results for Mg x 4.116 and Ca x 2.497 reported as mg/l $CaCO_3$	

1 As described in Environment Canada (1976).

2 As described in Department of Environment (1979).

APPENDIX I TABLE 2 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS

PARAMETER	COLLECTION/PREPARATION	ANALYSIS	METHOD CODE[1]
All Parameters	Creek and River Stations: Sediment samples were collected using an aluminum shovel to scoop sample into pre-labelled Whirl-Pak bags. Three samples were taken at each station. Samples were kept cool and were frozen (-19°C) as soon as possible.		
Mercury Hg (Total)	Sample was freeze-dried for 48 hours to remove water. Sample was sieved 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	231 236 238 275 284 411
Metals (Leachable) Al Ba Be Ca Cd Cr Cu Fe Mg	Same as Mercury except portion passing through was analyzed for metals. Sample was leached with HCL and HNO_3. The sample was heated for 3 hours.	Inductively Coupled Argon Plasma (ICAP) Combined with Optical Emission Spectrometer (OES)	231 236 238 242

APPENDIX I TABLE 2 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS (continued)

PARAMETER	PREPARATION	ANALYSIS	METHOD CODE[1]
Metals (Leachable) (continued)			
Mn			
Mo			
Na			
Ni			
P			
Pb			
Si			
Sn			
Sr			
Ti			
V			
Zn			
As	Same as other metals.	Hydride Generation ICAP	J. Davidson EPS Lab
Ag	Same as other metals.	Flame Atomic Absorption Spectrophotometry	290
Cd	Same as other metals.	Graphite Flameless Atomic Absorption	Jerrel-Ash 850 Manual
K	Same as other metals.	Flame Atomic Emission Spectrophotometry	423
Particle Size	Sample was freeze-dried.	Standard Sieving Operation	078

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

APPENDIX I TABLE 3 BOTTOM FAUNA COLLECTION, PRESERVATION AND IDENTIFICATION METHODS

FIELD COLLECTION, SAMPLING PROCEDURES AND PRESERVATION	LABORATORY PROCEDURES	IDENTIFICATION AND ENUMERATION
Surber Sampler: Creek and river samples were taken using a surber sampler with a 60 cm long net (mesh size 0.76 mm). Area sampled was 900 cm^2 (1 ft^2). Surber samples were washed into a cup at the bottom of a plankton net (0.75 mm mesh size), put in separate labelled glass jars and preserved with 10% formalin. 3 samples were taken at each station.	Bottom fauna was removed from other material in a labelled vial containing 70% methanol.	Bottom fauna was sent to Dr. C. Low, Consulting Invertebrate Biologist, Nanaimo, B. C. for identification to genus, species if possible, and enumeration.

APPENDIX I TABLE 4 WATER QUALITY CRITERIA FOR DRINKING WATER AND AQUATIC LIFE

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)
Physical				
Colour Pt. Counts	15	1		
Odour and taste	0	1		
Turbidity J.T.U.	5	1		
Chemical				
Alkalinity mg/l (Total)	Not considered a public health problem	4	>20	3
Aluminum (Al) mg/l	Not considered a public health problem	7	0.1	5
Ammonia (NH_3-N) mg/l	0.5	4	0.02	3
Antimony (Sb) mg/l				
Arsenic (As) mg/l	0.05	1	0.05	2
Barium (Ba) mg/l	1.0	1	5.0	7
Boron (Bo) mg/l	1.0	1		
Cadmium (Cd) mg/l	0.005	1	0.0002	2
Calcium (Ca) mg/l	75-200	7		
Chloride (Cl)mg/l	250	1		
Chromium (Cr) mg/l	0.05	1	0.04	2
Cobalt (Co) mg/l				
Conductivity @ 25°C (umhos/cm)	Depends on dissolved salts	7	150-500	6
Copper (Cu) mg/l	1.0	1	0.005	5
Cyanide (CN) mg/l	0.2	1	0.005	3
Dissolved oxygen (% saturation)	Near 100%	4	≥5.0 mg/l	3

APPENDIX I TABLE 4 WATER QUALITY CRITERIA FOR DRINKING WATER AND AQUATIC LIFE (continued)

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)
Fluoride (F) mg/l	1.5	1	1.5	7
Hardness (Total) as mg/l $CaCO_3$	80-100	1		
Iron (Fe) mg/l	0.3	1	1.0	3
Lead (Pb) mg/l	0.05	1	0.005 (soft H_2O*)	2
			0.01 (hard H_2O*)	2
Magnesium (Mg) mg/l	50	4		
Manganese (Mn) mg/l	0.05	1	1.0	7
Mercury (Hg) mg/l	0.002	1	0.0001-0.0002	2
Molybdenum (Mo)				
Nickel (Ni) mg/l	0.25	2	0.025 (soft H_2O*)	2
			0.25 (hard H_2O*)	2
Nitrate (NO_3-N) mg/l	10	1		
Nitrite (NO_2-N) mg/l	0.001	1		
pH units	6.5 - 8.5	1	6.5 - 9.0	3
Phosphorus (P) mg/l (Total)			0.020 to prevent algae	5
Potassium (K) mg/l				
Residue: Filterable mg/l (Total dissolved solids)	1000	4	70 - 400 with a maximum of 2000	6
Residue: Non-Filterable (mg/l)				
Selenium (Se) mg/l	0.01	1	0.01	2
Silica (Si) mg/l				
Silver (Ag) mg/l	0.05	1	0.0001	2
Sodium (Na) mg/l	20	1		
Strontium (Sr) mg/l	10	1		
Sulphate (SO_4) mg/l	500	1		

APPENDIX I TABLE 4 WATER QUALITY CRITERIA FOR DRINKING WATER AND AQUATIC LIFE (continued)

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)
Tin (Sn) mg/l	Not present in natural waters	7		
Titanium (Ti) mg/l				
Total Inorganic Carbon (TIC)				
Total Organic Carbon (TOC)	5.0	5		
Vanadium (V)				
Zinc (Zn) mg/l	5.0	1	0.030	5

* 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).

REFERENCES:

1. Health & Welfare Canada, Guidelines for Canadian Drinking Water Quality 1978, Supply and Services, Canada (1979).

2. Inland Waters Directorate, Guidelines for Surface Water Quality, Vol. 1, Inorganic Chemical Substances. Environment Canada, Ottawa (1979, 1980).

3. Thurston, R.V., R.C. Russo, C.M. Fetteroff Jr., T.A. Edsall, and Y.M. Barber Jr. (Eds.), A Review of the EPA Red Book: Quality Criteria for Water. Water Quality Section, American Fisheries Society, Bethesda, MD, 313p. (1979).

APPENDIX I TABLE 4 WATER QUALITY CRITERIA FOR DRINKING WATER AND AQUATIC LIFE (continued)

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)

4. Anonymous, Guidelines for Establishing Water Quality Objectives for the Territorial Waters of the Yukon and Northwest Territories. Report of the Working Group on Water Quality Objectives to the Chairmen, Water Boards, Yukon and Northwest Territories, July (1977).

5. Ontario Ministry of the Environment, Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment. (1978).

6. Environment Canada, Pollution Sampling Handbook. Pacific Region Laboratory Services, Fisheries Operations and Environmental Protection Service, West Vancouver, B.C. (1976).

7. California State Water Resources Control Board, Water Quality Criteria. Publication No. 3-A Second Edition by McKee and Wolf. (1963).

APPENDIX II

WATER QUALITY DATA

APPENDIX II

LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
Flow m^3/s	a	0.09	0.11	0.15
	b	0.20	0.24	0.25
	c	0.23	0.44	0.52
	d	0.11	0.15	0.12
	e	0.14	0.23	0.17
	f	0.10	---	---
Temperature (°C)	a	5.0	6.0	6.0
	b	6.0	8.5	11.0
	c	4.7	9.0	9.0
	d	9.0	9.0	11.0
	e	2.5	6.0	5.0
	f	2.0	3.0	3.5
Dissolved Oxygen (mg/l)	a	---	---	---
	b	15.2	11.9	10.8
	c	11.4	9.9	9.5
	d	11.1	9.9	9.8
	e	11.4	10.7	10.7
	f	12.4	12.0	12.1
% D.O. Saturation (%)	a	---	---	---
	b	133	111	107
	c	97.1	93.8	90.0
	d	105	93.8	97.0
	e	91.4	94.1	91.9
	f	98.7	97.7	99.2

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX II

LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
Settleable Solids (ml/l)	a	<0.1	>40	--	<0.1	0.5
	b	<0.1	--	--	0.1	<0.1
	c	<0.1	>40	<0.1	>40	6.5
	d	<0.1	0.1	0.1	0.1	0.1
	e	<0.1	<0.1	<0.1	<0.1	<0.1
	f	<0.1	>40	>40	>40	>40
Non-Filterable Residue In Situ (mg/l)	a	--	--	--	--	--
	b	--	--	--	--	--
	c	<5	62000	10000	31000	3700
	d	<5	220	360	90	110
	e	20	90	10	30	140
	f	<5	30000	33000	28000	25000
Non-Filterable Residue Laboratory (mg/l)	a	--	--	--	--	--
	b	<5	--	--	106	82
	c	<5	--	--	80900	6250
	d	<5	--	--	68	134
	e	17	--	--	30	131
	f	7	--	--	24700	22900
Filterable Residue (mg/l)	a	--	--	--	--	--
	b	95	--	--	132	168
	c	67	--	--	218	146
	d	104	--	--	137	137
	e	117	--	--	148	149
	f	105	--	--	3040	152

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX II

LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 2	STATION 3	STATION 4	STATION 5
pH In Situ	a	--	--	--	--	--
	b	7.3	--	--	6.7	7.2
	c	7.2	--	--	6.7	7.5
	d	8.4	7.6	8.0	7.6	8.3
	e	7.4	6.3	7.3	7.5	7.3
	f	7.8	6.9	6.8	7.0	7.1
pH Laboratory	a	--	--	--	--	--
	b	7.4	--	--	6.7	7.1
	c	6.5	--	--	6.4	6.6
	d	7.1	--	--	7.1	7.6
	e	7.4	--	--	7.4	7.6
	f	7.7	--	--	6.9	6.9
Conductivity In Situ (umhos/cm)	a	52	--	--	110	154
	b	85	--	--	130	160
	c	56	--	--	75	110
	d	81	--	--	132	142
	e	90	--	--	127	133
	f	78	--	--	88	85
Conductivity Laboratory (umhos/cm)	a	--	--	--	--	--
	b	139	--	--	203	262
	c	98	--	--	156	142
	d	153	--	--	200	203
	e	166	--	--	208	212
	f	146	--	--	183	171

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX II LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
Colour (colour units)	a	--	--	--
	b	<5	15	15
	c	18	>100	>100
	d	<5	10	10
	e	10	10	10
	f	5	--*	--*
Turbidity (FTU)	a	--	--	--
	b	0.1	28.0	28.0
	c	0.1	32500	650
	d	0.1	18.0	22.0
	e	0.7	4.7	14.5
	f	<0.1	26800	26000
Total Alkalinity (mg/l as $CaCO_3$)	a	--	--	--
	b	49	84	114
	c	33	54	56
	d	56	78	78
	e	60	80	80
	f	56	44	42
Total Hardness (mg/l as $CaCO_3$)	a	--	--	--
	b	66.0	110	149
	c	42.8	2470	466
	d	78.0	110	115
	e	81.9	108	116
	f	67.5	1840	1900

* Unable to obtain colour measurement due to high turbidity.

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX II

LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
Total PO_4-P (mg/l)	a	---	---	---
	b	<0.005	0.133	0.094
	c	0.006	72.6	3.20
	d	0.006	0.076	0.120
	e	0.010	0.024	0.125
	f	0.005	37.2	33.0
NO_2-N (mg/l)	a	---	---	---
	b	<0.005	0.008	0.009
	c	<0.005	0.025	0.025
	d	<0.005	<0.005	<0.005
	e	<0.005	<0.005	<0.005
	f	<0.005	0.042	0.039
NO_3-N (mg/l)	a	---	---	---
	b	0.01	0.02	0.01
	c	0.08	0.04	0.06
	d	0.02	0.03	0.03
	e	0.04	0.03	0.03
	f	<0.01	0.10	0.14
NH_3-N (mg/l)	a	---	---	---
	b	<0.005	0.008	0.009
	c	0.015	0.040	0.036
	d	<0.005	0.009	0.007
	e	<0.005	<0.005	<0.005
	f	<0.005	0.145	0.125

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX II LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
SO_4 (mg/l)	a	---	---	---
	b	17.9	19.8	21.7
	c	13.0	28.2	4.3
	d	21.7	24.1	23.9
	e	25.0	27.5	28.0
	f	19.2	48.5	50.0
Cl (mg/l)	a	---	---	---
	b	<0.5	0.7	0.5
	c	<0.5	7.8	3.6
	d	0.5	0.6	0.6
	e	0.6	<0.5	0.7
	f	0.6	4.0	5.7
Ag (mg/l)	a	---	---	---
	b	<0.03	<0.03	<0.03
	c	<0.03	<0.03	<0.03
	d	<0.03	<0.03	<0.03
	e	<0.03	<0.03	<0.03
	f	<0.03	<0.03	<0.03
Al (mg/l)	a	---	---	---
	b	<0.05	0.84	0.55
	c	0.07	186	30.0
	d	<0.05	0.71	1.03
	e	0.17	0.37	0.80
	f	<0.05	124	134

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX II LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
As (mg/l)	a	---	---	---
	b	<0.0005	0.0007	0.0008
	c	<0.0005	0.0095	0.0067
	d	<0.0005	0.0008	0.0009
	e	<0.0005	<0.0005	<0.0005
	f	<0.0005	0.0075	0.0052
Ba (mg/l)	a	---	---	---
	b	0.031	0.085	0.087
	c	0.022	9.12	1.21
	d	0.033	0.073	0.089
	e	0.039	0.055	0.082
	f	0.024	5.82	6.96
Be (mg/l)	a	---	---	---
	b	<0.001	<0.001	<0.001
	c	<0.001	0.018	0.002
	d	<0.001	<0.001	<0.001
	e	<0.001	<0.001	<0.001
	f	<0.001	0.016	0.016
Ca (mg/l)	a	---	---	---
	b	13.8	22.4	33.8
	c	8.6	236	36.2
	d	16.6	21.9	22.5
	e	17.4	22.9	23.8
	f	13.6	147	136

Date sampled:

a) June 25, 1982 d) August 10, 1982
b) July 7, 1982 e) September 2, 1982
c) July 20, 1982 f) September 23, 1982

APPENDIX II LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
Cd (mg/l)	a	---	---	---
	b	<0.0005	<0.0005	<0.0005
	c	<0.0005	0.0280	0.0029
	d	<0.0005	<0.0005	<0.0005
	e	<0.0005	<0.0005	<0.0005
	f	<0.0005	0.0080	0.0060
Co (mg/l)	a	---	---	---
	b	<0.005	<0.005	<0.005
	c	<0.005	0.771	0.098
	d	<0.005	<0.005	<0.005
	e	<0.005	<0.005	<0.005
	f	<0.005	0.948	0.905
Cr (mg/l)	a	---	---	---
	b	<0.005	<0.005	<0.005
	c	<0.005	0.375	0.090
	d	<0.005	<0.005	<0.005
	e	<0.005	<0.005	<0.005
	f	<0.005	0.236	0.268
Cu (mg/l)	a	---	---	---
	b	0.004	0.011	0.007
	c	0.004	1.48	0.128
	d	0.001	0.002	0.005
	e	0.001	0.002	0.005
	f	<0.001	0.898	0.884

Date sampled:

a) June 25, 1982 d) August 10, 1982
b) July 7, 1982 e) September 2, 1982
c) July 20, 1982 f) September 23, 1982

APPENDIX II LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
Fe	a	---	---	---
(mg/l)	b	0.024	1.48	1.12
	c	0.032	148	51.3
	d	<0.005	1.89	2.40
	e	0.155	0.877	1.77
	f	<0.005	167	167
Hg	a	---	---	---
(mg/l)	b	<0.0002	<0.0002	<0.0002
	c	<0.0002	0.0020	<0.0002
	d	<0.0002	<0.0002	<0.0002
	e	<0.0002	<0.0002	<0.0002
	f	<0.0002	0.0010	0.0010
K	a	---	---	---
(mg/l)	b	0.58	0.93	1.43
	c	0.39	8.50	2.70
	d	0.30	0.85	0.88
	e	0.66	0.80	0.86
	f	0.60	12.2	26.4
Mg	a	---	---	---
(mg/l)	b	7.6	11.1	14.3
	c	5.0	137	26.2
	d	8.8	11.4	11.5
	e	9.1	11.4	11.8
	f	8.3	114	121

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX II LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
Mn (mg/l)	a	---	---	---
	b	0.008	0.259	0.222
	c	<0.001	5.85	4.22
	d	<0.001	0.305	0.370
	e	<0.001	0.090	0.146
	f	<0.001	8.79	9.01
Mo (mg/l)	a	---	---	---
	b	<0.005	<0.005	<0.005
	c	<0.005	<0.005	0.009
	d	<0.005	<0.005	<0.005
	e	<0.005	<0.005	0.005
	f	<0.005	<0.005	<0.005
Na (mg/l)	a	---	---	---
	b	0.9	1.1	1.4
	c	0.3	5.7	2.2
	d	1.0	1.0	1.1
	e	1.0	1.1	1.1
	f	0.9	2.3	2.4
Ni (mg/l)	a	---	---	---
	b	<0.02	<0.02	<0.02
	c	<0.02	1.57	0.17
	d	<0.02	<0.02	<0.02
	e	<0.02	<0.02	<0.02
	f	<0.02	0.94	0.93

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX II — LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
Pb (mg/l)	a	---	---	---
	b	0.008	<0.001	<0.001
	c	<0.001	0.050	0.027
	d	<0.001	<0.001	<0.001
	e	<0.001	<0.001	<0.001
	f	<0.001	0.090	0.130
Sb (mg/l)	a	---	---	---
	b	<0.05	<0.05	<0.05
	c	<0.05	<0.05	<0.05
	d	<0.05	<0.05	<0.05
	e	<0.05	<0.05	<0.05
	f	<0.05	0.19	0.23
Se (mg/l)	a	---	---	---
	b	<0.05	<0.05	<0.05
	c	<0.05	<0.05	<0.05
	d	<0.05	<0.05	<0.05
	e	<0.05	<0.05	<0.05
	f	<0.05	<0.05	<0.05
Si (mg/l)	a	---	---	---
	b	4.0	4.3	4.6
	c	3.9	4.5	4.2
	d	4.2	4.4	4.3
	e	4.3	4.5	4.5
	f	4.3	4.1	3.9

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX II LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
Sn (mg/l)	a	---	---	---
	b	<0.01	<0.01	<0.01
	c	<0.01	<0.01	<0.01
	d	<0.01	<0.01	<0.01
	e	<0.01	<0.01	<0.01
	f	<0.01	<0.01	<0.01
Sr (mg/l)	a	---	---	---
	b	0.044	0.098	0.185
	c	0.028	0.863	0.150
	d	0.051	0.079	0.088
	e	0.054	0.074	0.082
	f	0.043	0.655	0.646
Ti (mg/l)	a	---	---	---
	b	<0.002	0.024	0.017
	c	<0.002	0.036	0.166
	d	<0.002	0.012	0.021
	e	<0.002	0.008	0.017
	f	<0.002	0.207	0.143
V (mg/l)	a	---	---	---
	b	<0.01	<0.01	<0.01
	c	<0.01	0.51	0.13
	d	<0.01	<0.01	<0.01
	e	<0.01	<0.01	<0.01
	f	<0.01	0.61	0.60

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX II LITTLE GOLD PLACER STUDY
WATER QUALITY DATA

PARAMETER		STATION 1	STATION 4	STATION 5
Zn	a	---	---	---
(mg/l)	b	0.110	0.020	0.019
	c	0.013	2.96	0.344
	d	<0.002	0.009	0.012
	e	<0.002	<0.002	<0.002
	f	<0.002	2.10	1.99

Date sampled:

a) June 25, 1982
b) July 7, 1982
c) July 20, 1982
d) August 10, 1982
e) September 2, 1982
f) September 23, 1982

APPENDIX III

SEDIMENT DATA

APPENDIX III TABLE 1 LITTLE GOLD CREEK SEDIMENT PARTICLE SIZE ANALYSIS - STATION 1

SAMPLE NUMBER		PERCENT COMPOSITION > 2360 um	1180 - 2360 um	300 - 1180 um	150 - 300 um	75 - 150 um	< 75 um
		Gravel	Very Coarse Sand	Med. Coarse Sand	Fine Sand	Very Fine Sand	Silt
1 - 1	a	---	---	---	---	---	---
	b	69.3	13.2	1.2	14.8	0.5	1.0
	c	38.3	21.8	32.6	4.7	1.5	1.0
	d	38.7	21.7	30.5	5.6	2.0	1.5
	e	74.8	11.8	8.6	0.5	0.9	3.4
	f	13.6	6.1	11.9	11.6	24.3	32.5
1 - 2	a	---	---	---	---	---	---
	b	67.6	16.4	13.2	1.3	0.6	0.9
	c	38.8	27.2	29.7	2.7	0.9	0.7
	d	28.3	22.8	36.8	7.4	2.5	2.2
	e	74.9	12.3	9.9	0.5	1.9	0.5
	f	4.0	14.4	20.4	11.3	22.6	27.3
1 - 3	a	---	---	---	---	---	---
	b	49.5	20.1	26.7	1.9	0.7	1.2
	c	25.3	22.3	40.2	6.8	2.9	2.5
	d	31.6	24.8	33.7	6.5	1.8	1.6
	e	79.0	9.4	7.9	0.5	0.6	2.7
	f	8.5	3.1	12.4	32.4	26.9	16.7

Sampling Dates: a) June 25, 1982 c) July 20, 1982 e) September 2, 1982
b) July 7, 1982 d) August 10, 1982 f) September 23, 1982

APPENDIX III TABLE 1 LITTLE GOLD CREEK SEDIMENT PARTICLE SIZE ANALYSIS - STATION 4

SAMPLE NUMBER		PERCENT COMPOSITION > 2360 um	1180 - 2360 um	300 - 1180 um	150 - 300 um	75 - 150 um	< 75 um
		Gravel	Very Coarse Sand	Med. Coarse Sand	Fine Sand	Very Fine Sand	Silt
4 - 1	a	---	---	---	---	---	---
	b	4.5	3.1	20.4	26.7	29.9	15.4
	c	0.0	0.0	0.3	16.5	55.3	27.9
	d	2.7	6.0	17.8	13.1	24.5	35.9
	e	78.7	10.1	8.5	1.3	0.7	0.8
	f	31.9	16.2	19.8	4.8	14.7	12.6
4 - 2	a	---	---	---	---	---	---
	b	38.4	9.2	17.2	13.9	10.1	11.1
	c	0.0	0.0	0.7	34.1	51.2	14.0
	d	10.5	13.1	27.4	13.5	19.7	15.8
	e	66.0	10.0	15.7	3.6	2.0	2.8
	f	9.2	1.0	0.8	2.3	18.2	68.4
4 - 3	a	---	---	---	---	---	---
	b	51.7	23.3	18.4	2.9	1.7	2.0
	c	0.0	0.0	0.3	19.0	55.7	25.0
	d	11.3	3.3	15.6	17.5	23.9	28.5
	e	60.8	16.1	16.6	3.0	1.6	1.8
	f	8.6	5.1	12.9	7.6	23.0	42.7

Sampling Dates: a) June 25, 1982 c) July 20, 1982 e) September 2, 1982
b) July 7, 1982 d) August 10, 1982 f) September 23, 1982

APPENDIX III TABLE 1 LITTLE GOLD CREEK SEDIMENT PARTICLE SIZE ANALYSIS - STATION 5

SAMPLE NUMBER		PERCENT COMPOSITION > 2360 um	1180 - 2360 um	300 - 1180 um	150 - 300 um	75 - 150 um	< 75 um
		Gravel	Very Coarse Sand	Med. Coarse Sand	Fine Sand	Very Fine Sand	Silt
5 - 1	a	---	---	---	---	---	---
	b	25.0	3.2	8.1	10.7	15.7	37.2
	c	0.0	0.0	0.0	7.5	41.3	51.1
	d	1.2	1.9	16.3	22.5	39.8	18.3
	e	74.2	10.1	12.2	1.7	0.9	0.9
	f	0.4	1.6	5.5	0.1	30.7	61.8
5 - 2	a	---	---	---	---	---	---
	b	47.6	24.2	19.3	3.3	2.4	3.3
	c	0.0	0.0	0.1	4.9	38.3	56.8
	d	0.4	0.1	1.6	16.4	46.5	34.9
	e	67.3	11.3	15.3	2.6	1.8	1.7
	f	2.4	1.2	1.3	6.0	30.2	58.9
5 - 3	a	---	---	---	---	---	---
	b	49.0	23.1	15.8	3.2	2.8	6.1
	c	0.0	0.0	0.4	14.9	47.3	37.3
	d	0.1	0.1	1.2	12.2	45.0	41.5
	e	63.4	14.1	17.7	2.4	1.2	1.2
	f	0.5	2.8	0.2	7.4	38.0	51.1

Sampling Dates: a) June 25, 1982 c) July 20, 1982 e) September 2, 1982
b) July 7, 1982 d) August 10, 1982 f) September 23, 1982

APPENDIX III TABLE 2 LITTLE GOLD CREEK SEDIMENT CHEMISTRY DATA - STATION 1
(All concentrations given in mg/kg dry weight unless otherwise noted)

DATE:	July 7, 1982			July 20, 1982			August 10, 1982			September 2, 1982			September 23, 1982		
STATION:	1 - 1	1 - 2	1 - 3	1 - 1	1 - 2	1 - 3	1 - 1	1 - 2	1 - 3	1 - 1	1 - 2	1 - 3	1 - 1	1 - 2	1 - 3
Ag	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Al	16800	17600	16400	11100	11800	12800	14400	15200	15100	17900	18500	17700	17500	15500	12900
As	16.4	16.1	15.8	12.9	14.7	15.1	14.6	14.2	15.1	15.5	11.0	12.3	10.9	9.45	8.68
B	0.4	4.9	5.1	7.5	6.1	6.3	5.6	2.5	5.2	3.5	4.3	9.5	---	---	---
Ba	251	264	251	155	163	185	215	220	217	250	244	232	220	202	177
Be	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2
Ca	5190	5370	4910	3240	3220	3740	3990	4400	4010	5330	5600	5450	5210	4710	3640
Cd	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	7.5	2.2	<0.3	<0.3	<0.3
Co	11.7	9.3	11.2	11.2	17.1	13.4	13.0	13.0	14.6	17.9	15.7	14.1	11.5	12.9	11.3
Cr	46.7	47.2	47.1	33.0	36.7	35.2	41.0	40.5	42.7	51.4	51.8	48.4	47.6	44.3	39.5
Cu	33.4	33.0	33.0	26.6	27.9	28.3	27.2	33.9	30.3	33.8	33.5	32.3	28.8	26.9	24.4
Fe	27900	28100	28400	23700	25000	24700	26200	25700	27100	30200	29900	28900	27600	25800	22900
Hg	0.13	0.20	0.12	0.19	0.24	0.22	0.16	0.16	0.24	0.18	0.09	0.16	0.13	0.11	0.11
K	999	1040	923	621	672	648	1190	1280	1150	1960	1990	1900	1520	1360	1280
Mg	6990	6930	6970	4730	5320	5180	5640	5600	6110	6500	6480	6200	5740	5270	4420
Mn	1240	1240	1160	905	1110	968	1230	1190	1460	1280	1120	993	882	958	770
Mo	1.8	3.6	1.0	5.8	5.1	4.5	5.4	4.7	5.8	8.0	8.6	7.8	14.3	13.0	11.7
Na	220	240	210	120	120	150	180	210	170	300	280	290	280	250	200
Ni	38	37	37	31	46	35	33	35	35	52	45	43	38	39	35
P	964	1010	974	992	954	1010	1040	1050	1050	913	936	925	969	924	898
Pb	5	4	3	5	8	6	5	4	7	13	10	8	6	10	9
Si	3550	3630	3400	2810	2900	2940	4210	4280	4060	4230	3390	2890	3650	4250	3540
Sn	<2	<2	<2	<2	<2	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sr	29.2	31.1	27.9	17.1	17.2	20.1	24.2	27.4	23.8	35.6	35.8	34.5	35.9	32.8	26.6
Ti	482	517	449	255	266	306	454	575	446	876	842	874	849	800	648
V	51	53	51	39	42	43	48	51	50	61	60	59	59	55	47
Zn	122	124	121	102	104	105	100	106	105	137	133	129	121	113	102

APPENDIX III TABLE 2 LITTLE GOLD CREEK SEDIMENT CHEMISTRY DATA - STATION 4
(All concentrations given in mg/kg dry weight unless otherwise noted)

DATE:	July 7, 1982			July 20, 1982			August 10, 1982			September 2, 1982			September 23, 1982		
STATION:	4 - 1	4 - 2	4 - 3	4 - 1	4 - 2	4 - 3	4 - 1	4 - 2	4 - 3	4 - 1	4 - 2	4 - 3	4 - 1	4 - 2	4 - 3
Ag	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Al	6990	11700	10800	6890	5860	6840	18300	14400	17700	14600	14300	16100	11500	13900	13900
As	8.24	11.8	12.4	7.60	7.50	7.70	21.2	12.6	18.6	9.0	12.2	11.0	8.22	9.02	8.71
B	3.7	2.8	4.7	6.9	8.4	8.1	7.7	4.9	4.9	10.3	28.1	22.8	---	---	---
Ba	215	372	260	130	125	137	355	272	362	294	305	305	228	211	214
Be	0.2	0.3	0.3	<0.2	<0.2	<0.2	0.4	0.3	0.4	0.3	0.3	0.3	0.4	0.3	0.4
Ca	3900	4380	3780	3090	2880	3180	·4780	4110	4560	3860	4740	4290	5630	4740	4890
Cd	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	21.4	6.1	<0.3	<0.3	<0.3	<0.3
Co	7.1	9.5	11.3	10.9	7.6	11.2	17.4	15.1	17.6	13.0	11.9	16.0	11.6	9.7	11.3
Cr	21.7	37.0	33.8	22.5	19.8	22.8	63.3	47.8	63.3	48.9	45.1	52.7	34.2	37.8	39.6
Cu	35.1	54.4	43.0	33.1	31.0	34.1	53.3	50.7	57.7	45.0	52.4	47.9	42.1	48.0	41.0
Fe	21500	30200	27400	19800	18800	20200	38100	32500	38500	31900	33600	34600	28600	30600	31000
Hg	0.11	0.12	0.12	0.07	0.14	0.07	0.15	0.14	0.14	0.09	0.24	0.16	0.21	0.15	0.16
K	829	1200	1100	691	575	614	1660	1430	1460	2290	1950	1960	1380	1620	1630
Mg	3440	6700	5640	3590	3150	3640	10500	7470	10500	7010	6260	7610	4550	6210	6160
Mn	817	1070	1060	383	354	393	1570	959	1660	1010	758	957	717	600	758
Mo	1.0	5.3	3.7	3.5	3.3	4.1	8.6	6.9	9.3	9.3	10.0	9.2	15.5	16.4	16.2
Na	120	170	170	130	110	120	200	190	180	180	230	210	260	280	270
Ni	30	45	42	32	29	32	49	46	54	42	42	46	33	40	35
P	1180	1170	932	969	977	1010	1080	1030	1090	1050	1180	1050	1340	984	991
Pb	4	4	5	5	<3	5	5	5	5	7	8	9	9	7	7
Si	2690	3050	3030	2570	2280	2350	3720	3610	3550	2640	3100	2380	4890	4830	4980
Sn	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sr	17.3	22.7	21.6	14.7	12.4	14.4	26.3	25.4	25.7	22.8	29.1	26.7	34.5	30.2	30.8
Ti	177	315	259	199	140	189	462	412	445	570	791	706	1160	796	847
V	30	45	41	30	27	31	71	56	70	58	59	63	58	55	58
Zn	91.9	140	119	94.5	88.6	94.5	133	134	141	129	139	140	108	134	121

APPENDIX III TABLE 2 LITTLE GOLD CREEK SEDIMENT CHEMISTRY DATA - STATION 5
(All concentrations given in mg/kg dry weight unless otherwise noted)

DATE:	July 7, 1982			July 20, 1982			August 10, 1982			September 2, 1982			September 23, 1982		
STATION:	5 - 1	5 - 2	5 - 3	5 - 1	5 - 2	5 - 3	5 - 1	5 - 2	5 - 3	5 - 1	5 - 2	5 - 3	5 - 1	5 - 2	5 - 3
Ag	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Al	10800	11300	12800	9940	9490	9660	10600	12300	13500	13500	12600	13300	16000	13600	15300
As	11.0	14.5	15.9	10.2	9.30	8.50	10.8	11.2	10.3	10.7	10.4	12.8	9.61	9.30	9.17
B	7.7	6.2	6.5	6.7	4.1	9.1	7.4	6.0	7.4	5.0	16.6	12.1	---	---	---
Ba	226	267	254	156	153	149	242	228	224	420	350	347	232	226	225
Be	<0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3
Ca	3930	3920	4420	3130	3100.	2980	4230	4140	3800	5050	5330	4200	4210	4930	4200
Cd	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Co	10.0	15.8	15.3	13.7	12.6	12.1	11.9	10.0	13.6	13.8	12.5	12.3	12.5	11.0	10.7
Cr	32.2	37.1	40.4	33.9	31.4	32.7	35.8	42.6	44.2	46.5	43.3	41.5	49.6	39.9	46.5
Cu	38.3	48.8	50.4	39.0	37.8	35.4	34.9	38.1	38.0	45.7	43.4	43.9	48.2	41.4	46.8
Fe	26300	30600	33300	24900	24400	23300	23800	26700	27000	32100	31100	29300	33400	29100	31500
Hg	0.12	0.18	0.19	0.06	0.07	0.07	0.15	0.15	0.18	0.25	0.17	0.10	0.16	0.11	0.16
K	834	966	958	789	740	831	1180	1220	1450	1810	1650	1840	1870	1680	1830
Mg	5580	6100	6770	5920	5500	5610	5600	6810	7250	6170	5700	6110	8120	5990	7590
Mn	991	1210	1220	607	574	555	693	701	680	895	769	981	750	672	690
Mo	1.5	3.0	3.0	5.1	4.6	4.3	4.7	5.5	6.2	7.9	7.6	6.8	18.1	14.7	16.9
Na	190	150	190	160	150	160	160	190	190	190	200	170	250	250	250
Ni	40	49	52	46	39	37	33	36	40	40	38	40	44	34	40
P	890	970	965	806	811	768	1190	1020	858	1360	1440	1160	844	1030	868
Pb	<3	8	5	6	4	5	5	<3	4	8	8	9	5	6	6
Si	2830	2850	3040	2750	2650	2850	3420	3480	3960	2750	3180	3640	4930	4230	4820
Sn	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sr	21.0	22.7	28.9	16.3	16.5	15.5	22.0	24.4	24.1	31.2	31.4	28.4	26.6	29.8	26.6
Ti	305	251	294	257	249	261	423	480	504	1000	1100	579	715	947	726
V	39	43	47	41	39	40	44	51	53	61	60	54	61	57	60
Zn	114	134	144	115	114	107	94	111	118	126	121	120	141	119	134

APPENDIX IV

BOTTOM FAUNA DATA

APPENDIX IV TABLE 1 BOTTOM FAUNA TAXONOMIC GROUPS

	Phylum:	Platyhelminthes
	Class:	Turbellaria
	Order:	Tricladida
	Family:	Planariidae
1.		*Phagocata morgani*
2.	Phylum:	Nematoda
	Phylum:	Annelida
	Class:	Oligochaeta
	Order:	Lumbriculida
	Family:	Lumbriculidae
3.		*Kincaidiana hexatheca*
4.		*Stylodrilus heringanus*
	Order:	Haplotaxida
5.	Family:	Enchytraeidae
	Family:	Tubificidae
6.		*Telmatrodilus* sp.
7.		*Tubifex* sp.
8.		*Ilyodrilus* sp.
	Phylum:	Anthropoda
	Class:	Arachnoidae
9	Order:	Acari
	Class:	Insecta
	Order:	Plecoptera
	Family:	Capniidae
10.		*Capnia* sp.
	Family:	Chloroperlinae
11.		*Alloperla* sp.
12.		*Paraleuctra* sp.
13.		*Utaperla* sp.
	Family:	Nemouridae
14.		*Zapada* sp.
15.		*Podmosta* sp.
16.		unid. dam.

APPENDIX IV TABLE 1 BOTTOM FAUNA TAXONOMIC GROUPS (Continued)

	Order:	Ephemeroptera
	Family:	Baetidae
17.		*Ameletus* sp.
18.		*Baetis* sp.
	Family:	Heptageniidae
19.		*Cinygmula* sp.
20.		*Epeorus* sp.
	Family:	Siphlonuridae
21.		*Siphlonurus* sp.
	Order:	Trichoptera
	Family:	Limnephilidae
22.		*Clostoeca* sp.
	Order:	Diptera
	Family:	Chironomidae
23.		Chironomidae adult
24.		Chironomidae pupae
25.		*Brillia* sp.
26.		*Cardiocladius* sp.
27.		*Cricotopus* sp.
28.		*Corynoneura* sp.
29.		*Epoicocladius* sp.
30.		*Eukiefferiella* sp.
31.		*Heterotrissocladius* sp.
32.		*Micropsectra* sp.
33.		*Orthocladius* sp.
34.		*Smittia* sp.
	Subfamily:	Diamesinae
35.		*Diamesa* sp.
36.		*Monodiamesa* sp.
37.		*Pseudodiamesa* sp.

APPENDIX IV TABLE 1 BOTTOM FAUNA TAXONOMIC GROUPS (Continued)

	Family:	Simulidae
38.		*Prosimulium* sp.
39.		*Gymnopais* sp.
	Family:	Tipulidae
40.		*Tipula* sp.
	Order:	Hymenoptera
41.	Sub Order:	Apocrita
	Order:	Homoptera
42.	Family:	Aphidadae

APPENDIX IV TABLE 2 BOTTOM FAUNA DATA - STATION 1

TAXONOMIC GROUP	June 25/82			July 7/82			July 20/82			August 10/82			Sept. 2/82			Sept. 23/82		
	1-1	1-2	1-3	1-1	1-2	1-3	1-1	1-2	1-3	1-1	1-2	1-3	1-1	1-2	1-3	1-1	1-2	1-3
1. Phagocata morgani	34	2	3	1	11	10	2	1	6	4	3	10	-	-	-	4	5	6
2. Nematoda	-	-	-	-	1	3	1	-	1	-	-	-	-	2	-	-	-	-
3. Kincaidiana hexatheca	29	25	19	10	97	58	36	25	31	14	14	34	4	5	5	30	11	6
4. Stylodrilus heringanus	7	4	7	1	93	34	11	13	34	-	-	-	-	-	-	-	-	-
5. Enchytraeidae	76	46	25	-	-	-	-	-	-	5	4	18	3	-	-	56	33	16
10. Capnia sp.	-	-	-	-	-	-	-	-	5	-	3	4	-	-	-	-	-	-
12. Paraleuctra sp.	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-
13. Utaperla sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	1	-	-
14. Zapada sp.	-	-	-	-	-	1	3	1	-	-	-	-	-	-	-	2	2	-
15. Podmosta sp.	6	6	3	-	1	5	-	2	7	5	4	4	-	-	-	-	-	-
16. Unid. dam.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
17. Ameletus sp.	13	9	9	2	39	13	8	3	26	1	2	5	2	20	9	-	-	-
18. Baetis sp.	2	1	-	-	1	4	1	1	5	6	6	-	-	1	-	-	-	1
19. Cinygmula sp.	15	8	11	7	6	34	58	11	69	7	11	7	-	-	1	2	-	-
20. Epeorus (Iron) sp.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
21. Siphlonurus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22. Clostoeca sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
23. Chironomidae adult	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
24. Chironomidae pupae	-	-	-	-	1	-	1	1	3	-	1	-	-	1	1	3	-	-
25. Brillia sp.	-	-	-	-	1	-	-	-	1	-	-	-	-	2	-	-	-	-
26. Cardiocladius sp.	9	4	3	5	10	17	7	9	15	-	-	1	-	-	-	-	-	-
27. Cricotopus sp.	-	-	1	1	2	1	-	-	3	-	2	1	-	-	1	2	6	2
28. Corynoneura sp.	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-
29. Epoicocladius sp.	-	-	-	-	-	-	5	3	4	-	-	-	-	-	-	-	-	-
30. Eukiefferiella sp.	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
31. Heterotrissocladius sp.	3	2	3	-	8	16	8	10	32	-	-	-	-	-	-	-	-	-
32. Micropsectra sp.	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-
33. Orthocladius sp.	-	-	-	-	2	-	1	-	2	-	-	-	-	-	-	-	-	-
34. Smittia sp.	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX IV TABLE 2 BOTTOM FAUNA DATA - STATION 1 (Continued)

TAXONOMIC GROUP	June 25/82			July 7/82			July 20/82			August 10/82			Sept. 2/82			Sept. 23/82		
	1-1	1-2	1-3	1-1	1-2	1-3	1-1	1-2	1-3	1-1	1-2	1-3	1-1	1-2	1-3	1-1	1-2	1-3
35. Diamesa sp.	-	-	-	-	-	-	-	-	-	3	4	-	-	-	1	18	9	3
36. Monodiamesa sp.	-	-	-	-	4	4	1	-	1	-	-	-	-	-	-	14	2	2
37. Pseudodiamesa sp.	-	-	-	4	1	3	5	-	4	3	15	3	2	2	2	37	10	15
39. Gymnopais sp.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
40. Tipula sp.	1	-	-	-	2	1	-	1	-	-	1	-	1	1	3	2	4	2
(T) Column Totals	201	107	84	31	288	207	148	83	245	48	70	87	12	36	25	171	82	53
(N) Total Number	125	61	59	30	285	204	146	82	241	43	65	69	9	32	24	112	49	37
(H^1) Diversity	0.88	0.78	0.82	0.77	0.78	0.93	0.80	0.90	0.97	0.81	0.91	0.71	0.55	0.55	0.77	0.75	0.84	0.75

NOTE: Column totals recorded per ft^2

APPENDIX IV TABLE 2 BOTTOM FAUNA DATA - STATION 4

TAXONOMIC GROUP	June 25/82			July 7/82			July 20/82			August 10/82			Sept. 2/82			Sept. 23/82		
	4-1	4-2	4-3	4-1	4-2	4-3	4-1	4-2	4-3	4-1	4-2	4-3	4-1	4-2	4-3	4-1	4-2	4-3
1. Phagocata morgani	-	x	-	-	1	-	-	-	-	-	-	2	1	-	-	-	-	-
2. Nematoda	-	x	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Kincaidiana hexatheca	-	x	-	10	-	-	-	-	1	6	-	-	1	-	1	1	-	-
4. Stylodrilus heringanus	-	x	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. Enchytraeidae	-	x	1	-	-	-	-	-	-	5	-	2	6	-	-	5	1	1
7. Tubifex (unid. Juv) sp.	-	x	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
10. Capnia sp.	-	x	-	13	-	-	-	-	-	-	-	-	-	-	-	-	1	-
11. Alloperla sp.	-	x	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12. Paraleuctra sp.	-	x	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15. Podmosta sp.	4	x	4	6	-	-	-	-	-	-	-	1	-	-	-	-	-	-
17. Ameletus sp.	2	x	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
18. Baetis sp.	4	x	1	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-
19. Cinygmula sp.	4	x	3	4	2	-	-	-	1	-	-	-	-	-	-	-	-	-
21. Siphlonurus sp.	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24. Chironomidae pupae	-	x	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
26. Cardiocladius sp.	-	x	-	12	-	-	-	-	2	-	-	-	-	-	-	-	-	-
27. Cricotopus sp.	-	x	-	2	1	-	2	3	2	-	-	-	-	-	-	-	-	-
28. Corynoneura sp.	-	x	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29. Epoicocladius sp.	-	x	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
30. Eukiefferiella sp.	-	x	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31. Heterotrissocladius sp.	-	x	-	18	1	1	2	9	7	-	-	-	1	-	-	-	-	-
33. Orthocladius sp.	-	x	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35. Diamesa sp.	-	x	-	-	-	-	-	-	-	-	-	1	-	-	-	1	1	-
36. Monodiamesa sp.	-	x	-	7	1	-	-	1	-	-	-	-	-	-	-	-	-	1

APPENDIX IV TABLE 2 BOTTOM FAUNA DATA - STATION 4

TAXONOMIC GROUP	June 25/82 4-1	June 25/82 4-2	June 25/82 4-3	July 7/82 4-1	July 7/82 4-2	July 7/82 4-3	July 20/82 4-1	July 20/82 4-2	July 20/82 4-3	August 10/82 4-1	August 10/82 4-2	August 10/82 4-3	Sept. 2/82 4-1	Sept. 2/82 4-2	Sept. 2/82 4-3	Sept. 23/82 4-1	Sept. 23/82 4-2	Sept. 23/82 4-3
37. Pseudodiamesa sp.	-	x	-	8	-	-	-	1	1	2	-	1	-	-	-	2	-	-
38. Prosimulium sp.	-	x	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40. Tipula sp.	-	x	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
42. Aphididae	-	x	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(T) Column Totals	14	x	10	104	7	1	5	14	14	15	0	10	9	1	1	9	3	2
(N) Total Number	14	x	9	102	6	1	5	14	14	10	0	8	3	1	1	4	2	1
(H^1) Diversity	0.59	x	0.53	1.07	0.68	0.00	0.46	0.43	0.64	0.47	0.00	0.75	0.48	0.00	0.00	0.45	0.30	0.00

x = not sampled

NOTE: Column totals recorded per ft^2

APPENDIX IV TABLE 2 BOTTOM FAUNA DATA - STATION 5

TAXONOMIC GROUP	June 25/82			July 7/82			July 20/82			August 10/82			Sept. 2/82			Sept. 23/82		
	5-1	5-2	5-3	5-1	5-2	5-3	5-1	5-2	5-3	5-1	5-2	5-3	5-1	5-2	5-3	5-1	5-2	5-3
1. *Phagocata morgani*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	3	-
2. Nematoda	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	1	-
3. *Kincaidiana hexatheca*	-	-	-	-	-	1	3	2	2	3	14	12	-	1	-	31	4	1
5. Enchytraeidae	-	1	-	-	-	-	-	-	-	-	5	-	-	1	2	2	1	-
6. *Telmatrodilus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
7. *Tubifex* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-
8. *Ilyodrilus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
9. Acari	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
10. *Capnia* sp.	-	-	3	2	1	2	4	3	9	-	-	-	-	-	-	-	-	-
14. *Zapada* sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
15. *Podmosta* sp.	1	1	-	-	-	-	-	1	1	-	8	2	-	4	-	2	-	-
17. *Ameletus* sp.	1	1	4	3	1	1	1	2	2	-	-	-	-	1	-	1	-	-
18. *Baetis* sp.	-	4	-	-	1	1	1	-	-	-	-	1	1	-	-	-	-	-
19. *Cinygmula* sp.	3	2	4	1	3	1	9	2	13	1	1	1	-	1	-	-	-	-
21. *Siphlonurus* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24. Chironomidae pupae	-	-	-	-	-	1	-	-	-	-	1	-	-	1	-	-	-	-
25. *Brillia* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-
26. *Cardiocladius* sp.	-	-	-	-	1	2	-	-	2	-	-	-	-	-	-	-	-	-
27. *Cricotopus* sp.	-	-	-	-	-	-	1	1	-	-	-	1	-	1	1	-	1	-
29. *Epoicocladius* sp.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
31. *Heterotrissocladius* sp.	-	-	-	-	3	4	1	2	5	-	-	-	-	-	-	-	-	-
33. *Orthocladius* sp.	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-
35. *Diamesa* sp.	-	-	-	-	-	-	-	-	-	-	1	3	1	6	1	-	1	-
36. *Monodiamesa* sp.	-	-	-	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX IV TABLE 2 BOTTOM FAUNA DATA - STATION 5

TAXONOMIC GROUP	June 25/82			July 7/82			July 20/82			August 10/82			Sept. 2/82			Sept. 23/82		
	5-1	5-2	5-3	5-1	5-2	5-3	5-1	5-2	5-3	5-1	5-2	5-3	5-1	5-2	5-3	5-1	5-2	5-3
37. <u>Pseudodiamesa</u> sp.	-	1	-	-	3	8	1	3	-	1	5	3	-	-	2	-	-	-
41. Apocrita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
42. Aphididae	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
(T) Column Totals	5	10	11	6	14	24	21	17	36	5	35	24	4	22	8	43	16	1
(N) Total Number	5	9	11	6	14	23	21	17	36	5	29	23	3	16	5	41	14	1
(H^1) Diversity	0.41	0.62	0.47	0.44	0.84	0.83	0.73	0.92	0.77	0.41	0.54	0.65	0.48	0.72	0.58	0.40	0.77	0.00

NOTE: *Column totals recorded per* ft^2