DEPARTMENT OF THE ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION



# HEAVY METALS IN CLASTIC STREAM SEDIMENTS OF THE YAKOUN RIVER DRAINAGE AND OTHER B.C. STREAMS

**Regional Program Report No. 84-05**

By

George Derksen

NOVEMBER 1985

## ABSTRACT

A monitoring program was conducted to assess sediment heavy metal levels in the Yakoun River and tributary streams adjacent to a proposed gold mine property. Several other British Columbia streams were also sampled to establish a data base to compare to. Intergravel fine sediments from clastic stream beds typical of salmon spawning areas were effectively sampled with a stainless steel syringe sampler. Barbie Creek which drains the area surrounding the mine property had the highest overall mean mercury and arsenic concentrations compared to the other streams sampled by the syringe method. The results indicate that both seasonal differences and sampler methodology are important considerations when establishing baseline heavy metal sediment levels.

## RÉSUMÉ

Un programme de surveillance a été mis en place pour permettre d'évaluer les niveaux de concentration des métaux lourds dans les sédiments de la rivière Yakoun et de ses affluents, cours d'eau qui ont pour caractéristique de longer des terrains aurifères proposés à l'exploitation.

En même temps on a prélevé des échantillons de sédiments dans d'autres cours d'eau de la Colombie-Britannique afin d'établir une base de données à laquelle se référer. À l'aide d'une seringue d'échantillonnage en acier inoxydable, on a ainsi prélevé des échantillons de sédiments fins à gravier dans le lit clastique de cours d'eau où le saumon abonde. C'est dans la rivière Barbie, cours d'eau qui draine la zone contiguë aux terrains aurifères qu'on a relevé les degrés de concentration moyenne de mercure et d'arsenic les plus élevés, en comparaison avec les autres cours d'eau dans lesquels on a aussi prélevé des échantillons à la seringue d'échantillonnage. Les résultats ont montré qu'il faut largement tenir compte à la fois des variations saisonnières et de la méthode d'échantillonnage lorsque l'on veut établir les niveaux de concentration de base des métaux lourds présents dans les sédiments.

# TABLE OF CONTENTS

## TABLE OF CONTENTS (Continued)

## LIST OF FIGURES

## LIST OF TABLES

## LIST OF PLATES

## SUMMARY AND CONCLUSIONS

Clastic stream sediments typical of salmon spawning grounds were effectively sampled with a stainless steel syringe sampler. Barbie Creek which drains the proposed Cinola gold mine property had the highest overall mean sediment mercury (0.47 ug/g) and arsenic (63 ug/g) levels of the British Columbia streams sampled with the syringe sampler. The highest mean zinc (164 ug/g) concentration was measured at Lemieux Creek and the highest mean copper (86 ug/g) concentration was measured at Quinsam River.

Mercury and arsenic concentrations measured at station Barbie-3 by two methods (freeze core, syringe) were significantly different. Samples were obtained from the same area of creek bed and the < 150 um sediment fraction was used in both cases. The reason for this variability is not known but indicates consideration has to be given to sample methods when documenting baseline metal levels from which to evaluate post-operational impacts. There was no indication either sampler had mercury or arsenic contamination problems.

An element of seasonal variability existed between samples collected at stations in September 1982 and again in February 1983. For mercury, significant differences were detected at Barbie Creek stations B1 and B3 and Canoe Creek station C1. Seasonal variability is a consideration that has to be taken into account when documenting baseline metal levels from which to evaluate post-operational impacts.

# 1 INTRODUCTION

In July, 1980 Consolidated Cinola Mines Ltd., submitted a Stage I report to the Provincial Steering Committee for Development of New Metal Mines (Fanning and Griffing, 1980). The report summarized that the ore, waste rock, soils and tailings may contain anomalously high levels of mercury and other heavy metals. The Cinola project is located on Graham Island (Queen Charlotte Islands) and was identified as having a potential for impacting upon the anadromous fishery resources of the Yakoun River drainage.

As part of a pre-development data collection program the Environmental Protection Service (Department of Environment) undertook a monitoring program in September 1982 and February 1983 to assess the heavy metal levels in clastic stream sediments adjacent to the proposed mine development. In addition, sediment samples were collected from other B.C. streams in 1983 to provide a data base to compare to. This report presents the data collected over 1982 and 1983.

## 2 DESCRIPTION OF STUDY AREA

The Yakoun River drains an area of approximately 477 $km^2$. The Yakoun River flows in a northerly direction and drains into Masset Inlet near Port Clements (Figure 1). Tributary streams of the Yakoun River that have been identified as having a possibility of being influenced by the Cinola project include Canoe Creek, Florence Creek and Barbie Creek (Figures 1 and 2).

Other rivers and streams that were sampled in B.C. include: Myra Creek, Quinsam River and Cowichan River on Vancouver Island; Pinchi, Foxy and Lemieux Creeks in Central B.C.; Salmon and Seymour Rivers in the Lower Mainland and the Mamin River on Graham Island (Figure 3).

A description of each station is provided in Appendix I.

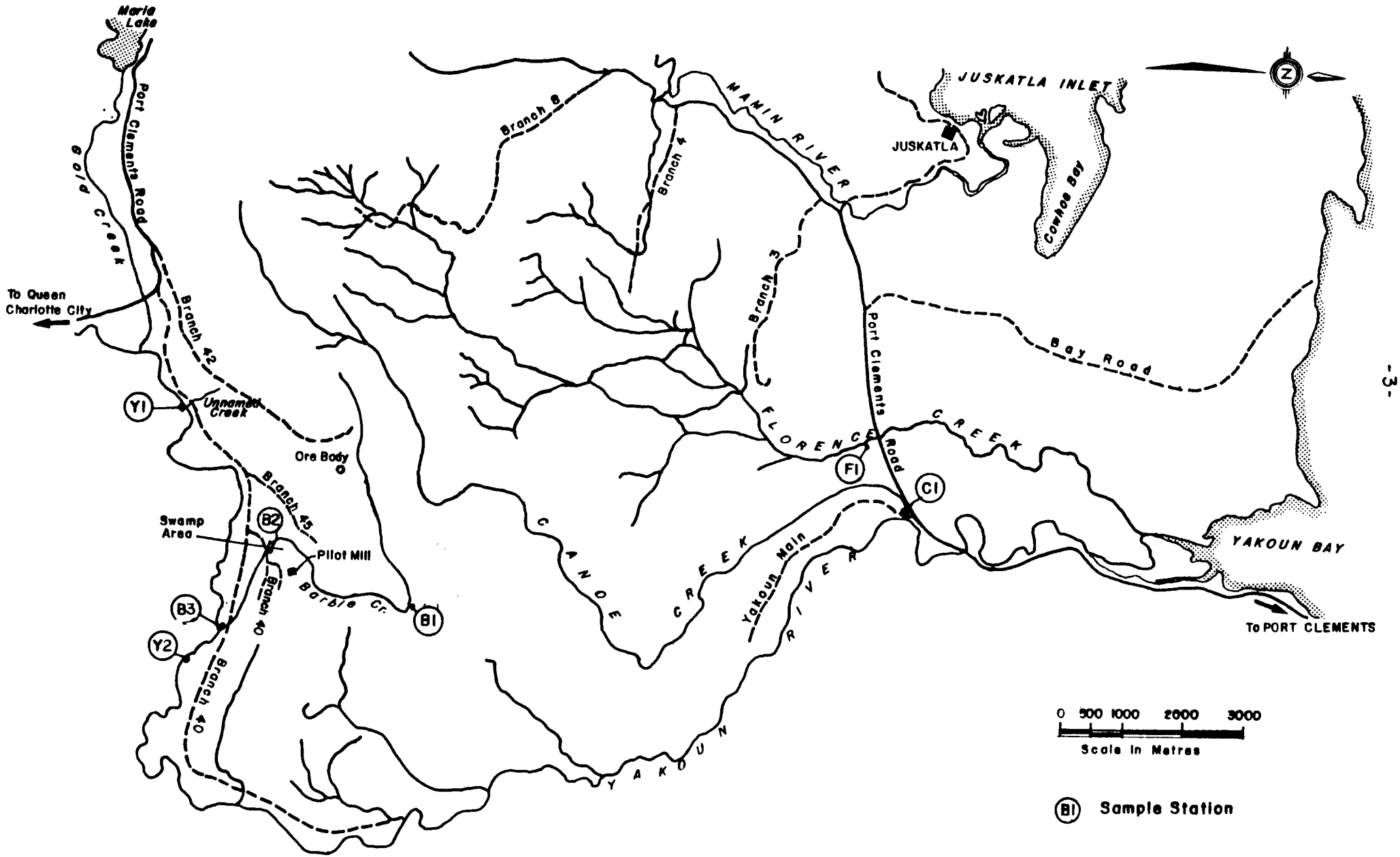


FIGURE 1 YAKOUN RIVER AND SEDIMENT SAMPLE STATION LOCATIONS

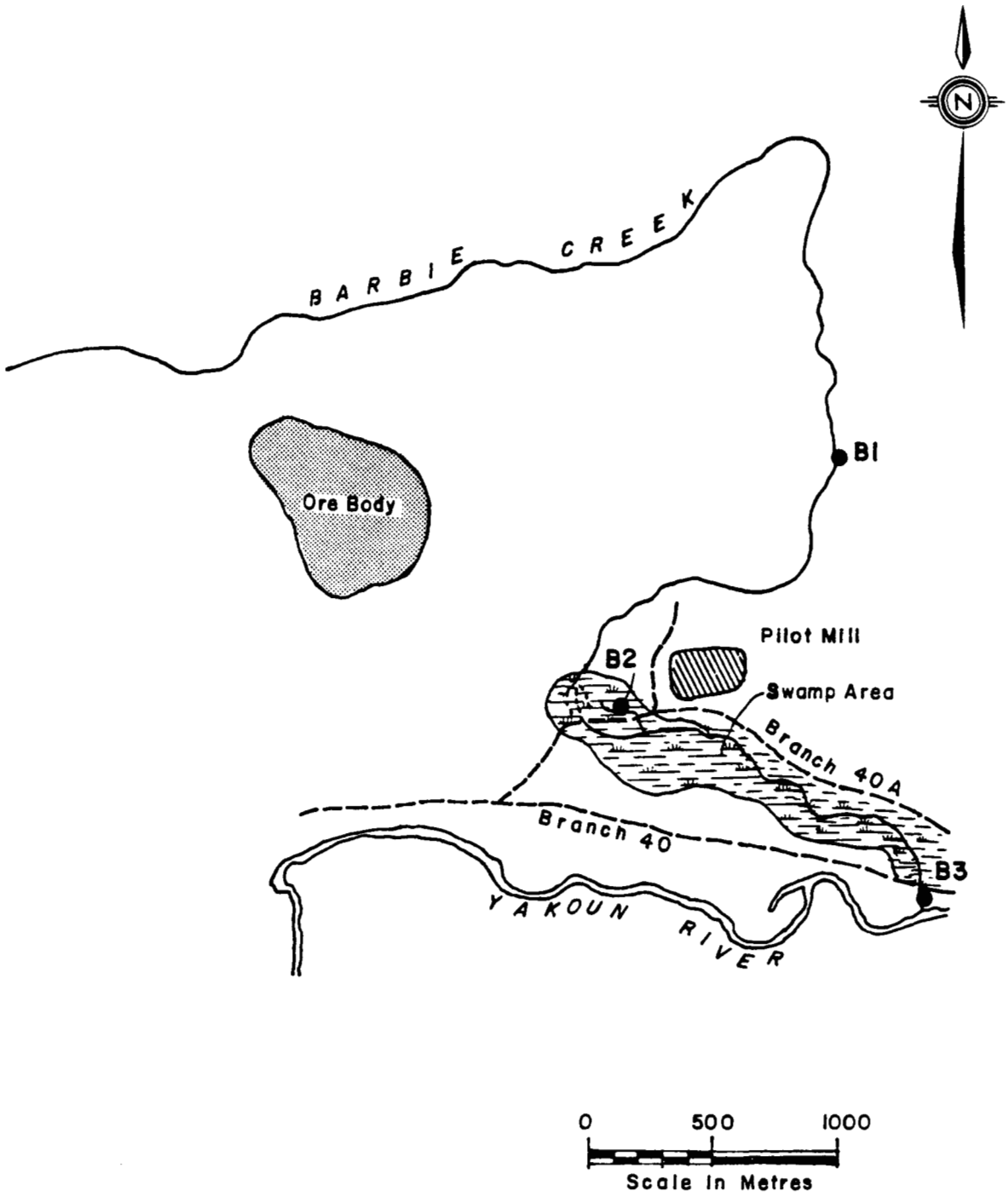


FIGURE 2 BARBIE CREEK SAMPLE STATION LOCATIONS

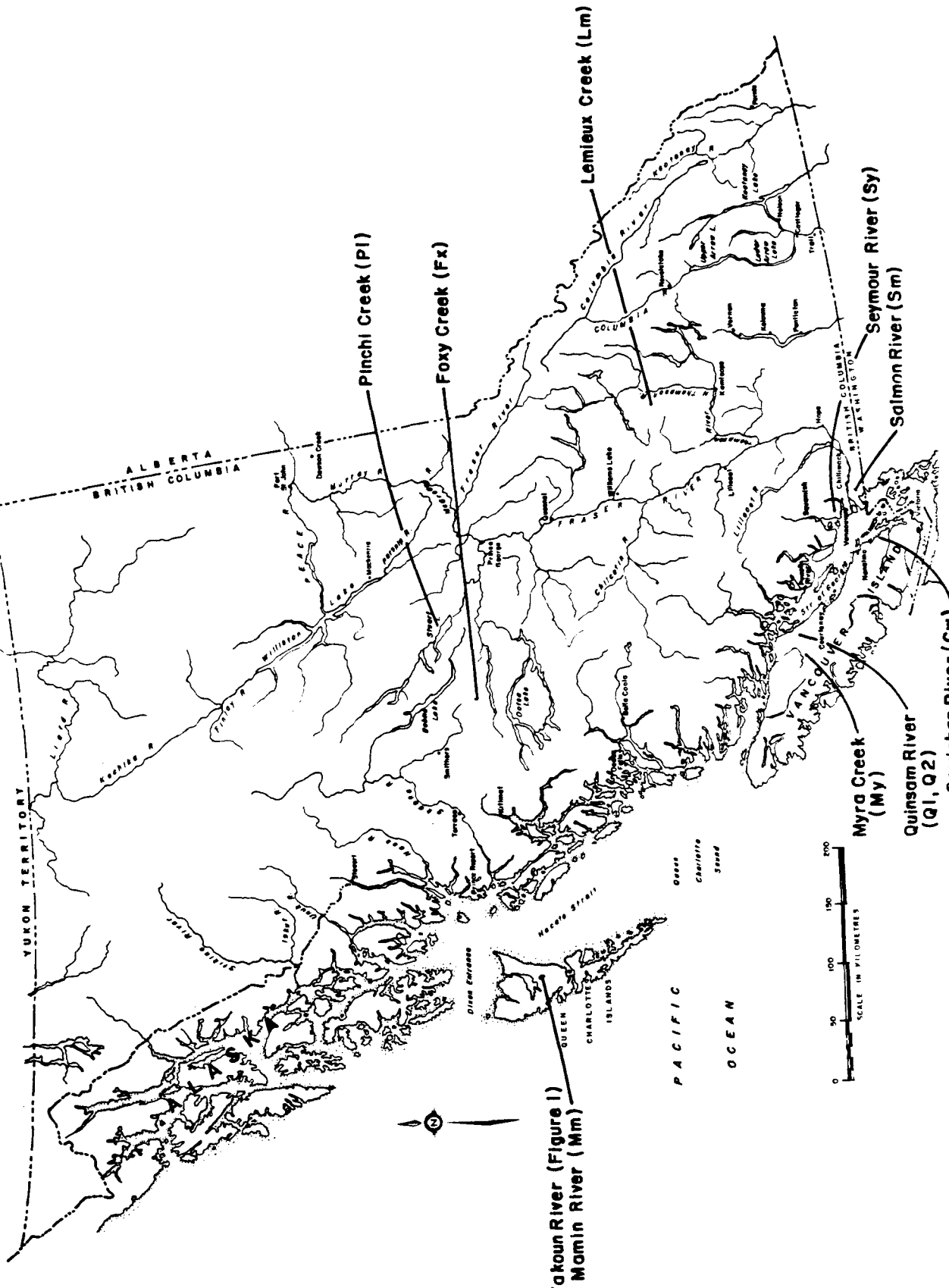


FIGURE 3 GENERAL LOCATION OF OTHER STREAMS SAMPLED FOR SEDIMENT

# 3 MATERIALS AND METHODS

## 3.1 Sampling

**3.1.1 Stainless Steel Syringe Samples.** Sediment samples were obtained using an 600 ml capacity stainless steel syringe modified after a sampler orignally designed to collect intragravel dissolved oxygen samples (Ryan, 1972). Some of the sampler tipholes were enlarged to 2.0 mm (Plate 1). The rubber O-rings were lightly lubricated with stopcock grease to ensure easy movement of the piston. Samples were collected from areas where spawning was known to occur or in gravelly areas of the stream.

The probe tip was worked into the substrate to a depth of 20-25 cm at all stations (11 cm at Station B2) and a sample was drawn up and evacuated into a clean 2 litre polyethylene sample bottle. Two separate samples were combined to make-up one replicate and three to five replicates were collected at each station for metal analyses. Additional samples were collected for particle size analysis and organic content.

To obtain the final sample, the content of each bottle was poured into a clean Imhoff cone and settled for one hour (Plate 2). The water in the cone was then decanted. The cone was inverted and the sediment fraction was drained into a kraft sediment bag. Distilled water was used to rinse any residual sediment into the kraft bag. The samples were kept frozen until preparation for analysis.

Between each sediment sample, the syringe was cleaned by drawing up a sample of creek water and then evacuating it. The sampler was dismantled between sample sites and rinsed with distilled water to remove any residual sediment.

**3.1.2 Freeze Core Samples** To assess if the syringe sampler mercury results were comparable to freeze core samples, freeze core samples were collected on one occasion using a sampler described by Walkotten, 1973. The probe was pushed into the streambed to 20-25 cm. The frozen sediment

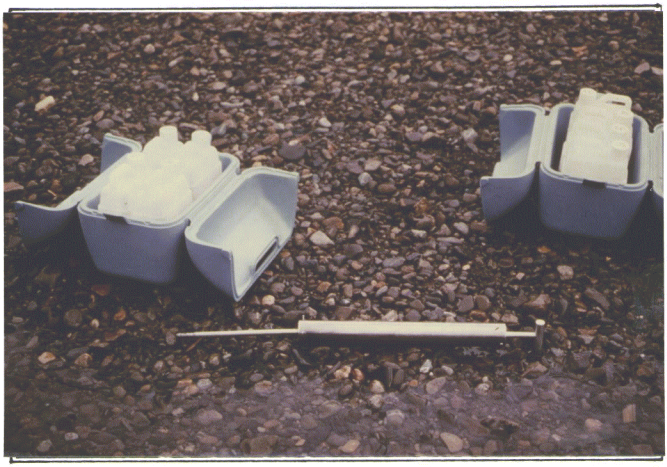

PLATE 1 - STAINLESS STEEL SYRINGE SAMPLER

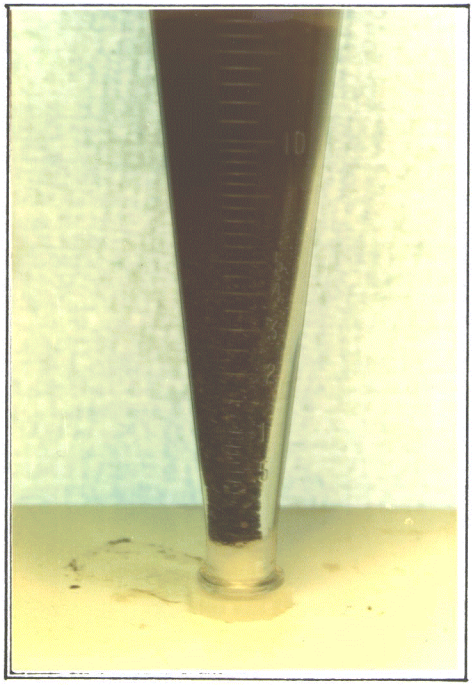

PLATE 2 - Settled Sediment Showing Lower Granular Fraction and Upper Floccule Fraction

plug was pulled out and placed in a stainless steel bucket. With disposable gloves on, pieces of sample were broken off with a piece of rock from the stream and then placed in a whirl pac. Any residual left in the pail was rinsed into the whirl pac with distilled water. The samples were kept frozen until preparation for analysis.

3.1.3 Quality Control. To assess the degree of metal contamination from the syringe sampler, over the study period, samples of distilled water were drawn up and then evacuated into acid washed 200 ml polyethylene sample bottles. The samples for ICAP analysis were acidified with nitric acid to a pH of 1.5 and those for mercury analysis with 10 ml of nitric-dichromate acid.

The freeze core sampler was constructed of copper and brass. To determine if contamination of samples with Hg was possible, scrapings from the probe were put into distilled water and preserved with nitric-dichromate acid. Samples for As and other metal analyses were acidified with nitric acid to pH 1.5.

## 3.2 Analytical Methods

3.2.1 Sediment Samples. All analyses were performed at the EPS/DFO Laboratory in West Vancouver. Analytical procedures are outlined in the Laboratory Manual, 1979 or addendum sections. The method for sediment sample preparation is reported in Appendix II. Mercury was analyzed on a Pharmacia Mercury Monitor Model 100 and the other metals by Inductively Coupled Argon Plasma (ICAP) Atomic Emission Spectrometry. An elemental correction for vanadium was made to the ICAP between the analysis of the September 1982 and February 1983 samples. This may have also made differences to the arsenic, aluminum, beryllium and nickel results between the two surveys. The September 1982 samples were rerun for V, As, Al, Be and Ni. A factor change was made for cadmium on the ICAP in June 1983. This did not affect the Yakoun River and tributary stream results but applied to the other streams sampled.

Percent organic content was determined from a volatile sediment residue analysis. The prepared sample (1-10 gm) was air dried at 90°C overnight followed by drying at 103°C for one hour. The sample was then muffled at 550°C for one hour.

Particle size distribution was based on the following sieve size ranges: > 9.5 mm; > 2.36 mm, < 9.5 mm; > 1.18 mm, < 2.36 mm; > .3 mm, < 1.18 mm; > .15 mm, < .3 mm; > .075 mm, < .15 mm and < .075 mm. The proportion of each sample < .15 mm was determined for all samples.

3.2.2 Reference Sediment Samples. National Research Council reference samples BCSS1 and MESS1 were tested to evaluate the methods utilized by the DOE/DFO Laboratory. The reverse aqua regia digest is not a total digest for silica associated or refractory compounds.

3.2.3 Water Samples. Mercury samples were analyzed on a Pharmacia Mercury Monitor Model 100 and other metals by ICAP.

# 4 RESULTS AND DISCUSSION

## 4.1 Syringe Sampler Contamination

Eight samples were tested to assess the extent of contamination of distilled water drawn into the sampler (Table 1). There was no evidence of mercury contamination in any of the samples and only one of the eight samples had a detectable arsenic level. Metals that indicated some level of increase included zinc which increased from 4 $\pm$ 4 ug/l to 12 $\pm$ 11 ug/l, iron which increased from < 5 ug/l to 56 $\pm$ 44 ug/l and manganese which increased from < 1 ug/l to 10 $\pm$ 16 ug/l. These levels of contamination are significant in the context of using the sampler for collecting water samples but not for sediment samples. As well, the liquid portion of the sample is decanted prior to obtaining the sediment sample.

## 4.2 Freeze Core Sampler Contamination

Due to the samplers soft copper/brass construction, sediment samples collected by this method would result in Cd, Cu, Pb and Zn contamination (abrasion on larger rocks as sampler is installed) (Table 2). There was no evidence of mercury contamination or other metals such as As, Fe, Al, Mn and Mg.

## 4.3 Reference Samples

Results obtained by the analytical methods used in this study for the most part compared well with certified NRC reference samples. The exceptions for both reference samples included Ba, Be, Cr, Mo, Sr, Ti, V, Al, and Na which were lower (Table 3). In addition, for reference sample MESS 1, Mn and Ca were lower. For metals such as As, Cd, Co, Cu, Mg, Ni, Pb, Zn and Fe a close similarity between mean results was evident. For the EPS-ICAP analyses, the relative standard deviation ranged between 23-39% for As, 33-64% for Cd and 26-35% for Co. For all other metals the relative standard deviation was less than 10% (Table 3).

TABLE 1 CONTAMINATION CONTROL TESTS FOR STAINLESS STEEL SYRINGE

| METAL* | DISTILLED WATER | | | | | | SYRINGE DRAWN DISTILLED WATER | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\bar{x}$ | S.D. | | | | | | | | | $\bar{x}$ | S.D. |
| Hg | < .2 | < .2 | < .2 | < .2 | < .2 | 0 | < .2 | < .2 | < .2 | < .2 | < .2 | - | < .2 | - | < .2 | 0 |
| As | < .5 | < .5 | < .5 | < .5 | < .5 | 0 | < .5 | < .5 | < .5 | < .5 | < .6 | 1.0 | < .5 | < .5 | .6 | .2 |
| Ba | < .001 | < .001 | < .001 | < .001 | < .001 | 0 | < .001 | < .001 | < .001 | < .001 | < .001 | < .001 | .001 | .001 | < .001 | 0 |
| Be | < .001 | < .001 | < .001 | < .001 | < .001 | 0 | < .001 | < .001 | < .001 | < .001 | < .001 | < .001 | < .001 | < .001 | < .001 | 0 |
| Cd | < .002 | < .002 | < .002 | < .002 | < .002 | 0 | < .002 | < .002 | < .002 | < .002 | < .002 | < .002 | < .002 | < .002 | < .002 | 0 |
| Co | < .005 | < .005 | < .005 | < .006 | < .005 | 0 | < .005 | < .005 | < .005 | < .005 | < .006 | < .006 | < .006 | < .006 | < .005 | 0 |
| Cr | < .005 | < .005 | < .005 | < .006 | < .005 | 0 | < .005 | < .005 | .006 | .010 | < .006 | < .006 | < .006 | < .006 | .006 | .002 |
| Cu | < .005 | < .005 | < .005 | < .006 | < .005 | 0 | < .005 | < .005 | < .005 | < .005 | .010 | < .006 | .007 | < .006 | .006 | .002 |
| Mn | < .001 | < .001 | < .001 | < .001 | < .001 | 0 | .002 | .002 | .002 | .007 | .049 | .009 | .003 | .002 | .010 | .016 |
| Mo | < .005 | < .005 | < .005 | < .006 | < .005 | 0 | < .005 | < .005 | < .005 | < .005 | < .006 | < .006 | < .006 | < .006 | < .005 | 0 |
| Ni | < .02 | < .02 | < .02 | < .02 | < .02 | 0 | < .02 | < .02 | < .02 | .03 | < .02 | < .02 | < .02 | < .02 | .02 | .004 |
| P | < .05 | < .05 | < .05 | < .06 | < .05 | 0 | < .05 | < .05 | < .05 | < .05 | < .06 | < .06 | < .06 | < .06 | < .05 | 0 |
| Pb | < .02 | < .02 | < .02 | < .02 | < .02 | 0 | < .02 | < .02 | < .02 | < .02 | < .02 | < .02 | < .02 | < .02 | < .02 | 0 |
| Sn | < .01 | < .01 | < .01 | < .01 | < .01 | 0 | < .01 | < .01 | < .01 | < .01 | < .01 | < .01 | < .01 | < .01 | < .01 | 0 |
| Sr | < .001 | < .001 | < .001 | < .001 | < .001 | 0 | < .001 | < .001 | < .001 | < .001 | .002 | < .001 | < .001 | < .001 | .001 | 0 |
| Ti | < .002 | < .002 | < .002 | < .002 | < .002 | 0 | < .002 | < .002 | < .002 | < .002 | < .002 | < .002 | .005 | .002 | .002 | .001 |
| V | < .01 | < .01 | < .01 | < .01 | < .01 | 0 | < .01 | < .01 | < .01 | < .01 | < .01 | < .01 | < .01 | < .01 | < .01 | 0 |
| Zn | < .002 | < .002 | .010 | < .002 | .004 | .004 | .005 | < .002 | .019 | .035 | .011 | .003 | .011 | .007 | .012 | .011 |
| Al | < .05 | < .05 | < .05 | < .06 | < .05 | 0 | < .05 | < .05 | < .05 | < .05 | < .06 | < .06 | .06 | .08 | .06 | .01 |
| Fe | < .005 | < .005 | < .005 | < .006 | < .005 | 0 | .011 | .008 | .050 | .141 | .062 | .024 | .084 | .065 | .056 | .044 |
| Si | < .1 | < .1 | < .1 | < .1 | < .1 | 0 | < .1 | < .1 | < .1 | < .1 | < .1 | < .1 | < .1 | .1 | < .1 | 0 |
| Ca | < .1 | < .1 | < .1 | < .1 | < .1 | 0 | < .1 | < .1 | < .1 | < .1 | .7 | < .1 | < .1 | < .1 | .2 | .2 |
| Mg | < .1 | < .1 | < .1 | < .1 | < .1 | 0 | < .1 | < .1 | < .1 | < .1 | < .1 | < .1 | < .1 | < .1 | < .1 | 0 |
| Na | < .2 | < .2 | < .2 | < .2 | < .2 | 0 | < .2 | < .2 | < .2 | < .2 | 1.2 | .2 | < .2 | < .2 | .3 | .4 |
| | E | E | E | T | | | E | E | E | E | T | T | T | T | | |

* mg/l except Hg and As as ug/l
E = extractable ICAP
T = total ICAP

TABLE 2 CONTAMINATION TEST FOR FREEZE CORE SAMPLES

| TOTAL METAL* | DISTILLED | SPIKED DISTILLED** |
|---|---|---|
| Hg | < .2 | < .2 |
| As | < .05 | < .05 |
| Ba | < .001 | < .001 |
| Be | < .001 | < .001 |
| Cd | < .002 | [.735] |
| Co | < .005 | < .005 |
| Cr | < .005 | < .005 |
| Cu | < .005 | [14.8] |
| Mn | .004 | < .001 |
| Mo | < .005 | < .005 |
| Ni | < .02 | < .02 |
| P | < .05 | [.52] |
| Pb | < .02 | [.35] |
| Sn | < .01 | < .01 |
| Sr | < .001 | < .001 |
| Ti | < .002 | < .002 |
| V | < .01 | < .01 |
| Zn | < .002 | [4.57] |
| Al | .07 | < .05 |
| Fe | .014 | .008 |
| Si | < .1 | < .1 |
| Ca | .2 | < .1 |
| Mg | .1 | < .1 |
| Na | < .2 | < .2 |

*mg/l except Hg as ug/l
**spiked with filings from the probe
[ ] - contamination evident

TABLE 3 NRC REFERENCE SEDIMENT DATA FOR 1983

| METAL | EPS - ICAP* (BCSS 1) | | | | NRC - BCSS 1 | | EPS - ICAP* (MESS 1) | | | | NRC - MESS 1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (ug/g) | n | $\bar{x}$ | (S.D.) | R.S.D. (%) | Certified $\bar{x}$ | (± 95%) | n | $\bar{x}$ | (S.D.) | R.S.D. (%) | Certified $\bar{x}$ | (± 95%) |
| As | 14 | 9.6 | (3.7) | 39 | 11.1 | (1.4) | 12 | 8.9 | (2.1) | 23 | 10.6 | (1.2) |
| Ba | 14 | 55.7 | (5.5) | 9.8 | 350 | | 12 | 48.1 | (3.1) | 6.5 | 270 | |
| Be | 14 | 0.56 | (0.05) | 8.8 | 1.3 | (0.3) | 12 | 0.68 | (.05) | 6.7 | 1.9 | (0.2) |
| Cd | 14 | 0.35 | (0.12) | 33 | 0.25 | (0.04) | 12 | 0.49 | (.31) | 64 | 0.59 | (0.1) |
| Co | 14 | 8.4 | (3.0) | 35 | 11.4 | (2.1) | 12 | 8.3 | (2.2) | 26 | 10.8 | (1.9) |
| Cr | 14 | 56.3 | (4.2) | 7.5 | 123 | (14) | 12 | 32.3 | (1.4) | 4.2 | 71 | (11) |
| Cu | 14 | 16.5 | (0.7) | 4.5 | 18.5 | (2.7) | 12 | 26.0 | (1.8) | 6.8 | 25.1 | (3.8) |
| Mn | 14 | 211 | (6) | 2.9 | 229 | (15) | 12 | 353 | (12) | 3.4 | 513 | (25) |
| Mo | 14 | 0.83 | (0.07) | 8.8 | 1.9 | | 12 | 0.83 | (0.08) | 9.3 | 2.2 | |
| Ni | 14 | 51.8 | (2.3) | 4.4 | 55.3 | (3.6) | 12 | 23.3 | (1.5) | 6.3 | 29.5 | (2.7) |
| P | 14 | 739 | (18) | 2.5 | 672 | (70) | 12 | 650 | (17) | 2.6 | 637 | (61) |
| Pb | 14 | 18.9 | (1.5) | 8.0 | 22.7 | (3.4) | 12 | 30.0 | (2.1) | 7.1 | 34.0 | (6.1) |
| Sn | 14 | < 2 | | | 3 | | 12 | < 2 | | | 6 | |
| Sr | 14 | 35.6 | (1.5) | 4.3 | 96 | | 12 | 30.6 | (1.3) | 4.3 | 89 | |
| Ti | 14 | 316 | (34) | 11 | 4400 | (144) | 12 | 438 | (39) | 8.8 | 5430 | (168) |
| V | 14 | 48.2 | (2.7) | 5.6 | 93.4 | (4.9) | 12 | 37.6 | (1.4) | 3.8 | 72.4 | (5.3) |
| Zn | 14 | 110 | (2.4) | 2.2 | 119 | (12) | 12 | 184 | (6) | 3.4 | 191 | (17) |
| Al (%) | 14 | 2.27 | (0.16) | 7.2 | 6.26 | (0.22) | 12 | 1.79 | (0.08) | 4.6 | 5.84 | (0.2) |
| Fe (%) | 14 | 2.74 | (0.07) | 2.5 | 3.29 | (0.10) | 12 | 2.39 | (0.07) | 2.9 | 3.05 | (0.17) |
| Ca | 14 | 4329 | (130) | 3.0 | 5430 | (530) | 12 | 2488 | (95) | 3.8 | 4810 | (460) |
| Mg (%) | 14 | 1.19 | (0.04) | 3.6 | 1.47 | (0.14) | 12 | .665 | (.024) | 3.7 | .868 | (.054) |
| Na (%) | 14 | .83 | (0.04) | 4.3 | 2.02 | (0.16) | 12 | 0.64 | (0.03) | 4.2 | 1.85 | (0.11) |
| Hg** | 18 | .239 | (.076) | 32 | 0.129 | (0.012) | 13 | .315 | (.108) | 34 | 0.171 | (0.014) |

*reverse aqua regia digest (not a total digest for silica associated or refractory compounds)
**Hg analyzed on Pharmacia Mercury Monitor
R.S.D. = relative standard deviation

For mercury, the EPS mercury results were higher than the reference samples and the relative standard deviation was 32-34% (Table 3).

## 4.4 Particle Size Analysis

Freeze core samples from the area of streambed that syringe samples were collected indicated that the < .15 mm fraction made up < 0.5% of the total sample for Yakoun-1 and < 3.1% for Florence-1 (Table 4). For the syringe samples, the < .15 mm fraction made up 45-49% of the sample for Yakoun-1 and 60-71% for Florence-1. The syringe method collects an adequate sample of the < .15 mm fraction, used for metal analyses and minimizes the need to sieve out the large fractions.

## 4.5 Organic Content

Organic content was not measured on the September 1982 samples. For the February syringe samples, Barbie-2 had the highest organic content ($\bar{x}$ = 26.5%) and Yakoun-2 the least ($\bar{x}$ = 6.4%) (Table 5). Organic content was measured on two freeze core samples collected at Barbie-3 ($\bar{x}$ = 13.3%). The syringe samples at the same location had a mean organic content of 13.6%.

## 4.6 Heavy Metal Content of Intergravel Fine Sediments

Results for the September 1982 and February 1983 metal analyses on Barbie Creek, Yakoun River, Canoe Creek and Florence Creek are presented in Appendix III. Results for the other streams sampled are presented in Appendix IV.

**4.6.1 Sampler Differences (at Barbie-3).** A comparison was made at Barbie-3 between the metal concentration of samples collected with the syringe sampler and the freeze core sampler. The results indicated that significant differences exist between the two methods, although both analyses were on the < 150 um fraction. A T-test indicated sample means were significantly different ($P < .05$) for Hg, As, Ba, Co, Cr, Sn and Fe (Table 6).

TABLE 4 PARTICLE SIZE DISTRIBUTION OF FREEZE CORE AND SYRINGE SAMPLES

| SIZE RANGE (mm) | YAKOUN-1 (SEPTEMBER 15, 1982) | | | | FLORENCE-1 (SEPTEMBER 15, 1982) | | | |
|---|---|---|---|---|---|---|---|---|
| | Freeze Core | | Syringe | | Freeze Core | | Syringe | |
| | i | ii | i | ii | i | ii | i | ii |
| > 9.5 (%) | 60.6 | 18.9 | 0 | 0 | 84.4 | 56.5 | 0 | 0 |
| > 2.36 , < 9.5 (%) | 28.3 | 54.8 | 0 | 0 | 10.6 | 14.6 | 0 | 0 |
| > 1.18 , < 2.36 (%) | 6.7 | 14.5 | 3.5 | 3.7 | 2.5 | 3.9 | 0.8 | 0 |
| > .30 , < 1.18 (%) | 4.0 | 10.8 | 37.5 | 41.4 | 1.8 | 18.3 | 16.9 | 10.2 |
| > .15 , < .30 (%) | 0.2 | 0.5 | 10.5 | 10.2 | 0.2 | 3.6 | 24.4 | 18.9 |
| > .075 , < .15 (%) | 0.1 | 0.2 | 17.3 | 12.0 | 0.2 | 1.3 | 32.3 | 34.8 |
| < .075 | 0.1 | 0.3 | 31.2 | 32.7 | 0.3 | 1.8 | 25.6 | 36.0 |
| < .15 (%) | 0.2 | 0.5 | 48.5 | 44.7 | 0.5 | 3.1 | 57.9 | 70.8 |

TABLE 5 PERCENT ORGANIC CONTENT OF < 150 um SEDIMENT FRACTION

| | BARBIE CREEK | | | | | | YAKOUN RIVER | | | | CANOE CREEK | | FLORENCE CR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 1 | | 2 | | 1 | | 1 | |
| | i | ii | i | ii | i | ii | i | ii | i | ii | i | ii | i | ii |
| Syringe Samples | | | | | | | | | | | | | | |
| Sep. 82 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Feb. 83 | 10.4 | 10.8 | 29.3 | 23.7 | 11.5 | 15.7 | 6.6 | 8.2 | 6.5 | 6.1 | 19.9 | 20.1 | 16.9 | 19.0 |
| Freeze Core Samples | | | | | | | | | | | | | | |
| Feb. 83 | - | - | - | - | 13.6 | 12.9 | - | - | - | - | - | - | 6.7 | - |

TABLE 6 COMPARISON OF HEAVY METAL CONCENTRATION OF INTERGRAVEL FINE SEDIMENTS COLLECTED BY FREEZE CORE SAMPLER AND SYRINGE SAMPLER AT BARBIE-3 (February 22, 1983)

| METAL* | FREEZE CORE | | | | | | SYRINGE | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | $\bar{x}$ | S.D. | 1 | 2 | 3 | 4 | 5 | $\bar{x}$ | S.D. |
| [Hg]** | .16 | .17 | .17 | .13 | .16 | .02 | .32 | .30 | .27 | .33 | .37 | .32 | .04 |
| [As] | 99 | 112 | 157 | 84 | 113 | 31 | 34 | 40 | 34 | 47 | 55 | 42 | 9 |
| [Ba] | 546 | 304 | 379 | 478 | 427 | 107 | 181 | 186 | 214 | 191 | 224 | 199 | 19 |
| Be | .5 | .4 | .6 | .4 | .5 | .1 | .4 | .3 | .3 | .4 | .4 | .4 | .1 |
| [Co] | 115 | 77.7 | 101 | 89.3 | 95.7 | 15.9 | 20.9 | 20.6 | 23.2 | 25.5 | 29.3 | 23.9 | 3.6 |
| [Cr] | 29.9 | 30.1 | 30.1 | 37.1 | 31.8 | 3.5 | 51 | 48 | 65 | 53 | 48 | 53 | 7 |
| Ni | 31 | 16 | 25 | 36 | 27 | 9 | 28 | 23 | 39 | 29 | 55 | 35 | 13 |
| [Sn] | 5 | 5 | 6 | 6 | 5 | 1 | 3 | 3 | 5 | 3 | 3 | 3 | 1 |
| Sr | 80.5 | 81 | 74.1 | 221 | 114 | 71 | 86.7 | 78.3 | 117 | 80 | 72.8 | 87 | 17.5 |
| V | 99 | 111 | 119 | 113 | 110 | 8 | 108 | 104 | 100 | 107 | 105 | 105 | 3 |
| Al | 34500 | 39000 | 38600 | 38400 | 37625 | 2098 | 41000 | 38300 | 39800 | 39500 | 37700 | 39260 | 1297 |
| [Fe] | 67100 | 69000 | 84100 | 63700 | 70975 | 9020 | 48800 | 51400 | 48500 | 51100 | 56600 | 51280 | 3249 |
| Si | 3760 | 5150 | 5200 | 4800 | 4727 | 669 | 4630 | 5600 | 5220 | 5600 | 5320 | 5274 | 398 |
| Ca | 5000 | 5330 | 5220 | 7120 | 5667 | 978 | 5000 | 5030 | 5860 | 4790 | 4700 | 5076 | 460 |
| Mg | 7400 | 7750 | 6610 | 10800 | 8140 | 1836 | 8750 | 7920 | 9190 | 8020 | 7400 | 8256 | 710 |
| Na | 520 | 510 | 420 | 850 | 575 | 189 | 570 | 600 | 750 | 550 | 520 | 598 | 90 |

* ICAP, < 0.15 mm Fraction, as ug/g

** Hg, (Pharmacia Mercury Monitor)

[] significantly different (T-test, $P < .05$)

The mean mercury concentration for the freeze core sample was 0.16 ug/g (S.D. = .02) compared to 0.32 ug/g (S.D. = .04) for the syringe samples. Analysis of the freeze core probe did not indicate a contamination problem with Hg, As or the other metals listed (Table 2). The reason for these differences is not readily explained and further work is required to assess this variability. A comparison of a set of samples fractioned by eye into a floccule fraction and granular fraction (Plate 2) indicated higher mercury levels occurred in the floccule fraction (Table 7). The floccule fraction contained 48-91% of the < 150 um fraction and the granular fraction contained 4-16% of the < 150 um fraction (Table 7).

There are some significant differences in the results of these two sample methods. The method of obtaining samples for metal analysis from clastic stream sediments could be a significant factor in determining pre-development (baseline) levels and post-development (impact) trends.

The mercury levels for the February 1983 freeze core samples are low at Barbie-3 compared to samples collected by EPS in 1981/82 (unpublished data, Appendix V). Mercury results collected over 1981 to 1983 at Barbie-3 are shown on Figure 4. The arsenic level of the freeze core sampler in February 1983 ($\bar{x}$ = 113 ug/g, S.D. = 31) is similar to that in March 1982 ($\bar{x}$ = 123 ug/g, S.D. = 19) as are the Al and Fe results (Appendix II, V).

**4.6.2 Mercury (syringe samples).** The mean mercury levels of sediment samples collected from the B.C. streams monitored to date indicate the Barbie-3 (September, 1982) samples had the highest overall mean of 0.47 ug/g (Figure 5, Appendix III, IV). On both the September 1982 and February 1983 surveys, Barbie-3 had a higher mean mercury level than the upstream control Barbie-1. This may reflect the reported high levels of mercury associated with the Cinola mine property. A T-test indicated that the seasonal differences between mean mercury levels for the stations monitored on the Yakoun drainage were significantly different ($P < .05$) for Barbie Creek stations 1 and 3 and Canoe Creek station 1.

TABLE 7 MERCURY CONCENTRATION AND PARTICLE SIZE DISTRIBUTION OF FLOCCULE AND GRANULAR FRACTIONS OF INTERGRAVEL FINE SEDIMENTS (syringe samples) - SEPTEMBER 15, 1982

| | B1 | | B2 | | B3 | | Y1 | | Y2 | | C1 | | F1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | G | F | G | F | G | F | G | F | G | F | G | F | G |
| Hg (ug/g) | .31 | .17 | .34 | .25 | .38 | .34 | .25 | .15 | .20 | .13 | .27 | .11 | .40 | .24 |
| % ≥ .15 mm | 9 | 94 | 40 | 90 | 52 | 84 | 49 | 95 | 35 | 94 | 45 | 96 | 18 | 93 |
| % < .15 mm | 91 | 6 | 60 | 10 | 48 | 16 | 51 | 5 | 65 | 6 | 55 | 4 | 82 | 7 |

F = floccule fraction which settled out as a layer over granualr material

G - granular layer

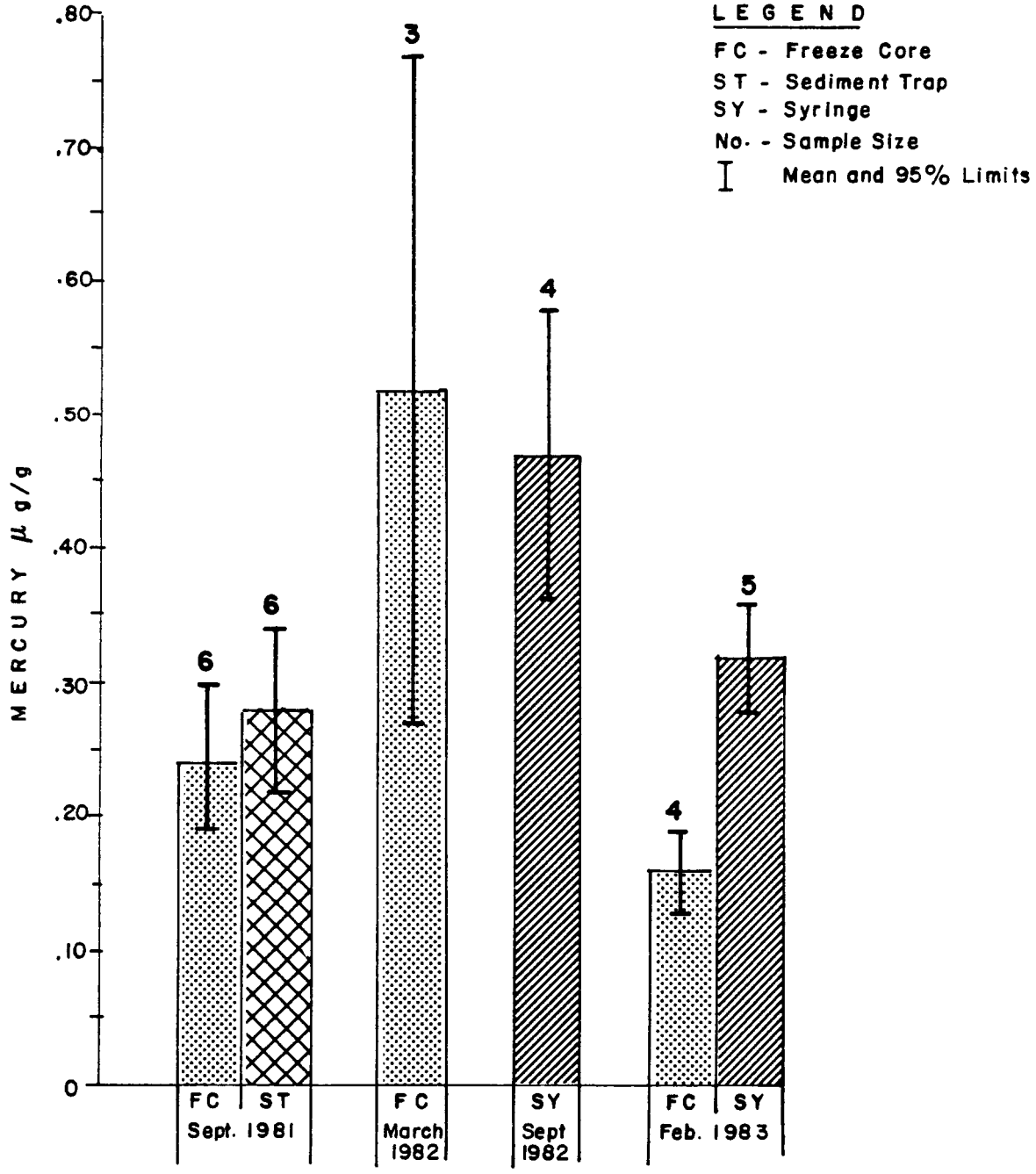


FIGURE 4 MERCURY LEVELS AT STATION BARBIE 3 OVER 1981 TO 1983

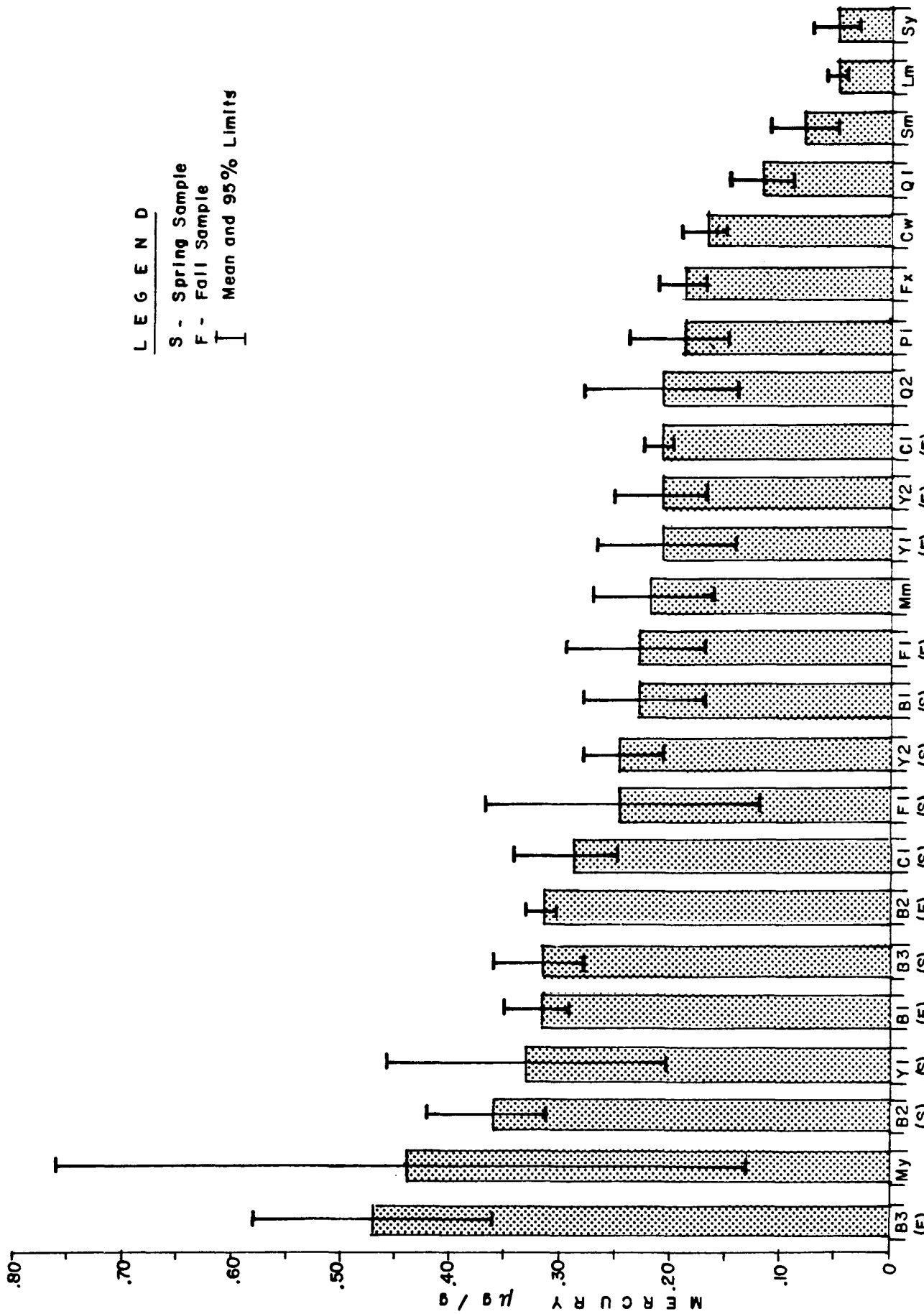


FIGURE 5 SYRINGE SAMPLER SEDIMENT MERCURY LEVELS

Sediment samples from Pinchi Creek had a mean mercury content of 0.19 ug/g (Appendix IV). Pinchi Creek drains Pinchi Lake the northern edge of which lies along the Pinchi fault zone (Siegel et al., 1985). Mercury was actively mined from a high grade cinnabar lode deposit near Pinchi Lake from 1940 to 1944.

4.6.3 Arsenic (syringe samples). The mean sediment arsenic levels indicate the Barbie Creek system has high levels compared to the other streams monitored in B.C. (Figure 6, Appendices III and IV). Again, these levels likely reflect the nature of Cinola mine property. Stations Barbie-2 (February 1983) and Barbie-3 (September 1982) had the highest mean concentrations (63 ug/g and 62 ug/g respectively).

4.6.4 Zinc (syringe samples). The highest mean zinc levels were recorded for Lemieux Creek (164 ug/g) and Foxy Creek (156 ug/g) (Figure 7, Appendices III and IV). For the Yakoun River drainage, station Barbie-3 had the next highest mean concentration of 127-130 ug/g) (Figure 7).

4.6.5 Copper (syringe samples). The highest mean copper level (86 ug/g) was recorded for the Quinsam River at station Q-1 (Figure 8, Appendices III and IV). The highest mean copper level for a Yakoun drainage station was 40 ug/g at station Yakoun-2 (Figure 8).

4.6.6 Iron (syringe samples). Results for sediment iron levels are shown in Figure 9. Florence Creek had the highest mean iron content (5.9%) followed by Barbie-3 (5.1%) (Figure 9, Appendices III and IV).

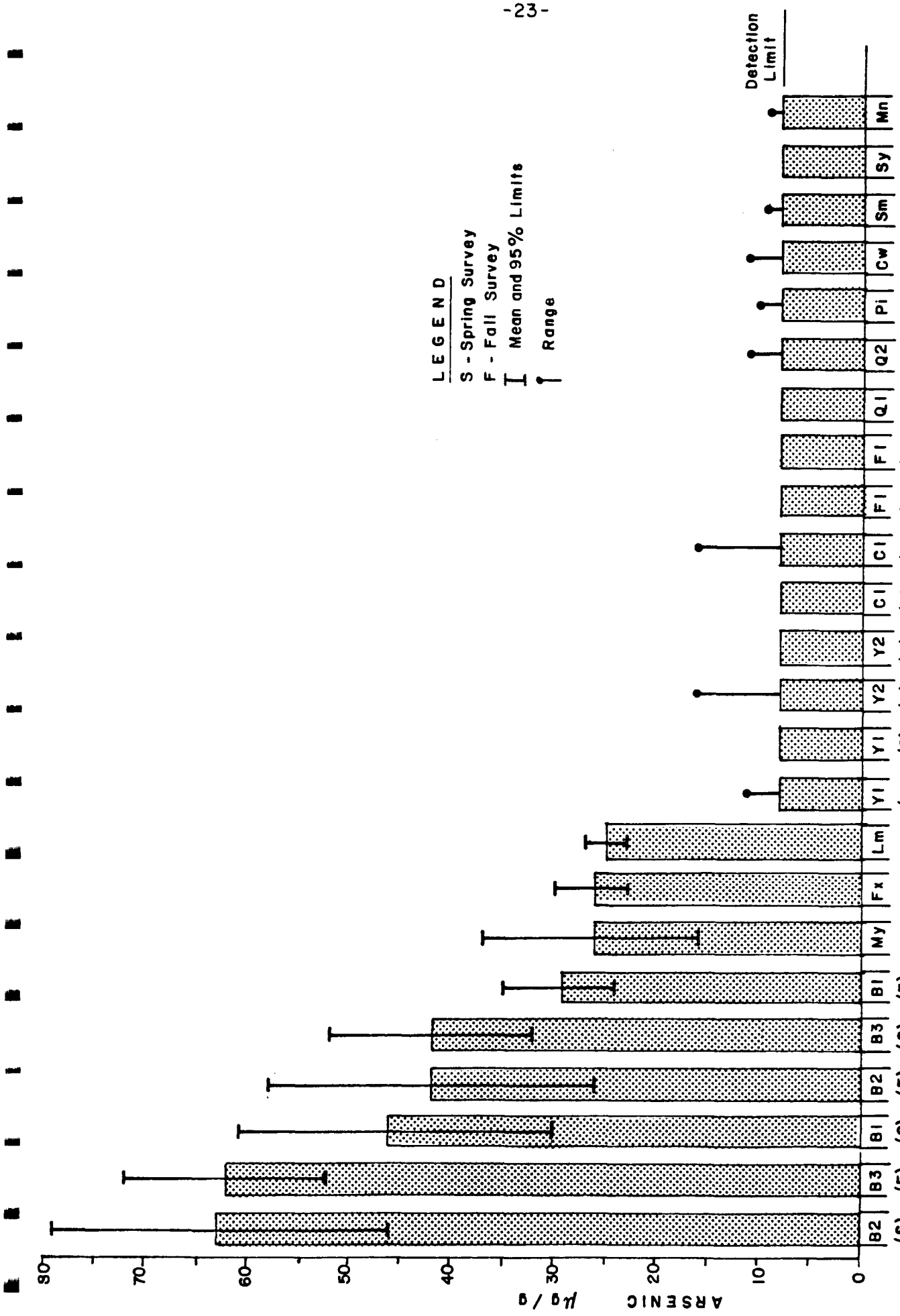


FIGURE 6 SYRINGE SAMPLER SEDIMENT ARSENIC LEVELS

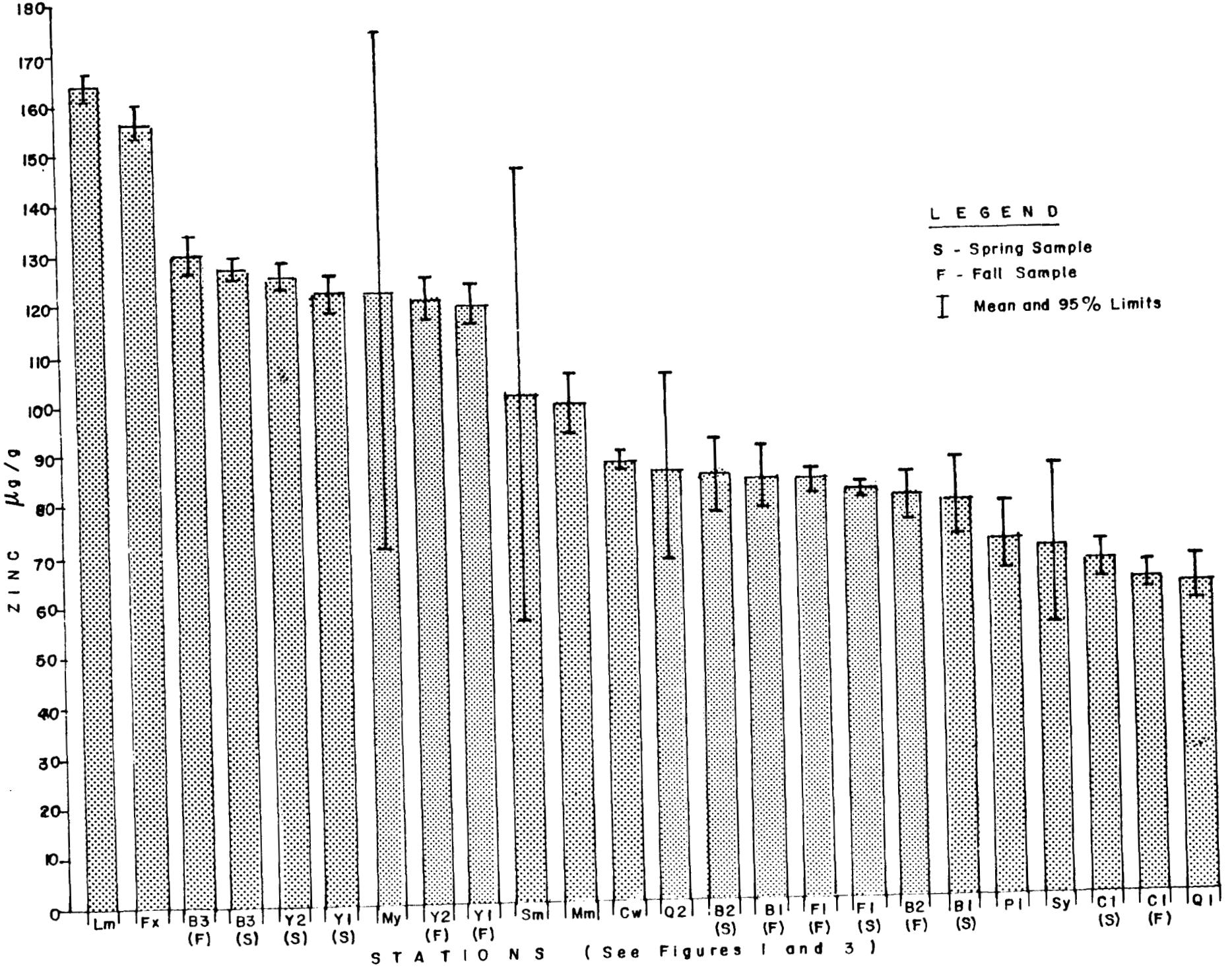


FIGURE 7 SYRINGE SAMPLER SEDIMENT ZINC LEVELS

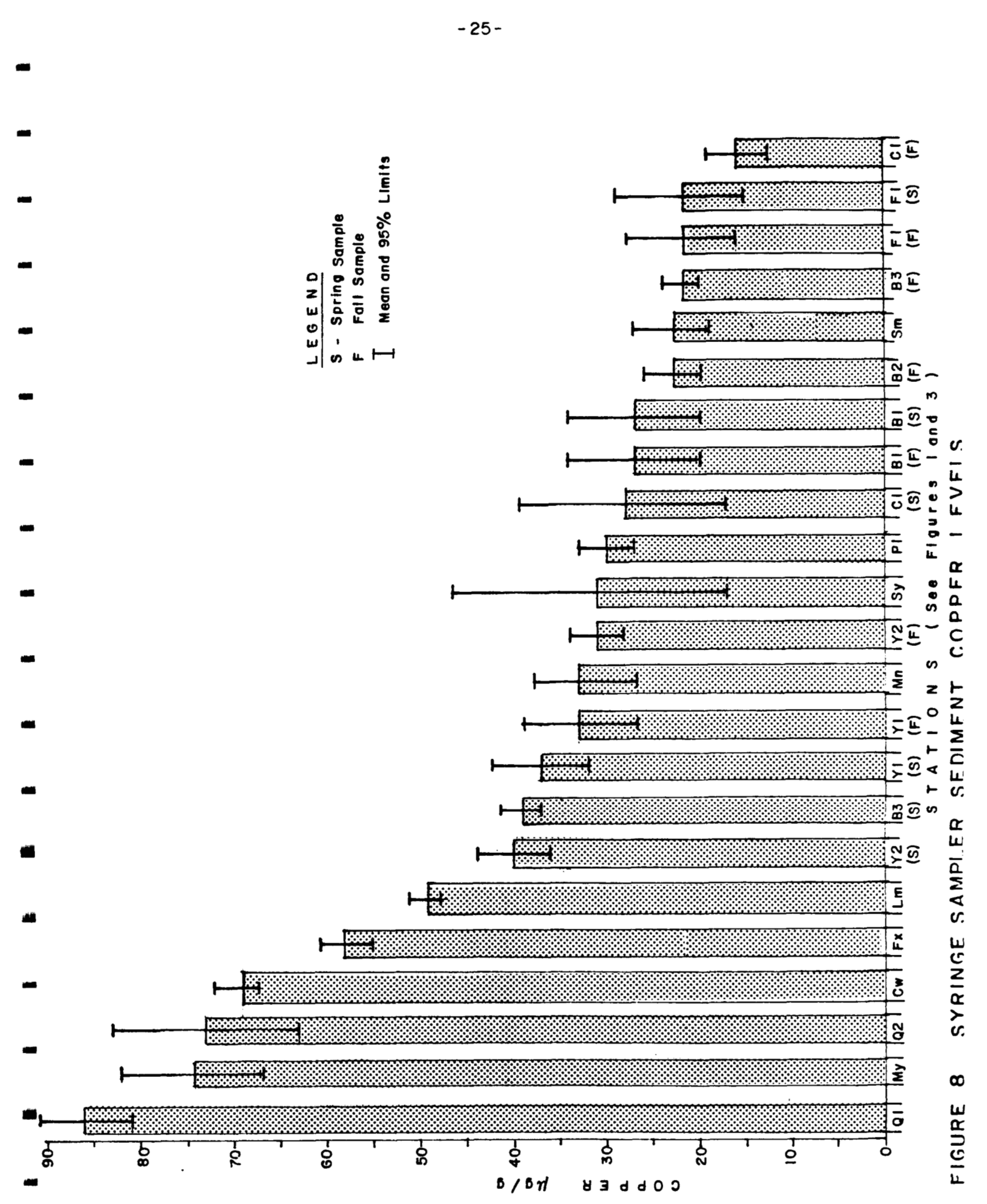


FIGURE 8 SYRINGE SAMPLER SEDIMENT COPPER LEVELS

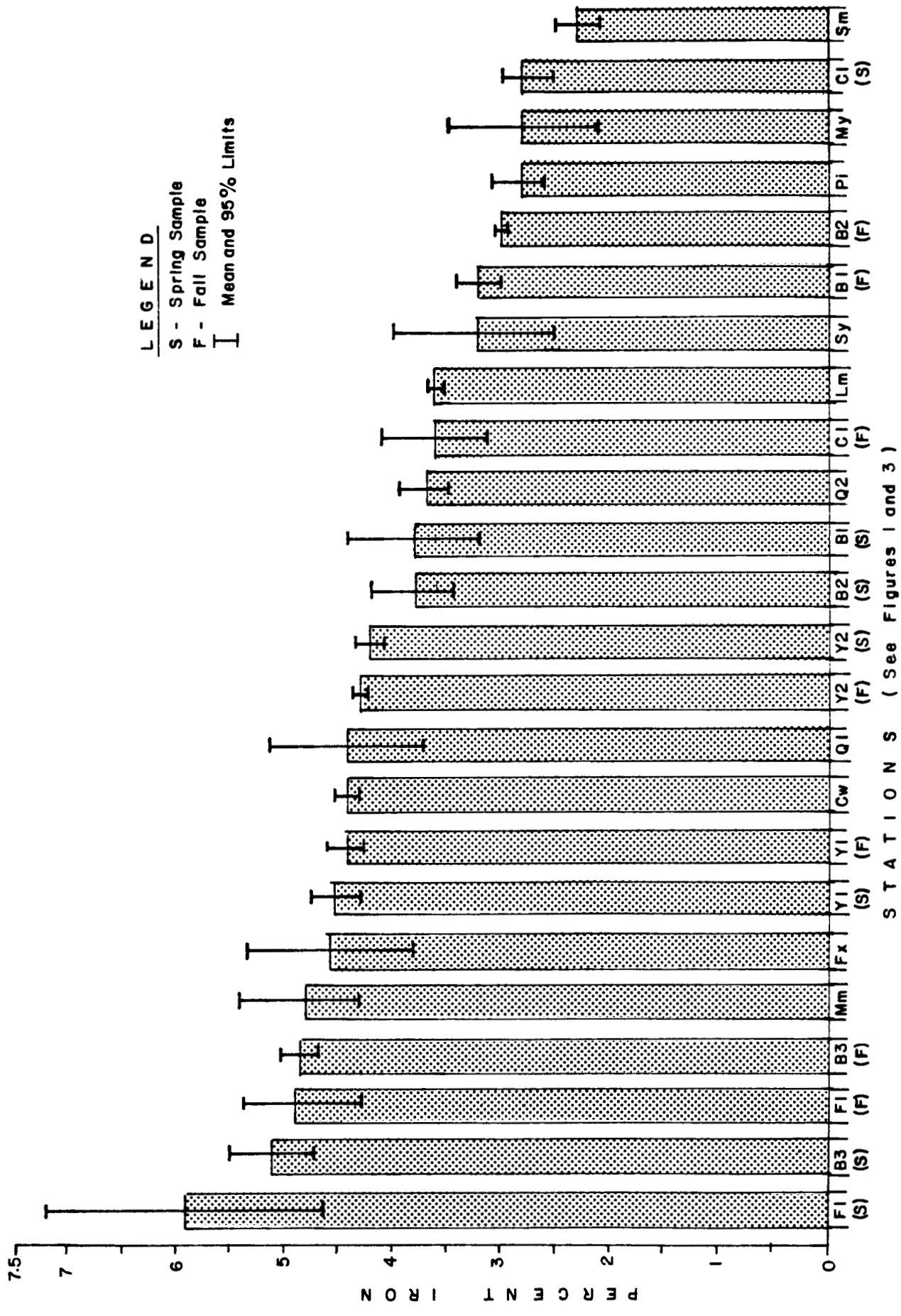


FIGURE 9 SYRINGE SAMPLER SEDIMENT IRON LEVELS

# 5 THE VALUE OF SEDIMENT MONITORING NEAR MINE SITES

Maintaining the quality of a stream bed made up of clastic material is an important aspect of environmental protection. The growth, development and survival of salmon eggs and alevin in clastic sediments are dependant on the physical and chemical characteristics of the intragravel water. To prosper, an embryo or alevin must receive an ample supply of oxygenated water of suitable temperature and free of toxic substances (McNeil and Ahnell, 1964). The transfer of metals between bottom materials and the water is a complex process depending on a multitude of factors such as the dissolved oxygen concentration, the nature and the concentration of heavy metals, the organic and inorganic ligands present, the pH and the particle size of the bottom sediments (Taylor and Demayo, 1980). Detritus in the form of fine (50-1000 um) and ultrafine (0.5-50 um) particulate organic matter is an important food source of filtering and gathering herbivorous insects (Cummins and Klug, 1979; Vannote et al., 1980). Forstner and Wittman, 1979 reported that these organisms could be affected by heavy metals occurring in their environment. There is a general increase of metal concentrations from coarse to finer-grained fractions and the affinity of heavy metals for organic substances and for their decomposition products is well recognized.

Birge et al., 1977 reported that the survival of trout embryos and alevins closely paralleled sediment test metal (Cd, Hg, Zn) concentrations. Sediment metals were substantially more lethal to eggs and embryos than to free living fish. The sediment $TL_{50}$ concentrations for trout stages cultured from 10 days prehatching through 10 days post-hatching were approximately 1 ppm for mercury, 2.15 ppm for cadmium and 210.6 ppm for zinc. Cairns et al., 1984 reported that based on a dry-weight sediment copper concentration, the 10-d $LC_{50}$ for the midge Chironomus tentans was 857-2296 ug/g. Malueg et al 1984 reported that stream sediments contaminated with copper (550-2700 ug/g) from mine tailings were significantly more toxic to the burrowing mayfly Hexagenia limbata than nonimpact control sediments (16-60 ug/g).

The occurrence, distribution and pollution effects of heavy metals in the aquatic environment has received extensive review (Hawkes and Webb, 1962; Hawkes 1976; Forstner and Wittman, 1979). Clastic stream sediments are composed predominantly of the residual and relatively insoluble products of weathering but during the course of transport along the streambed, the particle size is liable to be progressively reduced by chemical and physical disintegration (Hawkes and Webb, 1962).

Forstner and Wittman, 1979 reported that it is usually difficult to distinguish between contamination of industrial origin, "natural" pollution and pollution resulting from mining activities. Airborne dust and particulate material from smelter stacks, wind-blown particles and leachate from tailings ponds all contribute to an increase in the metal concentrations in river sediments. In order to measure changes due to a mine development, pre-monitoring data must be reproducible and have a measureable level of confidence. Thus, quantitative techniques are needed to establish these requirements. The syringe sampler used in this study fulfills those requirements to assess sediment metal levels in clastic stream sediments important to salmonids and invertebrates. While elevations in metal levels may be documentable, the significance and availability of these metals to various biological components requires further research.

## REFERENCES

Birge, W.J., J.A. Black, A.G. Westerman, P.C. Francis and J.E. Hudson. Embryopathic Effects of Waterborne and Sediment-Accumulated Cadmium, Mercury and Zinc on Reproduction and Sruvival of Fish and Amphibian Populations in Kentucky. University of Kentucky, Water Resources Research Institute, Research Report No. 100 (1977).

Cairns, M.A., A.V. Nebeker, J.H. Gakstatter and W.L. Griffis. Toxicity of Copper- Spiked Sediments to Freshwater Invertebrates. Environmental Toxicology and Chemistry. 3; 435-445 (1984).

Cummins, K.W., and M.J. Klug. Feeding Ecology of Stream Invertebrates. Ann. Rev. Ecol. Syst. 10, 147 (1979).

Fanning, M.L., and T.C. Griffing, Stage I Submision to Steering Committee for Development of New Metal Mines. Prepared for Consolidated Cinola Mines Ltd. by IEC Consultants (July, 1980).

Forstner, U., and G.T.W. Wittmann. Metal Pollution in the Aquatic Environment. Springer-Verlag, Berlin, Heidelberg, New York, (1979).

Hawkes, H.E. The Downstream Dilution of Stream Sediment Anomalies. Journal of Geochemical Exploration 6: 345-358 (1976).

Hawkes, H.E., and J.S. Webb. Geochemistry in Mineral Exploration. Harper & Row, Publishers, New York and Evanston (1962).

Laboratory Manual, Department of Environment and Department of Fisheries and Oceans (Pacific Region) (1979).

Malueg, K.W., G.S. Schuytema, J.H. Gakstatter and D.F. Krawczyk. Toxicity of Sediments from three Metal-Contaminated Areas. Environmental Toxicology and Chemistry. 3: 279-291 (1984).

McNeil, W.J., and W.H. Ahnell. Success of Pink Salmon Spawning Relative to Size of Spawning Materials. U.S.F.W.S. Special Scientific Report, Fisheries 469 (1964).

Ryan, P. Subgravel Monitoring Equipment, D.O. Monitor Mark 11. Fisheries and Oceans Canada Drawing 4-6-142 (1972).

Siegel, S.M., B.Z. Siegel, C. Lipp, A. Kruckeberg, G.H.N. Towers and H. Warren. Indicator Plant-Soil Mercury Patterns in a Mercury Rich Mining Area of British Columbia. Water, Air and Soil Pollution 25: 73-85 (1985).

Taylor, M.C., and A. Demayo. Guidelines for Surface Water Quality. Vol. 1 - Inorganic Chemical Substances, Inland Waters Directorate, Ottawa (1980).

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. The River Continuum Concept. Can. J. Fish. Aquat. Sci. 37, 130 (1980).

Walkotten, W.J. A Freezing Technique for Sampling Streambed Gravel. USDA Forest Service Research Note PNW 205 (1973).

## ACKNOWLEDGEMENTS

Thanks are extended to Mike Jones for field support, H. Grewel ad M. Araujo for metal analyses, P. Wakeman for typing and L. Pearson for drafting.

Thanks are extended to B. Kelso for reviewing this manuscript.

# APPENDIX I

## DESCRIPTION OF
## SAMPLE STATION LOCATIONS

## APPENDIX I DESCRIPTION OF SAMPLE STATION LOCATIONS

| RIVER/CREEK | STATION NUMBER* | DESCRIPTION |
|---|---|---|
| Yakoun River | Y1 | Located approximately 1.3 km downstream of Gold Creek on the north side. Access at a turnoff on Branch 40. The turnoff is located 1.2 km west of the Branch 40/Branch 47 junction. Sampled mid-stream where pink salmon were observed to spawn. |
| | Y2 | Located approximately 0.6 km downstream of Barbie Creek on the north side. Access at turnoff on Branch 40. The turnoff is located 0.5 km west of where Barbie Creek flows under Branch 40. Sampled midstream where pink salmon were observed to spawn. |
| Barbie Creek | B1 | Located upstream of Cinola Property in forested area. Approximately 30 m upstream of flagging tape marked COR OE 1 + 50. Gravel substrate and coho salmon observed at this site. |
| | B2 | Located approximately two-thirds way along road branching off to Cinola pilot plant. Creek runs along north side of road. Approximately 15 cm of gravel overlaying peat base. Sediment samples from 11 cm depth. Coho salmon observed spawning in this area. |
| | B3 | Located in gravel section half-way between Branch 40 road and the Yakoun River. Coho salmon observed to spawn at this site. |
| Canoe Creek | C1 | Located on upstream side of Yakoun logging road bridge crossing lower Canoe Creek. Gravel substrate. |
| Florence Creek | F1 | Located approximately 45 m upstream of Main Line road bridge crossing Florence Creek. Gravel substrate. Coho observed spawning in this area. |
| Cowichan River | Cw | Sampled July 27, 1983. Midstream in gravel area opposite Rotary Park, 0.5 km downstream of Highway #1. Chum salmon spawning area. |

*(See Figures 1 and 3)

CONTINUED...

## APPENDIX I DESCRIPTION OF SAMPLE STATION LOCATIONS

| RIVER/CREEK | STATION NUMBER* | DESCRIPTION |
|---|---|---|
| Foxy Creek | Fx | Sampled July 18, 1983. In gravel area downstream of Equity Mine seepage reclaim pond. |
| Lemieux Creek | Lm | Sampled October 10, 1983. Midstream in gravel area upstream of Eakin Creek. |
| Mamin River | Mm | Sampled November 3, 1983. In gravel area. At end of road turnoff approximately 0.6 km downstream of Juskatla Road branch. |
| Myra Creek | My | Sampled May 18, 1983. In gravel area at EPS station M1 just downstream of powerhouse at Westmin Mine. |
| Pinchi Creek | Pi | Sampled July 20, 1983. In gravel area immediately upstream of bridge crossing (approx. 2 km upstream of Stuart Lake). |
| Quinsam River | Q1 | Sampled June 22, 1983. In gravel area upstream of Argonaut Road crossing. Upstream of Middle Quinsam Lake. |
| | Q2 | Sampled June 22, 1983. In gravel area downstream of Argonaut Road crossing, downstream of Middle Quinsam Lake. |
| Salmon River | Sm | Sampled August 10, 1983. Midstream in gravel area upstream of 56th Avenue. |
| Seymour River | Sy | Sampled August 10, 1983. In gravel area of river running parallel to Edgewater Lane. |

*(See Figures 1 and 3)

# APPENDIX II

## SEDIMENT SAMPLE PREPARATION AND REVERSE AQUA REGIA DIGEST PROCEDURE

## APPENDIX II SEDIMENT SAMPLE PREPARATION AND REVERSE AQUA REGIA DIGEST PROCEDURE

1) Transfer sample material into labelled KRAFT soil sample envelopes, dry samples @ 60°C., until completely dry.

2) When samples are dry, disaggregate the sample material by rapping the sample bag with a rubber mallet. Occasionally, the sample bag may split, this usually occurs when the samples are marine sediments or if the bags are hit too hard. If particle sizing has been requested, split the sample material on a riffle - a normal split is ¼ for metals and ¾ for particle sizing. Ensure that the sample splits are done in a manner that minimizes biasing of the subsamples. If the particle sizing request is for only the +/- 100 mesh (0.150 mm) fractions sample splitting is not required.

3) Sieve samples through a 100 mesh (.150 mm) stainless steel screen, store the fine fraction in a labeled vial, retain the coarse fraction if requested.

4) Weigh 0.30 to 0.32 g of seived sample into calibrated 50 ml test tubes. Replicate samples, reference materials, and reagent blanks must be included with every set of samples. Normally one reference material and one blank should be run with every set of 30 or less samples, the number of replicates should be at least the square root of the number of samples in a given lot. Use computer program "SEDWT" to set up a weight file and take weights directly from the balance.

5) Add 4.5 ml concentrated NITRIC acid, 1.5 ml concentrated HYDROCHLORIC acid, swirl solution vigorously, allow to react for 30 minutes, then add 10.0 ml DI water. Reagents should be dispensed with automatic pipettors, use only "BAKER - INSTRA-ANALYZED" acids (used for trace metal analysis).

6) Place test tubes into pre-heated block and heat for three hours. Sample solutions should boil gently during the digestion period - exercise care with very fine grained samples, they are likely to cause bumping problems. Bring volume of sample down to approximately 12 ml in order to compromise for equal matrix of reagents, as are used in ICP and GFAA analysis.

7) Remove test tubes and allow to cool before diluting sample solutions to 50.0 ml. Cap test tubes and mix well, allow sample solutions to settle out overnight. Carefully decant sample solutions into 30 ml acid washed poly bottles, ensuring that particulate material is not transferred to the sample bottles.

8) Analyze sample solutions by ICAP and/or GFAA. Use computer program to calculate final results. Analyze mercury on Pharmacia Mercury Monitor Model 100.

# APPENDIX III

## HEAVY METAL CONCENTRATION AND PARTICLE SIZE DISTRIBUTION OF INTERGRAVEL FINE SEDIMENTS FOR BARBIE CREEK, YAKOUN RIVER, CANOE CREEK AND FLORENCE CREEK

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 1 (82/09/15)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .32 | .35 | .28 | .33 | | .32 | .03 |
| As | 33 | 25 | 28 | 32 | | 30 | 4 |
| Ba | 159 | 123 | 106 | 119 | | 127 | 23 |
| Be | .3 | .2 | .3 | .3 | | .3 | .0 |
| Cd | <.3 | <.3 | <.3 | <.3 | | .3 | .0 |
| Co | 14.8 | 14.7 | 13.2 | 17.3 | | 15.0 | 1.7 |
| Cr | 98 | 79 | 157 | 189 | | 131 | 51 |
| Cu | 35 | 24 | 21 | 27 | | 27 | 6 |
| Mn | 944 | 655 | 660 | 1020 | | 820 | 190 |
| Ni | 39 | 39 | 88 | 99 | | 66 | 32 |
| P | 942 | 768 | 737 | 823 | | 818 | 90 |
| Pb | <3 | 4 | <3 | 4 | | 4 | 1 |
| Sn | <2 | 2 | <2 | <2 | | 2 | 0 |
| Sr | 61.9 | 55.8 | 44.5 | 52.5 | | 53.7 | 7.3 |
| V | 73 | 67 | 71 | 77 | | 72 | 4 |
| Zn | 91.3 | 81.8 | 80.3 | 82.2 | | 83.9 | 5.0 |
| Al | 27900 | 26500 | 26900 | 28000 | | 27325 | 741 |
| Fe | 33200 | 29300 | 31800 | 34000 | | 32075 | 2061 |
| Si | 3130 | 3330 | 3260 | 4140 | | 3465 | 458 |
| Ca | 4690 | 4850 | 4280 | 4720 | | 4635 | 247 |
| Mg | 6740 | 6450 | 6140 | 6570 | | 6475 | 253 |
| Na | 460 | 470 | 420 | 420 | | 443 | 26 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 75.2 | 79.4 | 84.3 | 79.3 | | 79.6 | 3.7 |
| < .15 mm | 24.8 | 20.6 | 15.7 | 20.7 | | 20.5 | 3.7 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 1 (83/02/22)

| Metal • | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .21 | .21 | .27 | .28 | .16 | .23 | .05 |
| As | 55 | 29 | 63 | 38 | 45 | 46 | 13 |
| Ba | 103 | 102 | 114 | 100 | 112 | 106 | 6 |
| Be | .3 | .2 | .3 | .4 | <.2 | .3 | .1 |
| Cd | <.3 | <.3 | <.3 | <.3 | <.3 | .3 | .0 |
| Co | 18.4 | 6.1 | 15.2 | 9.6 | 4.0 | 10.7 | 6.1 |
| Cr | 73 | 43 | 64 | 48 | 74 | 61 | 14 |
| Cu | 24 | 21 | 36 | 29 | 24 | 27 | 6 |
| Mn | 1940 | 1060 | 1630 | 950 | 648 | 1246 | 527 |
| Ni | 41 | 19 | 34 | 24 | 40 | 32 | 10 |
| P | 944 | 763 | 1030 | 1520 | 785 | 1008 | 307 |
| Pb | 4 | <3 | <3 | <3 | <3 | 3 | 0 |
| Sn | <2 | 2 | <2 | <2 | 3 | 2 | 0 |
| Sr | 48.7 | 49.2 | 42.9 | 37.4 | 48.9 | 45.4 | 5.2 |
| V | 80 | 74 | 93 | 79 | 86 | 82 | 7 |
| Zn | 74.1 | 72.8 | 89.2 | 81.0 | 78.4 | 79.1 | 6.5 |
| Al | 27300 | 28600 | 33600 | 43200 | 30600 | 32660 | 6353 |
| Fe | 38400 | 31900 | 45100 | 33500 | 40200 | 37820 | 5308 |
| Si | 5060 | 5170 | 4630 | 5000 | 4940 | 4960 | 203 |
| Ca | 3870 | 3760 | 3550 | 2910 | 3530 | 3524 | 372 |
| Mg | 5280 | 5760 | 6040 | 4700 | 6430 | 5642 | 673 |
| Na | 340 | 350 | 350 | 310 | 320 | 334 | 18 |

• ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\geq$ .15 mm | 86.8 | 86.8 | 89.5 | 83.4 | 92.5 | 87.8 | 3.4 |
| $\leq$ .15 mm | 13.2 | 13.2 | 10.5 | 16.6 | 7.5 | 12.2 | 3.4 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 2 (82/09/15)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .33 | .30 | .31 | .33 | | .32 | .02 |
| As | 53 | 29 | 43 | 44 | | 42 | 10 |
| Ba | 120 | 112 | 110 | 108 | | 113 | 5 |
| Be | .3 | .2 | .3 | <.2 | | .3 | .1 |
| Cd | <.3 | <.3 | <.3 | <.3 | | .3 | .0 |
| Co | 11.6 | 11.9 | 14.1 | 13.4 | | 12.8 | 1.2 |
| Cr | 42 | 59 | 60 | 59 | | 55 | 9 |
| Cu | 20 | 22 | 23 | 26 | | 23 | 3 |
| Mn | 381 | 425 | 406 | 412 | | 406 | 18 |
| Ni | 19 | 30 | 33 | 33 | | 29 | 7 |
| P | 842 | 825 | 827 | 845 | | 835 | 10 |
| Pb | 3 | 3 | <3 | 5 | | 4 | 1 |
| Sn | <2 | <2 | <2 | 4 | | 3 | 1 |
| Sr | 44.0 | 46.9 | 43.7 | 44.9 | | 44.9 | 1.4 |
| V | 65 | 66 | 68 | 67 | | 67 | 1 |
| Zn | 74.1 | 81.0 | 79.9 | 84.1 | | 79.8 | 4.2 |
| Al | 28100 | 28300 | 29600 | 28400 | | 28600 | 678 |
| Fe | 29600 | 29600 | 29800 | 30200 | | 29800 | 283 |
| Si | 3140 | 2940 | 3200 | 3660 | | 3235 | 304 |
| Ca | 3550 | 3830 | 3540 | 3680 | | 3650 | 136 |
| Mg | 5420 | 5560 | 5430 | 5440 | | 5463 | 66 |
| Na | 420 | 470 | 430 | 480 | | 450 | 29 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\geq$ .15 mm | 56.5 | 67.0 | 74.5 | 70.1 | | 67.0 | 7.7 |
| $\leq$ .15 mm | 43.5 | 33.0 | 25.5 | 29.9 | | 33.0 | 7.7 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 2 (83/02/22)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .34 | .35 | .32 | .44 | .37 | .36 | .05 |
| As | 69 | 69 | 50 | 80 | 46 | 63 | 14 |
| Ba | 121 | 110 | 118 | 118 | 144 | 122 | 13 |
| Be | .2 | .2 | .3 | .2 | .2 | .2 | .0 |
| Cd | <.3 | <.3 | <.3 | <.3 | <.3 | .3 | .0 |
| Co | 4.9 | 6.3 | 5.5 | 4.4 | 5.0 | 5.2 | .7 |
| Cr | 39 | 36 | 45 | 49 | 58 | 45 | 8 |
| Cu | 35 | 28 | 28 | 27 | 32 | 30 | 4 |
| Mn | 690 | 656 | 572 | 530 | 569 | 603 | 67 |
| Ni | 20 | 18 | 23 | 30 | 32 | 25 | 6 |
| P | 1060 | 1050 | 907 | 1310 | 1220 | 1109 | 158 |
| Pb | 4 | <3 | 4 | 5 | 3 | 4 | 1 |
| Sn | 3 | <2 | 2 | <2 | 3 | 2 | 1 |
| Sr | 47.2 | 45.8 | 44.7 | 45.7 | 67.0 | 50.1 | 9.5 |
| V | 78 | 72 | 85 | 80 | 90 | 81 | 7 |
| Zn | 83.5 | 81.5 | 84.4 | 78.3 | 95.4 | 84.6 | 6.5 |
| Al | 32500 | 30400 | 32700 | 31400 | 34600 | 32320 | 1574 |
| Fe | 37400 | 35500 | 35100 | 42800 | 40800 | 38320 | 3369 |
| Si | 5480 | 5660 | 4980 | 5600 | 5540 | 5452 | 272 |
| Ca | 2860 | 3010 | 2760 | 3250 | 4440 | 3264 | 683 |
| Mg | 5020 | 5070 | 5450 | 4930 | 6200 | 5334 | 523 |
| Na | 370 | 360 | 430 | 420 | 730 | 462 | 153 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| ≥ .15 mm | 70.3 | 69.9 | 79.2 | 67.6 | 85.1 | 74.4 | 7.4 |
| ≤ .15 mm | 29.7 | 30.1 | 20.8 | 32.4 | 14.9 | 25.6 | 7.4 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 3 (82/09/15)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .39 | .47 | .42 | .60 | | .47 | .09 |
| As | 62 | 57 | 59 | 71 | | 62 | 6 |
| Ba | 194 | 184 | 183 | 207 | | 192 | 11 |
| Be | .4 | .4 | .4 | .5 | | .4 | .1 |
| Cd | <.3 | <.3 | <.3 | <.3 | | .3 | .0 |
| Co | 31.9 | 26.6 | 25.3 | 43.7 | | 31.9 | 8.4 |
| Cr | 56 | 62 | 51 | 53 | | 55 | 5 |
| Cu | 21 | 25 | 21 | 22 | | 22 | 2 |
| Mn | 1880 | 2040 | 2000 | 1830 | | 1938 | 99 |
| Ni | 36 | 36 | 24 | 29 | | 31 | 6 |
| P | 1170 | 1300 | 1300 | 1260 | | 1257 | 61 |
| Pb | <3 | <3 | <3 | <3 | | 3 | 0 |
| Sn | <2 | <2 | 3 | 4 | | 3 | 1 |
| Sr | 91.5 | 89.5 | 83.7 | 87.4 | | 88.0 | 3.3 |
| V | 92 | 88 | 86 | 94 | | 90 | 4 |
| Zn | 131.0 | 126.0 | 129.0 | 135.0 | | 130.2 | 3.8 |
| Al | 36900 | 33800 | 34800 | 36600 | | 35525 | 1477 |
| Fe | 49800 | 47800 | 46600 | 50000 | | 48550 | 1636 |
| Si | 3170 | 4050 | 3950 | 3780 | | 3737 | 394 |
| Ca | 6100 | 6090 | 5800 | 5690 | | 5920 | 207 |
| Mg | 8570 | 8000 | 8140 | 7950 | | 8165 | 282 |
| Na | 630 | 550 | 550 | 580 | | 578 | 38 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 30.9 | 39.5 | 43.4 | 48.8 | | 40.7 | 7.5 |
| < .15 mm | 69.1 | 60.5 | 56.6 | 51.2 | | 59.4 | 7.5 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : BARBIE 3 (83/02/22)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .32 | .30 | .27 | .33 | .37 | .32 | .04 |
| As | 34 | 40 | 34 | 47 | 55 | 42 | 9 |
| Ba | 181 | 186 | 214 | 191 | 224 | 199 | 19 |
| Be | .4 | .3 | .3 | .4 | .4 | .4 | .1 |
| Cd | <.3 | <.3 | <.3 | <.3 | <.3 | .3 | .0 |
| Co | 20.9 | 20.6 | 23.2 | 25.5 | 29.3 | 23.9 | 3.6 |
| Cr | 51 | 48 | 65 | 53 | 48 | 53 | 7 |
| Cu | 41 | 40 | 38 | 41 | 37 | 39 | 2 |
| Mn | 1720 | 1530 | 1560 | 1530 | 1050 | 1478 | 252 |
| Ni | 28 | 23 | 39 | 29 | 55 | 35 | 13 |
| P | 1100 | 1200 | 1060 | 1200 | 1250 | 1162 | 79 |
| Pb | 5 | <3 | 4 | 6 | 5 | 5 | 1 |
| Sn | 3 | 3 | 5 | 3 | 3 | 3 | 1 |
| Sr | 86.7 | 78.3 | 117.0 | 80.0 | 72.8 | 87.0 | 17.5 |
| V | 108 | 104 | 100 | 107 | 105 | 105 | 3 |
| Zn | 129.0 | 125.0 | 126.0 | 127.0 | 128.0 | 127.0 | 1.6 |
| Al | 41000 | 38300 | 39800 | 39500 | 37700 | 39260 | 1297 |
| Fe | 48800 | 51400 | 48500 | 51100 | 56600 | 51280 | 3249 |
| Si | 4630 | 5600 | 5220 | 5600 | 5320 | 5274 | 398 |
| Ca | 5000 | 5030 | 5860 | 4790 | 4700 | 5076 | 460 |
| Mg | 8750 | 7920 | 9190 | 8020 | 7400 | 8256 | 710 |
| Na | 570 | 600 | 750 | 550 | 520 | 598 | 90 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\geq$ .15 mm | 58.6 | 24.0 | 58.4 | 56.0 | 51.9 | 49.8 | 14.7 |
| $<$ .15 mm | 41.4 | 76.0 | 41.6 | 44.0 | 48.1 | 50.2 | 14.7 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : YAKOUN 1 (82/09/15)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .18 | .15 | .23 | .28 | | .21 | .06 |
| As | 15 | 11 | 9 | <8 | | 11 | 3 |
| Ba | 197 | 191 | 203 | 196 | | 197 | 5 |
| Be | .4 | .4 | .5 | .5 | | .5 | .1 |
| Cd | <.3 | <.3 | <.3 | <.3 | | .3 | .0 |
| Co | 16.4 | 15.0 | 18.3 | 15.6 | | 16.3 | 1.4 |
| Cr | 64 | 58 | 69 | 61 | | 63 | 4 |
| Cu | 30 | 28 | 40 | 34 | | 33 | 5 |
| Mn | 1280 | 1160 | 1700 | 1770 | | 1477 | 303 |
| Ni | 33 | 27 | 41 | 31 | | 33 | 6 |
| P | 950 | 906 | 1060 | 1040 | | 989 | 73 |
| Pb | 3 | <3 | <3 | <3 | | 3 | 0 |
| Sn | 5 | 2 | 2 | 4 | | 3 | 1 |
| Sr | 103.0 | 102.0 | 103.0 | 102.0 | | 102.5 | .6 |
| V | 96 | 95 | 95 | 94 | | 95 | 1 |
| Zn | 117.0 | 116.0 | 124.0 | 119.0 | | 119.0 | 3.6 |
| Al | 35900 | 35000 | 35100 | 35100 | | 35275 | 419 |
| Fe | 42600 | 42100 | 45900 | 45500 | | 44025 | 1952 |
| Si | 3680 | 4740 | 4430 | 4450 | | 4325 | 453 |
| Ca | 7860 | 7650 | 8060 | 7990 | | 7890 | 180 |
| Mg | 9270 | 9320 | 9560 | 9530 | | 9420 | 146 |
| Na | 770 | 720 | 720 | 740 | | 738 | 24 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 56.2 | 61.6 | 57.5 | 53.0 | | 57.1 | 3.6 |
| < .15 mm | 43.8 | 38.4 | 42.5 | 47.0 | | 42.9 | 3.6 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : YAKOUN 1 (83/02/22)

| Metal • | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .52 | .32 | .27 | .23 | .30 | .33 | .11 |
| As | <8 | <8 | <8 | <8 | <8 | 8 | 0 |
| Ba | 201 | 208 | 208 | 202 | 193 | 202 | 6 |
| Be | .4 | .5 | .4 | .4 | .4 | .4 | .0 |
| Cd | <.3 | <.3 | <.3 | <.3 | <.3 | .3 | .0 |
| Co | 5.4 | 6.7 | 5.1 | 4.8 | 7.2 | 5.8 | 1.1 |
| Cr | 47 | 53 | 49 | 47 | 54 | 50 | 4 |
| Cu | 38 | 43 | 34 | 32 | 39 | 37 | 4 |
| Mn | 1310 | 2010 | 1250 | 1020 | 1350 | 1388 | 370 |
| Ni | 24 | 25 | 23 | 21 | 28 | 24 | 3 |
| P | 1030 | 1050 | 900 | 901 | 949 | 966 | 71 |
| Pb | <3 | 5 | <3 | <3 | <3 | 3 | 1 |
| Sn | 3 | 3 | 4 | 4 | 5 | 4 | 1 |
| Sr | 104.0 | 103.0 | 104.0 | 118.0 | 101.0 | 106.0 | 6.8 |
| V | 116 | 126 | 116 | 118 | 111 | 118 | 5 |
| Zn | 123.0 | 124.0 | 118.0 | 120.0 | 124.0 | 121.8 | 2.7 |
| Al | 43700 | 46100 | 44300 | 44000 | 41700 | 43960 | 1571 |
| Fe | 47300 | 47400 | 44300 | 43700 | 43600 | 45260 | 1927 |
| Si | 5320 | 5640 | 4780 | 6100 | 5380 | 5444 | 482 |
| Ca | 7840 | 7990 | 7680 | 7620 | 7370 | 7700 | 234 |
| Mg | 9970 | 10700 | 9720 | 10100 | 9570 | 10012 | 437 |
| Na | 630 | 660 | 690 | 840 | 630 | 690 | 87 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\geq$ .15 mm | 56.9 | 60.4 | 78.9 | 61.1 | 70.7 | 65.6 | 9.0 |
| $\leq$ .15 mm | 43.1 | 39.6 | 21.1 | 38.9 | 29.3 | 34.4 | 9.0 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : YAKOUN 2 (82/09/15)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .22 | .21 | .25 | .16 | | .21 | .04 |
| As | 16 | <8 | 14 | 14 | | 13 | 3 |
| Ba | 212 | 201 | 215 | 208 | | 209 | 6 |
| Be | .5 | .5 | .5 | .4 | | .5 | .1 |
| Cd | <.3 | <.3 | <.3 | <.3 | | .3 | .0 |
| Co | 18.8 | 16.7 | 18.7 | 15.9 | | 17.5 | 1.5 |
| Cr | 81 | 86 | 70 | 83 | | 80 | 7 |
| Cu | 33 | 34 | 31 | 28 | | 32 | 3 |
| Mn | 1260 | 1230 | 1950 | 1220 | | 1415 | 357 |
| Ni | 43 | 40 | 36 | 45 | | 41 | 4 |
| P | 915 | 940 | 960 | 929 | | 936 | 19 |
| Pb | <3 | <3 | <3 | <3 | | 3 | 0 |
| Sn | 3 | 3 | 3 | 4 | | 3 | 0 |
| Sr | 121.0 | 89.3 | 98.6 | 97.5 | | 101.6 | 13.6 |
| V | 101 | 99 | 96 | 97 | | 98 | 2 |
| Zn | 126.0 | 118.0 | 118.0 | 120.0 | | 120.5 | 3.8 |
| Al | 38200 | 35900 | 36600 | 36500 | | 36800 | 983 |
| Fe | 43100 | 43400 | 43900 | 42500 | | 43225 | 585 |
| Si | 2620 | 4310 | 4710 | 3590 | | 3808 | 917 |
| Ca | 6970 | 6770 | 7000 | 6960 | | 6925 | 105 |
| Mg | 9580 | 9430 | 8910 | 9220 | | 9285 | 290 |
| Na | 730 | 700 | 680 | 730 | | 710 | 24 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 74.1 | 67.3 | 66.7 | 70.1 | | 69.6 | 3.4 |
| < .15 mm | 25.9 | 32.7 | 33.3 | 29.9 | | 30.5 | 3.4 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : YAKOUN 2 (83/02/22)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .24 | .22 | .25 | .30 | .22 | .25 | .03 |
| As | <8 | <8 | <8 | <8 | <8 | 8 | 0 |
| Ba | 203 | 211 | 204 | 204 | 226 | 210 | 10 |
| Be | .4 | .4 | .4 | .4 | .4 | .4 | .0 |
| Cd | <.3 | <.3 | <.3 | <.3 | <.3 | .3 | .0 |
| Co | 5.7 | 7.8 | 3.9 | 10.9 | 7.6 | 7.2 | 2.6 |
| Cr | 54 | 58 | 54 | 49 | 51 | 53 | 3 |
| Cu | 46 | 37 | 40 | 38 | 41 | 40 | 4 |
| Mn | 1490 | 1210 | 1390 | 1300 | 1250 | 1328 | 113 |
| Ni | 26 | 31 | 25 | 26 | 24 | 26 | 3 |
| P | 900 | 873 | 861 | 934 | 865 | 887 | 31 |
| Pb | <3 | <3 | <3 | <3 | <3 | 3 | 0 |
| Sn | 5 | 3 | 4 | 4 | 5 | 4 | 1 |
| Sr | 97.3 | 99.8 | 97.3 | 100.0 | 105.0 | 99.9 | 3.1 |
| V | 109 | 108 | 106 | 112 | 117 | 110 | 4 |
| Zn | 127.0 | 125.0 | 122.0 | 125.0 | 127.0 | 125.2 | 2.0 |
| Al | 41800 | 42400 | 42200 | 43700 | 47400 | 43500 | 2293 |
| Fe | 43200 | 41600 | 41200 | 42400 | 42300 | 42140 | 773 |
| Si | 5220 | 5000 | 4670 | 5130 | 5230 | 5050 | 232 |
| Ca | 6440 | 6160 | 6360 | 6750 | 6590 | 6460 | 224 |
| Mg | 9410 | 9510 | 9220 | 9860 | 9880 | 9576 | 288 |
| Na | 570 | 670 | 630 | 650 | 660 | 636 | 40 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\geq$ .15 mm | 27.7 | 33.3 | 60.9 | 63.5 | 58.5 | 48.8 | 16.9 |
| $\leq$ .15 mm | 72.3 | 66.7 | 39.1 | 36.5 | 41.5 | 51.2 | 16.9 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : CANOE 1 (82/09/15)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .20 | .21 | .20 | .22 | | .21 | .01 |
| As | 8 | <8 | <8 | 16 | | 10 | 4 |
| Ba | 79 | 77 | 80 | 81 | | 79 | 2 |
| Be | <.2 | .2 | <.2 | .3 | | .2 | .0 |
| Cd | <.3 | <.3 | <.3 | <.3 | | .3 | .0 |
| Co | 10.1 | 14.4 | 19.1 | 12.9 | | 14.1 | 3.8 |
| Cr | 63 | 73 | 51 | 47 | | 58 | 12 |
| Cu | 13 | 18 | 14 | 18 | | 16 | 3 |
| Mn | 1140 | 1580 | 1580 | 1260 | | 1390 | 225 |
| Ni | 33 | 26 | 29 | 23 | | 28 | 4 |
| P | 828 | 1230 | 919 | 1420 | | 1099 | 274 |
| Pb | <3 | <3 | 3 | <3 | | 3 | 0 |
| Sn | 3 | <2 | <2 | <2 | | 2 | 1 |
| Sr | 43.7 | 44.9 | 45.4 | 46.6 | | 45.2 | 1.2 |
| V | 71 | 86 | 77 | 93 | | 82 | 10 |
| Zn | 65.0 | 60.8 | 65.2 | 62.5 | | 63.4 | 2.1 |
| Al | 24100 | 27300 | 27800 | 28300 | | 26875 | 1895 |
| Fe | 31200 | 37200 | 33800 | 41700 | | 35975 | 4539 |
| Si | 4230 | 4590 | 4230 | 4550 | | 4400 | 197 |
| Ca | 4210 | 4430 | 4550 | 4520 | | 4428 | 154 |
| Mg | 5350 | 5000 | 5630 | 5070 | | 5262 | 288 |
| Na | 650 | 620 | 700 | 610 | | 645 | 40 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\geq$ .15 mm | 80.0 | 78.1 | 81.0 | 66.0 | | 76.3 | 7.0 |
| $\leq$ .15 mm | 20.0 | 21.9 | 19.0 | 34.0 | | 23.7 | 7.0 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : CANOE 1 (83/02/22)

| Metal • | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .25 | .29 | .28 | .29 | .36 | .29 | .04 |
| As | <7 | <8 | <8 | <8 | <8 | 8 | 0 |
| Ba | 133 | 95 | 107 | 90 | 96 | 104 | 17 |
| Be | .2 | <.2 | <.2 | <.2 | .2 | .2 | .0 |
| Cd | <.3 | <.3 | <.3 | <.3 | <.3 | .3 | .0 |
| Co | 7.0 | 2.9 | 4.5 | 2.1 | 1.9 | 3.7 | 2.1 |
| Cr | 46 | 52 | 59 | 44 | 42 | 49 | 7 |
| Cu | 20 | 41 | 37 | 22 | 22 | 28 | 10 |
| Mn | 307 | 361 | 465 | 415 | 365 | 383 | 60 |
| Ni | 23 | 24 | 28 | 24 | 24 | 25 | 2 |
| P | 933 | 1100 | 1270 | 1120 | 1460 | 1177 | 198 |
| Pb | 4 | <3 | <3 | <3 | <3 | 3 | 0 |
| Sn | 5 | 3 | 3 | 3 | 3 | 3 | 1 |
| Sr | 51.2 | 51.7 | 65.8 | 50.8 | 54.2 | 54.7 | 6.3 |
| V | 68 | 65 | 73 | 68 | 68 | 68 | 3 |
| Zn | 70.5 | 63.3 | 69.7 | 64.0 | 66.3 | 66.8 | 3.3 |
| Al | 31800 | 28300 | 30600 | 31900 | 33400 | 31200 | 1901 |
| Fe | 28700 | 26900 | 31800 | 25100 | 26700 | 27840 | 2555 |
| Si | 3800 | 5160 | 5220 | 4750 | 5490 | 4884 | 661 |
| Ca | 4960 | 4230 | 4660 | 4500 | 4950 | 4660 | 310 |
| Mg | 6210 | 4870 | 5410 | 5110 | 5350 | 5390 | 506 |
| Na | 910 | 640 | 630 | 730 | 720 | 726 | 112 |

• ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 77.9 | 81.2 | 79.9 | 87.4 | 83.8 | 82.0 | 3.7 |
| < .15 mm | 22.1 | 18.8 | 20.1 | 12.6 | 16.2 | 18.0 | 3.7 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : FLORENCE 1 (82/09/15)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .23 | .25 | .29 | .16 | | .23 | .05 |
| As | <8 | <8 | <8 | <8 | | 8 | 0 |
| Ba | 112 | 120 | 98 | 95 | | 106 | 12 |
| Be | .3 | .3 | .3 | .7 | | .4 | .2 |
| Cd | <.3 | <.3 | <.3 | <.3 | | .3 | .0 |
| Co | 37.9 | 41.9 | 20.7 | 16.4 | | 29.2 | 12.6 |
| Cr | 41 | 60 | 77 | 69 | | 62 | 15 |
| Cu | 26 | 20 | 27 | 16 | | 22 | 5 |
| Mn | 1900 | 1780 | 2190 | 1140 | | 1752 | 443 |
| Ni | 17 | 25 | 42 | 39 | | 31 | 12 |
| P | 1340 | 1420 | 1330 | 1150 | | 1310 | 114 |
| Pb | <3 | <3 | <3 | <3 | | 3 | 0 |
| Sn | 3 | 4 | 6 | 6 | | 5 | 2 |
| Sr | 68.9 | 71.5 | 64.3 | 60.1 | | 66.2 | 5.0 |
| V | 110 | 107 | 105 | 98 | | 105 | 5 |
| Zn | 80.3 | 84.5 | 83.6 | 85.6 | | 83.5 | 2.3 |
| Al | 33800 | 32400 | 31600 | 33500 | | 32825 | 1014 |
| Fe | 51100 | 54300 | 47200 | 43200 | | 48950 | 4809 |
| Si | 3840 | 2980 | 2950 | 3390 | | 3290 | 418 |
| Ca | 6450 | 6780 | 6420 | 6050 | | 6425 | 298 |
| Mg | 5200 | 5500 | 5570 | 6080 | | 5588 | 365 |
| Na | 840 | 960 | 1240 | 1110 | | 1038 | 174 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 55.6 | 61.8 | 66.1 | 73.8 | | 64.3 | 7.6 |
| < .15 mm | 44.4 | 38.2 | 33.9 | 26.2 | | 35.7 | 7.6 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : FLORENCE 1 (83/02/22)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .24 | .39 | .32 | .15 | .13 | .25 | .11 |
| As | <8 | <8 | <8 | <8 | <7 | 8 | 0 |
| Ba | 109 | 105 | 119 | 99 | 101 | 107 | 8 |
| Be | .4 | .4 | .3 | .3 | .6 | .4 | .1 |
| Cd | <.3 | <.3 | <.3 | <.3 | <.3 | .3 | .0 |
| Co | 13.3 | 6.5 | 39.6 | 8.3 | 7.1 | 15.0 | 14.0 |
| Cr | 60 | 44 | 49 | 49 | 35 | 47 | 9 |
| Cu | 26 | 30 | 19 | 19 | 16 | 22 | 6 |
| Mn | 1860 | 1460 | 1250 | 1700 | 1510 | 1556 | 234 |
| Ni | 36 | 25 | 29 | 23 | 12 | 25 | 9 |
| P | 1450 | 1700 | 2050 | 1750 | 1250 | 1640 | 305 |
| Pb | <3 | <3 | <3 | <3 | <3 | 3 | 0 |
| Sn | 6 | 7 | 4 | 5 | 8 | 6 | 2 |
| Sr | 74.0 | 77.9 | 81.0 | 71.1 | 69.3 | 74.7 | 4.8 |
| V | 111 | 131 | 149 | 130 | 113 | 127 | 15 |
| Zn | 81.9 | 81.6 | 81.0 | 80.2 | 80.2 | 81.0 | .8 |
| Al | 34900 | 33900 | 33800 | 31900 | 36400 | 34180 | 1648 |
| Fe | 50100 | 60800 | 75400 | 62200 | 47200 | 59140 | 11189 |
| Si | 4360 | 5260 | 4990 | 4940 | 3930 | 4696 | 539 |
| Ca | 6780 | 7380 | 7490 | 7140 | 6470 | 7052 | 424 |
| Mg | 5820 | 6010 | 5550 | 5990 | 6360 | 5946 | 296 |
| Na | 1330 | 1180 | 1040 | 1000 | 1060 | 1122 | 134 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 59.1 | 75.2 | 62.8 | 65.4 | 82.9 | 69.1 | 9.8 |
| ≤ .15 mm | 40.9 | 24.8 | 37.2 | 34.6 | 17.1 | 30.9 | 9.8 |

## APPENDIX IV

HEAVY METAL CONCENTRATION
AND PARTICLE SIZE DISTRIBUTION OF
INTERGRAVEL FINE SEDIMENTS FOR COWICHAN RIVER,
FOXY CREEK, LEMIEUX CREEK, MAMIN RIVER, MYRA CREEK,
PINCHI CREEK, QUINSAM RIVER, SALMON RIVER AND SEYMOUR RIVER

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : COWICHAN RIVER (83/07/27)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .17 | .19 | .16 | .18 | | .18 | .01 |
| As | <7 | 11 | <8 | 8 | | 9 | 2 |
| Ba | 100 | 107 | 98 | 100 | | 101 | 4 |
| Be | .6 | .6 | .6 | .6 | | .6 | .0 |
| Cd | 1.1 | 1.1 | 1.1 | | | 1.1 | .0 |
| Co | 24.9 | 21.4 | 27.1 | 22.0 | | 23.9 | 2.7 |
| Cr | 64 | 68 | 58 | 58 | | 62 | 5 |
| Cu | 70 | 72 | 68 | 68 | | 69 | 2 |
| Mn | 998 | 1150 | 1000 | 1030 | | 1044 | 72 |
| Ni | 35 | 34 | 29 | 28 | | 32 | 4 |
| P | 1120 | 1230 | 1140 | 1180 | | 1167 | 49 |
| Pb | 11 | 12 | 10 | 9 | | 10 | 1 |
| Sn | 11 | 11 | 10 | 10 | | 10 | 1 |
| Sr | 97.6 | 97.5 | 98.5 | 100.0 | | 98.4 | 1.2 |
| V | 150 | 152 | 159 | 155 | | 154 | 4 |
| Zn | 85.9 | 89.2 | 88.9 | 89.4 | | 88.3 | 1.6 |
| Al | 31000 | 31600 | 31500 | 31700 | | 31450 | 311 |
| Fe | 42900 | 44000 | 45200 | 43800 | | 43975 | 946 |
| Si | 4360 | 4270 | 3800 | 4780 | | 4303 | 402 |
| Ca | 13800 | 14000 | 14000 | 14300 | | 14025 | 206 |
| Mg | 14700 | 14700 | 14700 | 14700 | | 14700 | 0 |
| Na | 580 | 610 | 600 | 600 | | 597 | 13 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\geq$ .15 mm | | | | | | | |
| < .15 mm | | | | | | | |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : FOXY CREEK (83/07/18)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .17 | .19 | .20 | .20 | | .19 | .01 |
| As | 25 | 25 | 31 | 25 | | 27 | 3 |
| Ba | 498 | 556 | 628 | 492 | | 543 | 63 |
| Be | .6 | .8 | .7 | .5 | | .7 | .1 |
| Cd | 1.1 | 1.0 | .9 | 1.1 | | 1.0 | .1 |
| Co | 17.6 | 16.4 | 17.7 | 21.5 | | 18.3 | 2.2 |
| Cr | 86 | 83 | 66 | 57 | | 73 | 14 |
| Cu | 62 | 56 | 57 | 58 | | 58 | 2 |
| Mn | 1620 | 1600 | 1780 | 1980 | | 1745 | 176 |
| Ni | 50 | 50 | 41 | 37 | | 44 | 7 |
| P | 2010 | 2230 | 2230 | 2100 | | 2142 | 108 |
| Pb | 12 | 12 | 14 | 13 | | 13 | 1 |
| Sn | 4 | 4 | 5 | 3 | | 4 | 1 |
| Sr | 144.0 | 178.0 | 188.0 | 173.0 | | 170.8 | 18.9 |
| V | 125 | 128 | 115 | 106 | | 118 | 10 |
| Zn | 157.0 | 153.0 | 156.0 | 160.0 | | 156.5 | 2.9 |
| Al | 29400 | 33300 | 29000 | 24500 | | 29050 | 3600 |
| Fe | 50000 | 50600 | 45000 | 36900 | | 45625 | 6335 |
| Si | 3680 | 2880 | 3850 | 3830 | | 3560 | 460 |
| Ca | 15600 | 13100 | 11000 | 9970 | | 12417 | 2490 |
| Mg | 7590 | 8650 | 8260 | 7380 | | 7970 | 589 |
| Na | 850 | 860 | 860 | 890 | | 865 | 17 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | | | | | | | |
| < .15 mm | | | | | | | |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : LEMIEUX CREEK (83/10/10)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .05 | .05 | .05 | .05 | | .05 | .00 |
| As | 27 | 24 | 26 | 23 | | 25 | 2 |
| Ba | 128 | 139 | 123 | 126 | | 129 | 7 |
| Be | .3 | .3 | .3 | .3 | | .3 | .0 |
| Cd | 2.6 | 2.7 | 2.4 | 2.3 | | 2.5 | .2 |
| Co | 17.3 | 17.7 | 17.5 | 16.3 | | 17.2 | .6 |
| Cr | 90 | 90 | 92 | 88 | | 90 | 2 |
| Cu | 48 | 51 | 50 | 48 | | 49 | 1 |
| Mn | 763 | 773 | 726 | 708 | | 743 | 31 |
| Ni | 62 | 62 | 62 | 59 | | 61 | 1 |
| P | 1890 | 1960 | 1950 | 1920 | | 1930 | 32 |
| Pb | 13 | 14 | 12 | 11 | | 13 | 1 |
| Sn | <2 | <2 | <2 | <2 | | 2 | 0 |
| Sr | 116.0 | 122.0 | 117.0 | 125.0 | | 120.0 | 4.2 |
| V | 100 | 104 | 100 | 101 | | 101 | 2 |
| Zn | 163.0 | 168.0 | 163.0 | 162.0 | | 164.0 | 2.7 |
| Al | 22500 | 23600 | 22800 | 22600 | | 22875 | 499 |
| Fe | 35500 | 35900 | 36100 | 35500 | | 35750 | 300 |
| Si | 1900 | 2180 | 3200 | 2650 | | 2483 | 570 |
| Ca | 28400 | 29300 | 29300 | 31600 | | 29650 | 1367 |
| Mg | 9730 | 10300 | 10300 | 10100 | | 10107 | 269 |
| Na | 500 | 540 | 480 | 480 | | 500 | 28 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\geq$ .15 mm | 73.0 | 73.0 | 70.0 | 72.0 | | 72.0 | 1.4 |
| $\leq$ .15 mm | 27.0 | 27.0 | 30.0 | 28.0 | | 28.0 | 1.4 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : MAMIN RIVER (83/11/03)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .22 | .21 | .17 | .20 | .29 | .22 | .04 |
| As | <8 | 9 | <8 | <8 | <8 | 8 | 0 |
| Ba | 98 | 110 | 108 | 108 | 113 | 107 | 6 |
| Be | .3 | .4 | .3 | .3 | .5 | .4 | .1 |
| Cd | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.0 | .1 |
| Co | 20.2 | 17.2 | 15.6 | 19.7 | 18.0 | 18.1 | 1.9 |
| Cr | 79 | 68 | 70 | 71 | 82 | 74 | 6 |
| Cu | 38 | 36 | 29 | 27 | 34 | 33 | 5 |
| Mn | 1440 | 1570 | 1220 | 1260 | 1320 | 1362 | 143 |
| Ni | 65 | 37 | 37 | 39 | 47 | 45 | 12 |
| P | 1180 | 1270 | 1030 | 1130 | 1320 | 1186 | 115 |
| Pb | 6 | 7 | <3 | <3 | 8 | 5 | 2 |
| Sn | 8 | 5 | 9 | 6 | 6 | 7 | 2 |
| Sr | 109.0 | 102.0 | 108.0 | 140.0 | 124.0 | 116.6 | 15.4 |
| V | 99 | 112 | 102 | 105 | 109 | 105 | 5 |
| Zn | 103.0 | 106.0 | 97.6 | 92.1 | 96.8 | 99.1 | 5.5 |
| Al | 40000 | 38700 | 34200 | 38000 | 38800 | 37940 | 2211 |
| Fe | 48100 | 51900 | 42500 | 45300 | 53700 | 48300 | 4604 |
| Si | 1750 | 890 | 1930 | 1160 | 1870 | 1520 | 466 |
| Ca | 13000 | 11500 | 10600 | 12100 | 11700 | 11780 | 876 |
| Mg | 16800 | 11400 | 10700 | 12600 | 12400 | 12780 | 2375 |
| Na | 2600 | 2080 | 2050 | 2370 | 2050 | 2230 | 247 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| ≥ .15 mm | 62.0 | 56.0 | 74.0 | 50.0 | 66.0 | 61.6 | 9.2 |
| < .15 mm | 38.0 | 44.0 | 26.0 | 50.0 | 43.0 | 40.2 | 9.0 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : MYRA CREEK (83/03/18)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .64 | .35 | .34 | | | .44 | .17 |
| As | <40 | 24 | 29 | | | 31 | 8 |
| Ba | 100 | 133 | 152 | | | 128 | 26 |
| Be | <.8 | <.2 | .4 | | | .5 | .3 |
| Cd | <2.0 | .7 | .7 | | | 1.1 | .8 |
| Co | 21.0 | 14.4 | 15.6 | | | 17.0 | 3.5 |
| Cr | 91 | 42 | 81 | | | 71 | 26 |
| Cu | 73 | 71 | 79 | | | 74 | 4 |
| Mn | 921 | 708 | 1040 | | | 890 | 168 |
| Ni | 50 | 19 | 38 | | | 36 | 16 |
| P | 530 | 515 | 603 | | | 549 | 47 |
| Pb | <20 | 19 | 19 | | | 19 | 1 |
| Sn | <8 | 3 | 2 | | | 4 | 3 |
| Sr | 46.7 | 40.6 | 43.7 | | | 43.7 | 3.1 |
| V | 84 | 77 | 97 | | | 86 | 10 |
| Zn | 93.0 | 125.0 | 148.0 | | | 122.0 | 27.6 |
| Al | 24900 | 29000 | 34200 | | | 29367 | 4661 |
| Fe | 26200 | 25600 | 32400 | | | 28067 | 3765 |
| Si | 13300 | 4650 | 3580 | | | 7177 | 5330 |
| Ca | 9460 | 9930 | 9690 | | | 9693 | 235 |
| Mg | 7580 | 8350 | 9490 | | | 8473 | 961 |
| Na | 7000 | 350 | 370 | | | 2573 | 3834 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 79.0 | 61.0 | 58.0 | | | 66.0 | 11.4 |
| < .15 mm | 21.0 | 39.0 | 42.0 | | | 34.0 | 11.4 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : PINCHI CREEK (83/07/20)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .19 | .17 | .16 | .25 | | .19 | .04 |
| As | <8 | 10 | <8 | <8 | | 9 | 1 |
| Ba | 307 | 277 | 271 | 213 | | 267 | 39 |
| Be | <.2 | <.2 | <.2 | <.2 | | .2 | .0 |
| Cd | .6 | .5 | .5 | .7 | | .6 | .1 |
| Co | 13.2 | 16.0 | 12.2 | 19.6 | | 15.3 | 3.3 |
| Cr | 113 | 143 | 130 | 83 | | 117 | 26 |
| Cu | 33 | 31 | 28 | 29 | | 30 | 2 |
| Mn | 578 | 665 | 517 | 457 | | 554 | 89 |
| Ni | 71 | 82 | 66 | 60 | | 70 | 9 |
| P | 823 | 1000 | 814 | 788 | | 856 | 97 |
| Pb | 7 | 9 | 7 | 10 | | 8 | 1 |
| Sn | <2 | 3 | 4 | <2 | | 3 | 1 |
| Sr | 55.3 | 60.4 | 55.9 | 52.4 | | 56.0 | 3.3 |
| V | 74 | 90 | 85 | 68 | | 79 | 10 |
| Zn | 71.9 | 79.6 | 68.8 | 65.7 | | 71.5 | 6.0 |
| Al | 16200 | 16900 | 15700 | 15900 | | 16175 | 525 |
| Fe | 28100 | 31000 | 29600 | 25200 | | 28475 | 2484 |
| Si | 3860 | 2760 | 3600 | 4950 | | 3792 | 903 |
| Ca | 10100 | 10100 | 9370 | 8100 | | 9418 | 943 |
| Mg | 11600 | 10800 | 10500 | 9760 | | 10665 | 761 |
| Na | 390 | 440 | 370 | 370 | | 392 | 33 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\geq$ .15 mm | | | | | | | |
| $\leq$ .15 mm | | | | | | | |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : QUINSAM R Q1 (83/06/22)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .13 | .11 | .15 | .09 | | .12 | .03 |
| As | <8 | <8 | <8 | <8 | | 8 | 0 |
| Ba | 75 | 69 | 69 | 85 | | 75 | 8 |
| Be | .3 | .3 | .4 | <.2 | | .3 | .1 |
| Cd | .5 | .7 | .5 | .7 | | .6 | .1 |
| Co | 13.1 | 15.3 | 13.0 | 14.4 | | 14.0 | 1.1 |
| Cr | 65 | 46 | 66 | 87 | | 66 | 17 |
| Cu | 83 | 84 | 85 | 93 | | 86 | 5 |
| Mn | 1210 | 944 | 1360 | 894 | | 1102 | 221 |
| Ni | 32 | 23 | 32 | 47 | | 33 | 10 |
| P | 639 | 572 | 662 | 647 | | 630 | 40 |
| Pb | 5 | 4 | 7 | <3 | | 5 | 2 |
| Sn | 6 | 10 | 8 | 7 | | 8 | 2 |
| Sr | 66.8 | 66.0 | 61.2 | 77.7 | | 67.9 | 7.0 |
| V | 134 | 131 | 122 | 132 | | 130 | 5 |
| Zn | 62.5 | 57.3 | 66.6 | 63.4 | | 62.5 | 3.9 |
| Al | 29400 | 28800 | 28800 | 34300 | | 30325 | 2665 |
| Fe | 47000 | 41800 | 50400 | 36200 | | 43850 | 6206 |
| Si | 4110 | 4360 | 3930 | 4390 | | 4197 | 218 |
| Ca | 26000 | 23700 | 30200 | 19000 | | 24725 | 4670 |
| Mg | 6600 | 6890 | 6540 | 8240 | | 7068 | 796 |
| Na | 730 | 790 | 700 | 930 | | 788 | 102 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 77.0 | 83.0 | 74.0 | 71.0 | | 76.3 | 5.1 |
| < .15 mm | 23.0 | 17.0 | 26.0 | 29.0 | | 23.8 | 5.1 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : QUINSAM R Q2 (83/06/22)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .28 | .24 | .16 | .15 | | .21 | .06 |
| As | 9 | <8 | <8 | 11 | | 9 | 1 |
| Ba | 122 | 121 | 83 | 89 | | 104 | 20 |
| Be | .2 | .3 | .4 | .3 | | .3 | .1 |
| Cd | .7 | .6 | .6 | .5 | | .6 | .1 |
| Co | 13.5 | 13.7 | 12.5 | 10.4 | | 12.5 | 1.5 |
| Cr | 52 | 67 | 47 | 55 | | 55 | 9 |
| Cu | 67 | 64 | 81 | 79 | | 73 | 9 |
| Mn | 1970 | 1870 | 1070 | 2150 | | 1765 | 478 |
| Ni | 24 | 28 | 19 | 21 | | 23 | 4 |
| P | 763 | 712 | 881 | 896 | | 813 | 90 |
| Pb | 17 | 15 | 8 | 5 | | 11 | 6 |
| Sn | 5 | 3 | 7 | 7 | | 6 | 2 |
| Sr | 112.0 | 117.0 | 70.1 | 67.7 | | 91.7 | 26.4 |
| V | 114 | 130 | 127 | 134 | | 126 | 9 |
| Zn | 97.5 | 103.0 | 73.6 | 71.5 | | 86.4 | 16.2 |
| Al | 37600 | 36000 | 36600 | 34500 | | 36175 | 1297 |
| Fe | 35300 | 38400 | 35000 | 37700 | | 36600 | 1703 |
| Si | 7950 | 7240 | 4760 | 5380 | | 6333 | 1508 |
| Ca | 17100 | 17300 | 13200 | 13000 | | 15150 | 2370 |
| Mg | 8730 | 9000 | 7190 | 7010 | | 7982 | 1028 |
| Na | 500 | 460 | 480 | 510 | | 488 | 22 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 64.0 | 63.0 | 47.0 | 26.0 | | 50.0 | 17.8 |
| < .15 mm | 36.0 | 37.0 | 53.0 | 74.0 | | 50.0 | 17.8 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : SALMON RIVER (83/08/10)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .07 | .07 | .10 | | | .08 | .02 |
| As | <8 | <8 | 9 | | | 8 | 1 |
| Ba | 116 | 109 | 94 | | | 106 | 11 |
| Be | <.2 | <.2 | <.2 | | | .2 | .0 |
| Cd | .7 | .6 | .4 | | | .6 | .2 |
| Co | 10.8 | 10.6 | 4.3 | | | 8.6 | 3.7 |
| Cr | 56 | 59 | 45 | | | 53 | 8 |
| Cu | 25 | 22 | 21 | | | 23 | 2 |
| Mn | 722 | 935 | 637 | | | 765 | 154 |
| Ni | 33 | 35 | 23 | | | 30 | 6 |
| P | 1140 | 986 | 859 | | | 995 | 141 |
| Pb | 4 | 5 | <3 | | | 4 | 1 |
| Sn | 5 | 3 | 3 | | | 4 | 1 |
| Sr | 56.2 | 51.7 | 49.7 | | | 52.5 | 3.3 |
| V | 69 | 65 | 65 | | | 66 | 2 |
| Zn | 118.0 | 112.0 | 73.3 | | | 101.1 | 24.3 |
| Al | 24000 | 21500 | 20800 | | | 22100 | 1682 |
| Fe | 23600 | 23700 | 21600 | | | 22967 | 1185 |
| Si | 4530 | 4320 | 5020 | | | 4623 | 359 |
| Ca | 11300 | 10700 | 6860 | | | 9620 | 2409 |
| Mg | 7260 | 6600 | 6460 | | | 6773 | 427 |
| Na | 620 | 540 | 530 | | | 563 | 49 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 59.0 | 80.0 | 77.0 | | | 72.0 | 11.4 |
| < .15 mm | 41.0 | 20.0 | 23.0 | | | 28.0 | 11.4 |

APPENDIX III

Heavy Metal Concentration and Particle Size Distribution of Intergravel Fine Sediments for : SEYMOUR RIVER (83/08/10)

| Metal * | Sample No. - Replication No. 1 | 2 | 3 | 4 | 5 | Mean | S.D. |
|---|---|---|---|---|---|---|---|
| Hg ** | .06 | .05 | .04 | | | .05 | .01 |
| As | <8 | <8 | | | | 8 | 0 |
| Ba | 87 | 83 | 57 | | | 75 | 17 |
| Be | <.2 | <.2 | <.2 | | | .2 | .0 |
| Cd | .7 | .5 | .3 | | | .5 | .2 |
| Co | 12.0 | 7.3 | 11.3 | | | 10.2 | 2.5 |
| Cr | 25 | 31 | 30 | | | 29 | 3 |
| Cu | 40 | 29 | 25 | | | 32 | 8 |
| Mn | 729 | 633 | 450 | | | 604 | 142 |
| Ni | 9 | 8 | 3 | | | 7 | 3 |
| P | 671 | 662 | 582 | | | 638 | 49 |
| Pb | 15 | 7 | 5 | | | 9 | 5 |
| Sn | 4 | 4 | <2 | | | 3 | 1 |
| Sr | 58.0 | 67.6 | 56.4 | | | 60.7 | 6.1 |
| V | 84 | 102 | 126 | | | 104 | 21 |
| Zn | 79.2 | 68.4 | 61.8 | | | 69.8 | 8.8 |
| Al | 20100 | 20100 | 15500 | | | 18567 | 2656 |
| Fe | 28500 | 31900 | 36600 | | | 32333 | 4067 |
| Si | 4520 | 4220 | 4100 | | | 4280 | 216 |
| Ca | 8290 | 9380 | 8160 | | | 8610 | 670 |
| Mg | 7270 | 7010 | 5370 | | | 6550 | 1030 |
| Na | 1020 | 1160 | 900 | | | 1027 | 130 |

* ICAP, <0.15 mm fraction, as ug/g (ppm)
** Hg (Pharmacia Mercury Monitor)

| Portion of total Sample (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| > .15 mm | 69.0 | 74.0 | 89.0 | | | 77.3 | 10.4 |
| < .15 mm | 31.0 | 26.0 | 11.0 | | | 22.7 | 10.4 |