MINISTRY OF ENVIRONMENT

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A 1985 SURVEY OF METALS, PCB'S, AND CHLOROPHENOLS IN THE SEDIMENTS, BENTHIC ORGANISMS AND FISH OF THE LOWER FRASER RIVER

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SUMMARY

Monitoring was undertaken in the riverine section of the Fraser River Estuary in January and February 1985 to: 1) determine locations where sediments, benthic organisms and fish could be collected, 2) measure metals, chlorophenols and PCB's, and 3) determine if provisional water quality objectives were being met.

Samples were collected from six sites, two in each of the Main Stem, North Arm, and Main Arm. Chlorophenol values in sediments were approximately the same as measured in earlier studies, PCB's in the North Arm and Main Stem were three to ten times higher than before, copper was slightly higher, while mercury and lead values had approximately doubled. More widespread sampling is needed to check possible sources of these contaminants, although stormwater may be one source of PCB's and lead to the river.

An insufficient mass of benthic organisms was collected at most sites to permit laboratory measurements of chlorophenol and PCB's. PCB's could not be detected in any benthic organisms where measurements were possible. Chlorophenols were measured in a total of six benthic organism samples. If the provisional objective for chlorophenols in fish flesh were applicable to benthic organisms, which it is not, the objective would be met for all benthic organisms from all but one site. This site contained polychaetes from the lower North Arm (25-fold higher than the objective level).

Copper and zinc were bioconcentrated from sediments to eight of the nine benthic organisms for which measurements were made. Since copper in sediments seems to be increasing, it is important that the source of the copper be determined.

The number of individuals collected from each fish species was insufficient to allow a valid comparison to earlier data. Generally, metal values for fish muscle and livers were within the ranges reported earlier. The highest metal values in flesh generally were for fish collected from the lower North Arm.

Provisional water quality objectives exist for chlorophenols and PCB's in fish. The objectives for PCB's (0.5 μg/g wet weight) and for chlorophenols (0.1 μg/g wet weight) were not exceeded in any of the fish collected from any of the six sites. However, the fish collected may not have been resident species since they were about to spawn and may have recently returned from the ocean.

The provisional water quality objectives in place for chlorophenols and PCB's in bottom sediments are ≤0.01 μg/g (dry weight) and ≤0.03 μg/g (dry weight), respectively. Sediments from two sites in the Main Arm and from a site just upstream from New Westminster in the Main Stem had chlorophenol and PCB concentrations which were less than the objective levels. Sediments from both sites in the North Arm and from a site near Barnston Island in the Main Stem had PCB and chlorophenol levels from three to six times the objective level. Further sampling is required to determine if these values are changing with time and if the objectives are realistic.

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1. INTRODUCTION

A program to monitor metals, polychlorinated biphenyls (PCB's), and chlorophenols in the sediments, invertebrates, and fish of the Lower Fraser River was carried out in January and February 1985. The purpose of the survey was two-fold:

1. To determine if sites proposed by an earlier Committee(1) for the river section of the estuary were appropriate for the successful collection of sediments, invertebrates, and fish, or if other nearby sites were more appropriate.

2. To determine the degree to which values in sediments and fish would meet provisional water quality objectives for this section of the estuary(2).

1.1 SITE SELECTION

The Working Committee on Fraser River Estuary Monitoring(1) recognized that sites which they had recommended were "general" locations, and that specific locations would be determined on the basis of pilot sampling. This report provides information on such a pilot sampling program for the river section of the estuary.

The pilot sampling program related to the river section of the estuary took place during January/February 1985 since it had been recommended that sediments should be collected at low river flow, "when downstream movement of sediments is minimal"(1). It was recommended that for the sake of convenience of sampling, benthic organisms should be collected at the same time as sediments.

An attempt was also made to collect fish at the same time as sediments and benthos. Fish had successfully been collected during the summer months in earlier studies(3). However, it was not known if this success could be duplicated in the winter.

If geographical or temporal trends over several years are ever to be determined, variability inherent in sampling must be reduced. This can be done by sampling the same sites, at the same time of the year, using the same sampling and analytical techniques. As well, enough samples have to be collected, as is feasible, to define the mean values with a known confidence so that significant changes can be identified.

1.2 PROVISIONAL WATER QUALITY OBJECTIVES

The B.C. Ministry of Environment is currently establishing provisional water quality objectives on a site-specific basis. One area where such objectives have been prepared is the Fraser River, from Hope to Sturgeon and Roberts Banks. Of particular interest to this study is that sub-basin, from Kanaka Creek to the Banks.

Provisional objectives which are applicable to the environmental compartments examined in this survey are[2]:

Chlorophenols: 10 ppb (dry weight) maximum in bottom surface sediments
0.1 ppm (wet weight) maximum in fish muscle

PCB's : 30 ppb (dry weight) maximum in bottom surface sediments
0.5 ppm (wet weight) maximum in fish muscle

The rationale for these provisional objectives was outlined as follows: the provisional "objective for chlorophenols in fish muscle (0.1 ppm wet weight) is an objective which appears to be met in the North Arm and Main Stem, but may not always be met in the Main Arm in the future. It represents a level found in uncontaminated areas of the Fraser River. This fact, and the general relationship of concentrations in the water column to concentrations in fish muscle, were used to determine the objective, since there are no working criteria for chlorophenols in fish.

Existing chlorophenol levels in certain bottom sediments were used in setting a provisional objective at 10 ppb (dry weight). Levels of this magnitude occur in relatively uncontaminated parts of the Fraser River and of other rivers in Canada. At 10 ppb or less in sediments, there should be little tendency for chlorophenols to accumulate in aquatic life.

Polychlorinated biphenyls (PCB's) can enter the river channels through urban stormwater runoff, sewage discharges or from the Belkin paperboard plant on the North Arm. Objectives are therefore proposed to limit a buildup of these substances. The objective of 0.5 ppm (wet weight) in muscle from fish is based upon a recognized working criterion to protect aquatic life. The objective of 30 ppb (dry weight) in sediments has been set to minimize the passage of PCB's along the food web. It is met generally in parts of the river which are relatively uncontaminated by PCB's"[2].

2. SELECTED SITES

The areas chosen for sampling by the Working Committee on Fraser River Estuary Monitoring[1] were at upstream and downstream locations of major reaches of the river. These are shown on Figure 1 as, MS-1, MS-2, on the Main Stem; MA-1, MA-2, on the Main Arm and NA-1 and NA-2 on the North Arm.

During the pilot project, an attempt was made to establish sites at these locations. However, several of the sites had to be adjusted due to water currents, the inability to collect sediments, the inability to set gill nets, or other factors. Three sites, one site in each of the three reaches, were found to be appropriate for sampling. These were MS-2, NA-1, and MA-1. Modifications to the other sites were as follows:

The site located near Kanaka Creek (MS-1) was moved approximately two km downstream from Barnston Island. The new MS-1 site was on the south side of the river. It had been used in earlier studies reported by Stancil[4]. Site MS-2 was located in Sapperton Channel.

A new NA-2 site was established in McDonald Slough in the North Arm. This site replaced the old NA-2, which was felt by field staff to be located too far seaward to reflect riverine conditions. The actual North Arm site used in McDonald Slough was across from the entrance from the slough to the North Arm. It had been used by Singleton to collect fish in a survey in 1980[3]. Site NA-1 was located in a backwater on the north shore, opposite Belkin Packaging.

Site MA-2 was replaced by a new MA-2 site in Ewen Slough. It also had been used in past studies by Singleton[3]. Site MA-1 was located in Annacis Channel, to the North from Annacis Island.

3.0 MATERIALS AND METHODS

Fish were collected using sinking gill nets. A number of different sized net panels (13 m long by 2.5 m deep) were used, with the mesh size of several being in the two to two and one-half inch (5.1-6.4 cm) range, some three inch (7.6 cm), and others three and one-half inches (8.9 cm). Nets were usually set overnight and collected early the following morning. The procedure used in this program to obtain fish muscle and livers for analysis duplicated that used earlier by Singleton, and described more fully in his earlier report(3).

Sediments and benthic organisms were collected at the same time as the fish, using a Petersen grab. Three replicate sub-samples of sediments were placed in acid-washed plastic bottles for metals, and dark brown glass bottles for PCB and chlorophenol analyses.

Sediments were sieved through plastic buckets with screens (≈0.5 mm) on the bottom to try and collect adequate numbers of benthic organisms for analysis. Generally, six to eight glass jars (~0.5 L) were filled per site with material retained on the screens. About 20 to 30 discrete sediment samples were required per site to obtain sufficient volume to fill the benthic organism containers. The samples at this point contained wood, organic debris, and benthos. The containers were sent within 8 hours to the Environmental Laboratory for sorting of benthic organisms (KEY: Pennak, R.W., 1953, Freshwater Invertebrates of the United States) and subsequent analysis.

Metals in sediments were analyzed following drying and grinding of the sediments, while fish muscle and livers and benthic organisms were initially homogenized separately. Most were then subjected to nitric/perchloric acid digestion and ICP analysis. The ICP was replaced by Heated Graphite Atomizer for analyses of lead, chromium and nickel in fish and cadmium in sediments and fish. For mercury analyses, a nitric/sulphuric acid digestion was used prior to a manual cold vapour analysis.

Carbon analyses used the Leco Carbon analyzer, while total volatile residue used a graphite furnace at 550°C, following drying and grinding.

Sediments, fish and benthic organisms were extracted, fluorosil was added, and the samples analyzed for PCB's on the gas chromatograph with electron capture. Acidification, extraction, back extraction, methylation and fluorsilation were completed prior to analysis for chlorophenols on the gas chromatograph. Samples of fish and benthic organisms were initially homogenized separately.

4. RESULTS AND DISCUSSION

4.1 SEDIMENTS

Particle size distributions are in Table 1 for the collected sediment samples. Based upon the percentage of sediment particles that passed the 400 mesh size (Tyler), the coarsest particles were associated with Main Stem sediments, and the finest particles were associated with sediments from the Main Arm. The coarsest particles were associated with sediments from Barnston Island in the Main Stem. Main Arm sediments were finer textured than North Arm sediments.

Particle size can be important with respect to metal concentrations of sediments. Stancil reported that sediments composed of finer material usually had higher metal contents, since fine grained particles have large surface areas to which metals are easily sorbed(4). High organic matter and humic content increase adsorption and binding capacities of bottom sediments(5).

4.1.1 POLYCHLORINATED BIPHENYLS

Total PCB's could not be detected (<0.02 μg/g - wet weight) at the Sapperton Channel site (MS-2), or at sites in the Main Arm of the river. They were detected at the other sites. The total PCB's at these sites could be higher than reported here, since those reported here are for only one Arochlor (1242), the only form analyzed in the Laboratory. The values, converted from wet to dry weight, are reported below.

	Aroclor 1242 Concentrations (μg/g)(dry)		
	Sample 1	Sample 2	Sample 3
BARNSTON ISLAND (MS-1)	0.093	0.28	0.092
UPPER NORTH ARM (NA-1)	0.140	0.168	0.137
LOWER NORTH ARM (NA-2)	0.099	-	0.097

Garrett[5] reported PCB concentrations from a July 1976 survey of 0.03 µg/g (dry weight) downstream from Barnston Island, close to Sapperton Channel. Values from this survey for Sapperton Channel (MS-2) were about that level, however the values for the Barnston Island site (MS-1) were three to ten times higher. This could reflect the fact that:

1. The sites are too far separated to be comparable, or
2. The difference in time of year of sampling (July compared to February) was significant, since sediments in this survey were collected following nearly one year's deposition, while those from Garrett's study were just freshly renewed, or
3. There is an upstream localized source of PCB's to the lower Fraser River, possibly since 1976.

Garrett[5] also found higher PCB values throughout the North Arm, particularly adjacent to Belkin Paper, but also upstream and downstream from the plant. The site used in our survey (NA-1) was across the river from the Belkin plant.

All the detectable PCB values in sediments from this survey exceeded the provisional objective (0.03 µg/g dry) for the river. The objective was chosen as being typical of uncontaminated areas, so the results indicate the need for more widespread sampling and the checking of possible PCB sources. The data obtained for the North Arm sites indicate that:

1. The sediments in the North Arm are not renewed quickly, or
2. There may be a continuing source of PCB's to the sediments of the North Arm (although the average values for MS-1 and NA-1 are the same).

Levels of PCB's in fish muscle (Section 4.3.14) were low. Swain[6] has reported that "stormwater constitutes a diffuse source of PCB's at low levels to the river". Values for stormwater sediments expressed on a dry-weight basis ranged from <0.02 to 0.19 µg/g (Arochlor 1242) and from <0.02 to 0.45 µg/g (Arochlor 1260). These maximum values in stormwater sediments exceed the maximum found in the North Arm.

Swain[7] has indicated that there are a large number of stormwater outfalls, especially to the North Arm of the river. Therefore the high sediment values may originate from stormwater.

4.1.2 CHLOROPHENOLS

Chlorophenols (pentachlorophenol and tetrachlorophenol), as was the case for PCB's, could not be detected (<0.005 μg/g - wet weight basis) at Sapperton Channel, Annacis Channel, or at Ewen Slough. Concentrations in sediments from the other three sites were converted from wet to dry weight, and are reported below:

Chlorophenol Concentrations (μg/g)(dry)

		Sample 1	Sample 2	Sample 3	Average	Average Total
Barnston Island:	penta	0.027	0.040	0.013	0.027	
(MS-1)	tetra	0.013	0.013	<0.007	0.011	0.038
Upper N. Arm :	penta	0.028	0.056	0.031	0.038	
(NA-1)	tetra	<0.007	0.019	0.009	0.012	0.050
Lower N. Arm :	penta	0.042	-	0.042	0.042	
(NA-2)	tetra	0.014	-	0.014	0.014	0.056

Garrett[5] reported levels of pentachlorophenol in sediments in the North Arm to be as high as 0.09 μg/g. A similar maximum was found for tetrachlorophenol. Average values were 0.017 and 0.021 μg/g, respectively, or 0.038 total. Average values found in this survey for the North Arm sediments were slightly higher than those mean values.

All the detectable chlorophenol values (sum of penta and tetra) exceeded the provisional objective (0.01 μg/g) for bottom sediments in the river, including the upstream "control" at Barnston Island. Such a result indicates that further sampling and a study of chlorophenol sources are required. Fish muscle levels were low (Section 4.3.13).

Hall *et al.* reported that "phenol was the only acidic contaminant found in sediments" (i.e. tetra and pentachlorophenol could not be detected) in 1983[8]. The sediment samples discussed by Hall *et al.* had been collected in the North Arm and Main Arm below New Westminster. Chlorophenols may be biodegraded in sediments and generally not available to biota. This would explain why levels were low in fish, but not why these continue to be found in sediments unless the material had been freshly deposited and had not had time to degrade.

4.1.3 METALS

Metal values in sediments are reported in Table 2 on a dry-weight basis. Certain metals could not be detected. These metals, and the detection level, were as follows: arsenic, 25 µg/g; boron, 1 µg/g; beryllium, 1 µg/g; selenium, 10 µg/g; tin, 5 µg/g; and tellurium, 20 µg/g. The other metals measured are discussed below.

In the following discussion, values cited refer to mean values of the replicate samples, unless otherwise stated.

4.1.3.1 Aluminum

Aluminum values increased in the Main Stem from about 8 400 µg/g at Barnston Island, a site with the coarsest sediments, to 10 000 µg/g at Sapperton Channel. Values in the North Arm were between 10 000 and 11 000 µg/g, and about 13 000 µg/g in the Main Arm. Higher values tended to be associated with sediments of a finer texture.

4.1.3.2 Barium

Barium values increased in the Main Stem from about 75 to 97 µg/g. Values in both the North and Main Arms decreased going downstream. This was not related to particle size distribution (Table 1), and therefore may be related to the tidal influence at the two downstream sites.

4.1.3.3 Cadmium

Cadmium values increased from 0.20 μg/g at Barnston Island to about 0.32 μg/g at Sapperton Channel. This latter value was also representative of cadmium in sediments of the North and Main Arms. There was no obvious relationship between cadmium values and sediment texture. These values are similar to those reported by Stancil but significantly lower than some earlier values reported by Stancil (see Table 3-10, reference 4). This indicates that there likely has been no significant change in cadmium content of sediments.

4.1.3.4 Cobalt

There was no apparent trend in cobalt values in sediments. All values ranged between 10 and 18 μg/g. In the Main Stem, values increased from about 13 to 17 μg/g, Main Arm values increased from 15 to 18 μg/g, while North Arm values decreased from about 14 to 12 μg/g. There was not an obvious relationship between the cobalt values and the texture of the sediments. These values are typical of more recent values reported by Stancil (see Table 3-9. reference 4), indicating no significant change in cobalt content of sediments.

4.1.3.5 Chromium

Chromium values in the Main Stem and in the North Arm were about the same (31 μg/g) at both sites. Values in the Main Arm were about 36 μg/g. Therefore the higher values tended to be associated with finer textured sediments.

4.1.3.6 Copper

Copper values increased in the Main Stem from about 27 to 31 μg/g. Values going in a downstream direction in the North Arm decreased from 38 to 32 μg/g, while they increased from about 39 to 42 μg/g in the Main Arm.

Other than the decreasing North Arm values, the higher values tended to be associated with finer textured sediments. Copper values reported here are generally higher than reported by Stancil[4], who had reported 28.4 µg/g at Sapperton Channel area, between 17 and 19.6 µg/g in the Main Arm, and between 22.2 and 28.4 µg/g in the North Arm. This may indicate a potential new source of copper to the river. Swain reported copper in stormwater sediments ranging between 22 and 29 µg/g (dry). Therefore stormwater likely is not the source of these possibly higher copper levels in sediments.

4.1.3.7 Iron

Going in a downstream direction, values increased in the Main Stem from 19 400 to 23 300 µg/g, and decreased in the North Arm from 25 600 to 22 000 µg/g and the Main Arm from 31 400 to 29 900 µg/g. Although iron values within each reach were not directly related to particle size distribution, apparent values for each reach were related to particle size (i.e. values increased from about 21 500 µg/g in the Main Stem to 23 800 µg/g in the North Arm and 36 000 µg/g in the Main Arm).

The Main Stem values reported herein are about the same, although those for the North and Main Arms are higher than reported by Stancil[4], who had found about 23 000 µg/g in the Main Stem, between 16 820 and 20 000 µg/g in the Main Arm, and from 18 350 to 20 450 µg/g in the North Arm. Iron is not particularly toxic to aquatic life.

4.1.3.8 Mercury

Mercury could not be detected (0.05 µg/g) at Sapperton Channel in the Main Stem. Values at all other sites, including the Barnston Island site upstream from the major discharges, were fairly consistent at about 0.06 to 0.07 µg/g. Therefore mercury could not be related to particle size distribution. These values are significantly higher than reported by Stancil, possibly reflecting an upstream source of mercury to the river. Mercury had not been detectable (varying detection limits) in the data from Stancil[9].

An area of high natural mercury exists on Pinchi Lake in the upper reaches of the Fraser River. Sediment samples should be collected between the headwaters and the Lower Mainland area to determine the overall status of mercury in sediments of the Fraser River.

4.1.3.9 Manganese

The lowest values were in the Lower North Arm, at 284 µg/g. Values in the Main Stem increased in a downstream direction from about 410 to 460 µg/g and in the Main Arm from 520 to 590 µg/g. Other than sediments from the North Arm, higher manganese values were correlated with smaller particle size. These values are higher than reported by Stancil[4]. Stancil had reported about 370 µg/g in the Main Stem, between 261.2 to 309.3 µg/g in the Main Arm, and between 213.1 and 319.7 µg/g in the North Arm.

4.1.3.10 Molybdenum

Molybdenum values were about the same at all sites, between 6 and 8 µg/g.

4.1.3.11 Nickel

Nickel values increased in a downstream direction in the Main Stem from about 35 to 40 µg/g. They were slightly lower than this latter value in the North Arm, and slightly higher in the Main Arm. These values are typical of those reported earlier by Stancil[4], indicating no apparent change over time. There was no obvious correlation to sediment particle size.

4.1.3.12 Lead

Lead values in the Main Stem and Main Arm were considerably higher than the values reported by Stancil (<10 µg/g)[4], at about 20 µg/g. Values in the North Arm were virtually unchanged, at about 20 to 25 µg/g. These values do not appear to be correlated to particle size. Swain[6] reported lead values of 180 µg/g for sediments associated with stormwater. This could explain the higher values in the North Arm, since there are a considerable number of stormwater outfalls to the North Arm.

4.1.3.13 Strontium

Values for strontium increased in the Main Stem in a downstream direction, from about 32 to 39 µg/g. Values in the Main Arm were at about this latter value, however North Arm values were between 28 and 35 µg/g. These values do not seem to be correlated to particle size.

4.1.3.14 Titanium

Titanium values in Main Stem sediments increased from 210 to 265 µg/g. Sediments in the Main Arm were slightly higher (285 µg/g) while those in the North Arm were slightly lower (200 to 245 µg/g). Therefore there did seem to be a slight trend correlating titanium values in the Main Stem and Main Arm to particle size; however, North Arm values did not correlate.

4.1.3.15 Thallium

Thallium could not not be detected (20 µg/g) in the sediments from the North or Main Arms. In the Main Stem, values ranged from about 23 to 27 µg/g. This indicates that no apparent correlation existed between thallium values and particle size.

4.1.3.16 Vanadium

Vanadium increased slightly in a downstream direction in the Main Stem, increasing from about 24 to 29 µg/g. North Arm values were about the same (28 to 29 µg/g), while values in the Main Arm were slightly higher (33 to 34 µg/g). Thus these values had a slight correlation with particle size.

4.1.3.17 Zinc

Zinc values increased slightly in a downstream direction. In the Main Stem, values increased from about 47 to 55 μg/g. These are lower than reported by Stancil[4].

Values in the North Arm were the highest, and were 98 μg/g at the Upper North Arm site and 71 μg/g at the second site. These are of about the same magnitude as reported by Stancil[4]. Sediment and grit from a storm-water outfall draining to the North Arm had a zinc concentration of 140 μg/g[6]. This, or seepage from Western Canada Steel and Tree Island Steel, could explain the higher values of zinc in North Arm sediments than found in other reaches.

Values in the Main Arm were about 70 μg/g, considerably higher than reported by Stancil (45 μg/g)[4]. There was no apparent correlation between zinc concentrations and particle size, although the high zinc values in stormwater sediments, in the discharge from Noranda Metals located on Annacis Island, or in seepage from Titan Steel and Wire may skew any trend.

4.1.4 CONCLUSIONS

Some differences were noted between metal data reported earlier by Stancil[4] and those reported here. These could be real or could be artifacts of sampling location or time of year. Future sampling at the same sample locations and time of year will help to determine which of the two factors is responsible for any observed differences. Some metal values apparently have changed since the last report by Stancil[4]. In the estuary area, these metals include copper which was 50 to 100% higher, iron which was about 20 to 50% lower, mercury which was detectable, manganese which was only about 50% of those data reported earlier and, in the Main Stem and Main Arm, lead which had at least doubled.

PCB's and chlorophenols in the North Arm and at the Barnston Island site in the Main Stem exceeded the provisional water quality objectives. Further sampling will determine if these values are changing with time. Studies are required to trace the source of PCB's and chlorophenols, both of which were found to be exceeding the objective, and to determine upstream background levels.

Metal values generally were higher in the North and Main Arms compared to values in sediments in the Main Stem. Data for most metals had some correlation to particle size, i.e., higher metals values were associated with smaller particle size.

Detectable mercury values are suspected to be due to some upstream source. A survey of the Fraser River sediments, from the Lower Mainland to the headwaters, should be undertaken so that a better understanding of mercury in Fraser River sediments can be obtained.

4.2 BENTHIC ORGANISMS

Under this general title, some selected vertebrates (lampreys) will be discussed in addition to several invertebrates. The data are reported in Table 3, on a dry-weight basis, unless otherwise indicated.

The same benthic organisms were not found at all six sites due to particle size differences of sediments among sites, and salinity differences which increased going downstream.

Nine taxanomic groups of benthic organisms were obtained from the sediments. These included chironomids, lampreys, oligochaetes, amphipods, polychaetes, pelecypods, crustaceans, diptera, and leeches. The latter three were found at only one site.

Generally, only metal analyses were performed on the benthic organisms, although PCB's and chlorophenols were measured if sufficient sample mass was available. Metals which were not detectable on a dry-weight basis in any of the benthic organisms were arsenic (25 μg/g), beryllium (1 μg/g), cobalt (10 μg/g), and selenium (10 μg/g).

4.2.1 LEECHES

Leeches were found only in Annacis Channel in the Main Arm. The highest levels of boron (87 μg/g), chromium (48 μg/g) and nickel (96 μg/g) were found in leeches as compared to any other invertebrates (dry-weight). Zinc values were higher in leeches (814 μg/g) than in all other benthic organisms except a lamprey from Sapperton Channel (1 870 μg/g). There was no obvious correlation between the maximum values for boron and zinc and maximum values in sediments; i.e., if benthic organisms biomagnify values in sediments, the highest metal values should be associated with benthic organisms from the Main Arm. This can only be said to be true for chromium and nickel in leeches.

The use of bioconcentration factors (concentration of metal in organism/concentration of metals in sediment) can indicate a relationship between levels in organisms and sediments. Those characteristics for which there was a value > 1:1 are shown below.

	Bioconcentration Factors (Leeches from Annacis Channel)
Chromium	1.33:1
Copper	3.2 :1
Nickel	2.2 :1
Zinc	11.1 :1

These data indicate that chromium, copper, nickel and zinc are possibly bioconcentrated from the sediments.

4.2.2 DIPTERA

Diptera were obtained only from Sapperton Channel. Metal values were less than found in other benthic organisms. This may provide some basis for a correlation between values in sediments and invertebrates; however, not enough information is available to ascertain the effect of factors such as species differences.

Bioconcentration factors > 1:1 were present only for copper (1.5:1) and for zinc (1.97:1).

4.2.3 CRUSTACEA

Crustacea were found only at the Barnston Island site. These had the highest copper level (271 μg/g) found in any of the benthic organisms. Since copper in sediments was lowest at Barnston Island, this highest copper value seems to discount the existence of any trend between metal values and location. However, once again species differences may explain the high copper in crustacea.

Bioconcentration factors were calculated and found to be >1:1 for the characteristics shown below.

	Bioconcentration Factors (Crustacea at Barnston Island)
Barium	1.46:1
Copper	10.1 :1
Manganese	2.48:1
Strontium	10.7 :1
Zinc	4.5 :1

These data indicate that a possible relationship for barium, copper, manganese, strontium, and zinc exists between levels found in organisms and sediments.

4.2.4 CHIRONOMIDS

Chironomids were collected at one site in each of the main river reaches, at Barnston Island, Annacis Channel, and at the upper North Arm site. None of the highest metal values for any metals were recorded in the chironomid samples.

Among the three sites, the highest metal values were recorded in the chironomids from Annacis Channel. The one exception was boron at the upper North Arm, at 7 µg/g compared to not being detectable at the other two sites (1 µg/g). Boron had not been detected in any of the sediment samples (Section 4.1.3).

Stancil reported values for chironomid larvae for a site in each of the major reaches for cadmium, cobalt, copper, iron, lead, manganese, nickel, zinc, and mercury(4). Some selected values are in Table 6 for comparison. Mercury values were not obtained in this survey due to insufficient sample. Other metal values in this survey were less or in the range reported by Stancil.

COMPARISON OF VALUES IN CHIRONOMIDS BETWEEN THIS SURVEY AND THOSE REPORTED BY STANCIL(4)

	THIS SURVEY		STANCIL(4)	
Cd	Annacis Ch.	(4 µg/g)	Ladner Side Ch.	(1.2 µg/g)
Cu	Barnston Is.	(55 µg/g)	New Westminster	(26.5-46.4 µg/g)
	Upper N. Arm	(91 µg/g)	Oak Street	(27.5-41.9 µg/g)
	Annacis Ch.	(93 µg/g)	Ladner Side Ch.	(19 µg/g)
Mn	Barnston Is	(268 µg/g)	New Westminster	(75 µg/g)
	Upper N. Arm	(165 µg/g)	Oak Street	(103 µg/g)
Zn	Annacis Ch.	(178 µg/g)	Ladner Side Ch.	(152 µg/g)

Since chironomids were found at one site in each of the reaches, bioconcentration factors were calculated at the three sites. Those with values >1:1 are below.

Bioconcentration Factors

	Barnston Is.	Upper North Arm	Annacis Channel
Cadmium	5:1	<3.1:1	11.4:1
Copper	2.1:1	2.4:1	2.4:1
Zinc	3.8:1	1.8:1	2.4:1

These data indicate a possible correlation between metal values in chironomids and those in sediments for cadmium, copper, and zinc.

An adequate amount of sample was available for chironomids from the Barnston Island site to conduct PCB and chlorophenol analyses. PCB's were not detectable (0.1 μg/g wet weight); however, pentachlorophenol and tetrachlorophenol values were 0.06 and 0.03 μg/g (wet weight), respectively. If the objective of 0.1 ppm (wet weight) for chlorophenols in fish applied to other aquatic life, the objective would be met for chironomids at Barnston Island.

4.2.5 OLIGOCHAETES

Oligochaetes were found at both sites in the Main Stem and in Annacis Channel in the Main Arm. The highest values for any benthic organism for aluminum (5 010 μg/g), titanium (355 μg/g) and vanadium (20 μg/g) were found in oligochaetes collected at the Barnston Island site. Sediments from Barnston Island had the lowest concentrations of these three metals.

Among sites where metal values could be detected, oligochaetes in Annacis Channel had higher zinc (259 μg/g) than in the Main Stem (180 μg/g). Otherwise, the Main Stem sites had higher metal values than in oligochaetes from Annacis Channel. Within the Main Stem, barium, molybdenum, and nickel values at Sapperton Channel were higher; while from the Barnston Island site, aluminum, boron, chromium, copper, iron, manganese, strontium, titanium, and vanadium were higher. These data tend to discount the existence of a correlation between metal values in chironomids and sediments due to particle size of sediments.

Bioconcentration factors were calculated for all metals at the three sites. Values >1:1 were found at all sites, for copper and zinc. These are shown below.

Bioconcentration Factors

	Barnston Island	Sapperton Channel	Annacis Channel
Copper	7:1	1.8:1	2.77:1
Zinc	3.85:1	3.3:1	3.5 :1

Stancil reported values for oligochaetes for a site in each of the major reaches for cadmium, cobalt, copper, iron, lead, manganese, nickel, zinc, and mercury[4]. Some selected values are in Table 6 for purposes of comparison. Mercury values were not obtained in this survey due to a lack of sample mass. Values reported for this survey were within the range or lower than values reported by Stancil for cadmium, cobalt, manganese, nickel, and lead. Higher values have been found in oligochaetes from this survey for the following: copper in the Main Stem (56-188 μg/g) compared to data for New Westminster (11.8-35.3 μg/g), and in Annacis Channel (108 μg/g) compared to data for Ladner Side Channel (19 to 40 μg/g); iron in the Main Stem (8 930- 10 400 μg/g) compared to data for New Westminster (1030 - 5400 μg/g); zinc in the Main Stem (179-180 μg/g) compared to data for New Westminster (82.4 - 153 μg/g), and in Annacis Channel (259 μg/g) compared to Ladner Side Channel (40-96 μg/g).

No PCB's or chlorophenols were analyzed in the oligochaetes.

4.2.6 AMPHIPODS

Amphipods were collected at Ewen Slough and in the lower North Arm. They did not have the highest metal values of any of the benthic organisms.

Between the two sites, boron (15 μg/g), strontium (978 μg/g), and zinc (165 μg/g) were higher in amphipods from the lower North Arm than in those from Ewen Slough. There did not appear to be a correlation with metal values found in sediments other than the fact that higher values were mostly found in the amphipods from the Main Arm.

Bioconcentration factors were calculated for all metals. Values >1:1 at both sites for metals are below.

Bioconcentration Factors for Amphipods

	Ewen Slough	lower North Arm
Barium	2.8:1	2:1
Copper	3.7:1	2.5:1
Strontium	9.3:1	34.9:1
Zinc	2.3:1	2.3:1

These data indicate that barium, copper, strontium, and zinc are concentrated in amphipods from the sediments.

Stancil reported on metal values for amphipods from the North and Main Arms[4]. Values obtained in this survey were less than or in the range of values reported by Stancil for cadmium, cobalt, chromium, lead, and nickel. In this survey, values of copper, iron (in the North Arm only), manganese, and zinc (in the North Arm only) were higher.

PCB's and chlorophenols were not detectable (0.1 µg/g and 0.01 µg/g, wet weight, respectively) in the amphipods sampled from Ewen Slough.

4.2.7 POLYCHAETES

Polychaetes were found only at Ewen Slough in the Main Arm and in the lower North Arm. Polychaetes from Ewen Slough had the highest cadmium value (5 µg/g) of any invertebrate. A polychaete and pelecypods from Ewen Slough each had 5 µg/g molybdenum, the highest concentration for invertebrates. Those polychaetes from the Lower North Arm had the highest iron value (11 600 µg/g). There is no apparent correlation between values for these metals in sediments and values in the polychaetes.

At the two sites, metal values were approximately the same with the following exceptions. Metal values for the polychaetes from the lower North Arm were considerably higher for aluminum, nickel, and vanadium. Metal values for the polychaetes from Ewen Slough were considerably higher for cadmium, copper, manganese, molybdenum, strontium, and zinc. Thus some correlation between metal values in sediments and invertebrates may have existed.

Bioconcentration factors were calculated to determine if a relationship existed. Values >1:1 for metals at both sites are shown below.

Bioconcentration Factors for Polychaetes

	Ewen Slough	lower North Arm
Copper	2.1:1	1.8:1
Strontium	2.2:1	2.1:1
Zinc	4.3:1	2.7:1

These data indicate that copper, strontium and zinc are concentrated in polychaetes from the sediments.

PCB's and chlorophenols were analyzed in the polychaetes from both sites. PCB's could not be detected (0.1 µg/g) in polychaetes from either site; however, the sum of the two measured chlorophenols was 2.5 µg/g in the lower North Arm, but only 0.11 µg/g in Ewen Slough. Thus, if the objective for chlorophenols of 0.1 ppm (wet weight) in fish muscle were applied to benthic organisms, the objective would not be met in the Lower North Arm. However, fish muscle samples did meet the objective (Section 4.3.13).

4.2.8 PELECYPODA

Pelecypoda were collected in the lower North Arm and in Annacis Channel. The highest values of manganese, lead, tin, strontium, tellurium, and thallium were recorded for these invertebrates, higher than in any other benthic organism. Pelecypoda and polychaetes from Ewen Slough each had a concentration of 5 µg/g molybdenum, the highest concentration in a benthic organism.

At the two sites, metal values were approximately the same with the following exceptions. Metal values for the pelecypoda from the lower North Arm were considerably higher for aluminum, iron, nickel, strontium, tellurium, titanium, vanadium, and zinc. Metal values for pelecypoda from Ewen Slough were considerably higher for boron, barium, managanese, molybdenum, lead, tin, and thallium.

Bioconcentration factors >1:1 for both sites for pelecypoda were found only for strontium. These factors were 9.2:1 at Annacis Channel and 35.3:1 at the lower North Arm.

Pelecypoda from the Lower North Arm had non-detectable values for PCB's (0.1 µg/g) but a detectable chlorophenol concentration (0.03 µg/g). This latter value would meet the water quality objective for chlorophenols which presently applies to fish flesh, if it were applicable to benthic organisms.

4.2.9 LAMPREYS

Lampreys were collected at sites at Barnston Island and Sapperton Channel in the Main Stem and Annacis Channel in the Main Arm. Lampreys from Sapperton Channel had the highest zinc value (1870 µg/g) of any benthic organism.

Among the sites, many of the metal values were similar. However, lampreys from Barnston Island were higher considerably in values of aluminum, barium, iron, and titanium. Lampreys from Sapperton Channel were higher considerably for boron, chromium, copper, and zinc. There was no apparent trend between metal values in invertebrates and those found in sediments.

Bioconcentration factors calculated for all metals were >1:1 at all sites for only copper and zinc. These are detailed below.

Bioconcentration Factors for Lampreys

	Barnston Island	Sapperton Channel	Annacis Channel
Copper	1.4:1	5.1:1	1.1:1
Zinc	3.8:1	34.2:1	2.2:1

PCB's and chlorophenols were measured only in lampreys from Barnston Island. PCB's could not be detected (0.1 µg/g), while the sum of the two measured chlorophenols was about 0.05 µg/g. This chlorophenol value would meet the water quality objective for chlorophenols which applies to fish flesh, if it were in fact applicable to benthic organisms.

4.2.10 CONCLUSIONS

Cadmium, copper, manganese, and zinc levels in chironomids; copper and manganese in amphipods; and copper and zinc in oligochaetes were higher than reported by Stancil[4] for an earlier study. However, samples were collected at different times of year and at different sites, which might explain the variability.

It was difficult to determine if a correlation existed between metal values in benthic organisms and those in sediments since the same benthic organisms were not found at all six sites. As well, sufficient mass of benthic organisms for only one measurement was available from each site. However, using bioconcentration factors and assuming values >1:1 represent bioconcentration of metals by organisms, copper and zinc were concentrated by all organisms (except pelecypoda) at all sites. Strontium was concentrated by four of the nine organisms (amphipods, polychaetes, crustacea and pelecypoda) at those sites where this organism was found. Bioconcentration among organisms and sites for the other metals appears to be randomly distributed.

Due to laboratory requirements for mass of benthic organisms, inadequate collections prevented chlorophenol and PCB determinations at most sites for most benthic organisms. Chlorophenols and PCB's were tested in chironomids and lampreys from Barnston Island, amphipods and polychaetes from Ewen Slough, and polychaetes and pelecypoda from the lower North Arm. PCB's could not be detected in any of the benthic organisms at any of the sites, indicating that high sediment levels were not being reflected in the populations of benthic organisms tested.

An objective of 0.1 ppm (wet weight) has been established for the sum of chlorophenols in fish. If this objective were to apply to benthic organisms as well, and if the sum of penta and tetrachlorophenols gave a true indication of the sum of all chlorophenols, then the objective would be considered as having been exceeded about 5-fold in polychaetes from the lower North Arm. Values from this same site for sediments also exceeded the proposed water quality objective for sediments.

4.3 FISH

Fish were collected from all six sites. Several characteristics could not be detected in fish muscle at any of the sites. These characteristics and their detection limits on a dry-weight basis were arsenic (25 μg/g), boron (1 μg/g), barium (1 μg/g), beryllium (1 μg/g), cadmium (0.2 μg/g), cobalt (10 µg/g), nickel (1 µg/g), selenium (10 µg/g), tin (5 µg/g), tellurium (20 µg/g), titanium (1 µg/g), thallium (20 µg/g), and vanadium (1 µg/g). The remaining values for fish muscle are in Table 4.

Livers were analyzed from these same fish, except for a peamouth chub from Barnston Island and a prickly sculpin form Sapperton Channel. Characteristics (and their detection limits) which could not be detected in any of the liver samples were arsenic (25 µg/g), barium (1 µg/g), beryllium (1 µg/g), cobalt (10 µg/g), tin (5 µg/), and thallium (20 µg/g). The remaining results are in Table 5, expressed on a dry weight basis.

4.3.1 ALUMINUM

Aluminum could not be detected (2 µg/g - dry weight) in the muscle of Dolly Varden, rainbow or cutthroat trout in the Main Arm. Values for Dolly Varden, rainbow and cutthroat trout, and sculpin at the other sites were all less than 10 µg/g (dry), except for one staghorn sculpin from the lower North Arm. It had a concentration in its flesh of 28 µg/g (dry) or 4.34 µg/g (wet). The highest aluminum concentrations had been found in sediments from the Main Arm and oligochaetes from Barnston Island. Thus there was no apparent correlation among maximum values in environmental compartments.

Aluminum was detected in livers from fish from all reaches of the river. The maximum concentration was 12 µg/g (dry) or 2.77 µg/g (wet) from a rainbow trout caught in the upper North Arm. The staghorn sculpin which had the highest muscle concentration had a non-detectable concentration (2 µg/g-dry) in its liver. There was no apparent correlation between muscle and liver concentrations.

Neither Singleton[3] nor Stancil[4] reported aluminum values for fish. Stancil[4] reproduced information of a 1973 survey of 350 fish specimens collected downstream from Hope. Singleton[3] collected and reported on a 1980 survey of 273 fish specimens caught along the total length of the Fraser River.

4.3.2 CADMIUM

Cadmium was not detected (0.2 µg/g-dry) in muscle; however, it was found in livers from some fish (Table 5). The highest value of 0.61 µg/g (dry) or 0.138 µg/g (wet) was found in a staghorn sculpin from the lower North Arm. Cadmium had been found at approximately equal concentrations in sediments from most sites. The maximum concentration in benthic organisms was in a polychaete (5 µg/g) from Ewen Slough.

Singleton[3] also reported not detecting cadmium in muscle samples but detecting it in a large number of livers, a finding Singleton pointed out as being consistent with that of other researchers.

4.3.3 CHROMIUM

Chromium was detected in all the muscle samples. Values ranged from 0.44 to 1.87 µg/g (dry) and 0.105 to 0.318 µg/g (wet). The highest dry weight value was for a staghorn sculpin from the lower North Arm, while the highest wet-weight value was for a prickly sculpin from Sapperton Channel. Chromium had been found at the highest concentration in Main Arm sediments and in leeches from Annacis Channel. Thus, there was no apparent correlation among maximum values in different environmental compartments.

Singleton[3] reported that chromium had been found in fish muscle collected throughout the Fraser River system and that the highest value had been recorded for a squawfish from near McBride.

Chromium was also detected in all the liver samples. Values ranged from 0.55 to 2.7 µg/g (dry) or 0.13 to 0.89 µg/g (wet). The highest value was from a cutthroat trout from Annacis Channel. Leeches from Annacis Channel had the highest concentration found in benthic organisms. Therefore there may be some basis for a correlation between environmental compartments. Singleton[3] had found chromium in liver samples from only one salmon (0.25 µg/g-wet) from the lower North Arm.

There was no apparent correlation among sites or species for chromium in liver or muscle samples.

4.3.4 COPPER

Copper values in all the fish muscle samples ranged from 2 to 4 µg/g (dry) or 0.314 to 0.952 µg/g (wet). The maximum value was in a cutthroat trout and a rainbow trout from the upper North Arm and a staghorn sculpin (which had the highest aluminum and iron) from the lower North Arm. The maximum sediment concentrations had been in samples from Ewen Slough. The maximum concentration in benthic organisms was in crustacea from Barnston Island. Thus, there was no apparent correlation among maximum values in environmental compartments. Singleton found the "majority of muscle samples had copper concentrations less than 1.0 µg/g (wet)"[3], the same as found in this survey.

Copper was found in all the liver samples at concentrations from 3 to 140 µg/g (dry), or 0.753 to 31.9 µg/g (wet). The maximum concentration was found in a second cutthroat trout from Annacis Channel, which also had the highest lead in livers. Thus, there was no apparent correlation among maximum values in muscle and liver. The liver values were considerably higher than values for the muscle, by factors as high as 70:1. Singleton had reported factors of 35:1 to 250:1. These ratios were noted by Singleton as being typical of other water bodies[3].

4.3.5 IRON

Concentrations of iron in muscle tissues ranged from 18 to 59 µg/g (dry) or 3.8 to 9.15 µg/g (wet). The maximum value was in a staghorn sculpin (which had highest copper and aluminum) from the lower North Arm. Polychaetes from the lower North Arm also had the highest iron concentration; however, samples from Annacis Channel had the highest sediment concentration. Thus, there may be some basis for a correlation between iron in invertebrates and fish muscle. These values are about the same as reported by Singleton for fish sampled in 1980 and 1972[3].

Liver concentrations ranged from 79 to 1060 µg/g (dry) or from 19.36 to 251 µg/g (wet). The highest value was from a third cutthroat trout from Annacis Channel. This location had the highest sediment concentration. Thus, there may be some basis for a correlation between iron in sediments and fish livers. These fish liver values were within the range reported by Singleton(3).

4.3.6. LEAD

Concentrations in fish muscle were all low, either 1 or < 1 µg/g (dry), i.e. all values were ≤0.258 µg/g (wet). The highest value on a wet-weight basis was in a Dolly Varden from Annacis Channel. All values were similar to those reported by Singleton(3) for this reach of the river.

In livers, lead concentrations ranged from <1 to 9 µg/g (dry) or to as high as 2.05 µg/g (wet). This highest value was from the second cutthroat trout from Annacis Channel, which also had the highest liver copper concentration. This maximum value exceeded the maximum reported by Singleton (0.36 µg/g) for a composite sample from peamouth chub from Ewen Slough(3).

The highest lead concentration in an organism was in pelecypoda from Ewen Slough. The highest concentrations in sediments were in samples from the North Arm. Therefore, there is no basis for a correlation among maximum values in different environmental compartments.

4.3.7 MANGANESE

All manganese values in fish muscle (Table 4) were at or below the detection limit of 1 µg/g. All fish from the Main Arm had non-detectable values of manganese, while all values in the Lower North Arm were detectable. However, different species were tested in each of these cases.

All manganese values in fish livers (Table 5) ranged from 3 to 8 µg/g (dry) or 0.68 to 1.98 µg/g (wet). Singleton had reported the highest concentration of 3.98 µg/g (wet) in a composited liver sample from six largescale suckers caught in Ewen Slough[3]. Thus, all liver and tissue manganese values were within ranges reported by Singleton.

The maximum concentrations for other environmental compartments examined in this survey had been in pelecypoda and sediment samples from Ewen Slough.

4.3.8 MERCURY

Values for mercury reported in Tables 4 and 5 are on a wet-weight basis. Values for fish muscle (Table 4) ranged from 0.07 to 1.36 µg/g. The highest value was for a prickly sculpin from Sapperton Channel. All other values were ≤ 0.26 µg/g. Mercury had not been found in sediments from Sapperton Channel (Section 4.1.3.8), and had not been measured in invertebrates. Singleton reported the highest mercury value to be 1.23 µg/g in a northern squawfish from Chilliwack[3].

Mercury values in livers ranged from <0.05 to 0.13 µg/g. This maximum value was recorded for a cutthroat trout from Annacis Channel and a staghorn sculpin from the lower North Arm. The liver from the prickly sculpin from Sapperton Channel was of insufficient mass to permit the analysis to be carried out. Singleton reported a maximum mercury in liver to be 0.19 µg/g for a white sturgeon from Chilliwack.

4.3.9 MOLYBDENUM

Molybdenum was detected in the muscle from only one sample, a cutthroat trout from the upper North Arm. The value was at the detection limit of 1 µg/g (dry) (Table 4). Singleton had reported a maximum 1.39 µg/g (wet) in a longnose sucker from Moose Lake and, in the Lower Mainland area, 0.8 µg/g (wet) in a white sturgeon from the Main Arm.

In fish livers, molybdenum ranged from < 1 to 3 µg/g (dry), the maximum value being from a rainbow trout captured in the upper North Arm. This maximum value corresponds to a value of 0.69 µg/g (wet). Singleton reported a maximum value of 1.23 µg/g (wet) in the liver of an adult sockeye salmon from the lower North Arm. Thus, molybdenum values were within the ranges of values for muscle and liver samples reported by Singleton.

Molybdenum concentrations in sediments were about the same at all sites. In invertebrates, the maximum values were in pelecypoda and polychaetes from Ewen Slough. Thus, there is no apparent correlation among environmental compartments.

4.3.10 NICKEL

Nickel could not be detected (1 µg/g-dry) in fish muscle. Singleton also had not detected nickel in fish collected downstream fom Hope[3].

In livers, nickel was detected (i.e. ≥1 µg/g dry) in only one sample, a Dolly Varden captured at Barnston Island. The nickel concentration of 5.43 µg/g (dry) corresponds to a wet-weight value of 1.19 µg/g. Singleton had not detected (5.0 µg/g dry) nickel in any livers[3].

Nickel values probably are unchanged since the time data reported by Singleton were collected.

For other environmental compartments, nickel was highest in leeches from Annacis Channel and sediment samples from the Main Arm. Thus, nickel levels in these environmental compartments could not be correlated with values found in fish.

4.3.11 ZINC

Zinc values in fish muscle ranged from 14 to 50 µg/g on a dry-weight basis (Table 4) or 3.26 to 7.3 µg/g on a wet-weight basis. The highest values were in sculpins, the maximum in a staghorn sculpin from the lower

North Arm and the second highest in a prickly sculpin from Sapperton Channel (43 µg/g-dry). Interestingly, the maximum concentration in a benthic organism was in lamprey collected from Sapperton Channel, while the highest sediment level was for samples from the upper North Arm. Thus, there may be some correlation between environmental compartments at Sapperton Channel. Singleton had reported a maximum value of 33 µg/g (wet) in a peamouth chub from Ewen Slough.

Values in livers ranged form 84 to 222 µg/g (dry) or 18.5 to 49.7 µg/g (wet). The maximum value was from a second staghorn sculpin from the lower North Arm. Singleton reported values in livers below Chilliwack ranging from 17.7 µg/g to 41.8 µg/g (wet)[(3)]. Thus, values found in this survey for zinc in muscle and liver samples were about the same as reported by Singleton.

4.3.12 OTHER METALS

Results are reported in Tables 4 and 5 for several metals for which neither Singleton nor other researchers have reported results.

In muscle, strontium values ranged from < 1 µg/g to 20 µg/g, although all but one value was ≤5 µg/g (dry). The highest value was in a staghorn sculpin from the lower North Arm. Strontium values ranged from < 1 to 2 µg/g (dry) in livers.

Titanium and vanadium were also measured in livers. All titanium and vanadium values were below detection (<1 µg/g) except in a rainbow trout (<1 µg/g) from the upper North Arm which contained 1 µg/g (dry) of each metal.

4.3.13 CHLOROPHENOLS

A provisional water quality objective of 0.1 ppm (wet weight) has been proposed for the sum of tri-, tetra-, and pentachlorophenol in fish muscle. In this survey, only penta- and tetrachlorophenol were measured. The sum of all values for the fish tested met the objective for chlorophenols in fish muscle (i.e. 0.06 µg/g wet, maximum).

Chlorophenol values were higher (Table 4) in fish captured in the Main Stem and North Arm compared to fish from the Main Arm of the river. In fact, fish collected from the Main Arm had non-detectable levels of pentachlorophenol (<0.01 µg/g wet) and tetrachlorophenol (<0.01 µg/g wet).

When chlorophenols were detectable, pentachlorophenol was higher or equal in concentration to tetrachlorophenol. The highest sum of chlorophenols was 0.06 µg/g (wet) for a rainbow trout captured in the upper North Arm. The highest sum of chlorophenols in a benthic organism was from polychaetes from the lower North Arm (2.5 µg/g wet).

Therefore, chlorophenols do not appear to be a problem in fish muscle at this time.

4.3.14 POLYCHLORINATED BIPHENYLS

The objective for the total of all PCB's is 0.5 µg/g (wet) in fish muscle. Values for all species were < 0.1 µg/g (wet) (Table 4). Therefore, PCB's do not appear to be a problem in fish muscle.

4.3.15 CONCLUSIONS

A sufficient number of individuals from each species was not collected to permit a valid comparison to the work reported by Singleton(3) (i.e., judgements as to trends of increasing or decreasing values could not be made).

However, it generally can be stated that values for fish muscle and livers were within ranges reported earlier by Singleton(3). Exceptions to this were related to liver samples. Some chromium and lead values for livers from cutthroat trout from Annacis Island were higher than reported in the past as was zinc in the liver from a staghorn sculpin from the lower North Arm. Generally, the highest metal values in muscle were for fish collected from the lower North Arm.

Objectives have been proposed for PCB's and chlorophenols in fish muscle. These were met in the fish tested in this survey.

There did not appear to be a correlation among maximum values found in sediments, benthic organisms and fish. However, some evidence of a correlation seemed to exist for two of these three compartments for the same metals.

Attempting to relate contaminant levels in salmonids to other environmental compartments is questionable, since all the salmonids were "ripe" adults ready for spawning. Thus, they had likely recently returned from the ocean, and were not representative species for the sites where they were captured. The only freshwater fish captured which may be representative was the prickly sculpin from Sapperton Channel.

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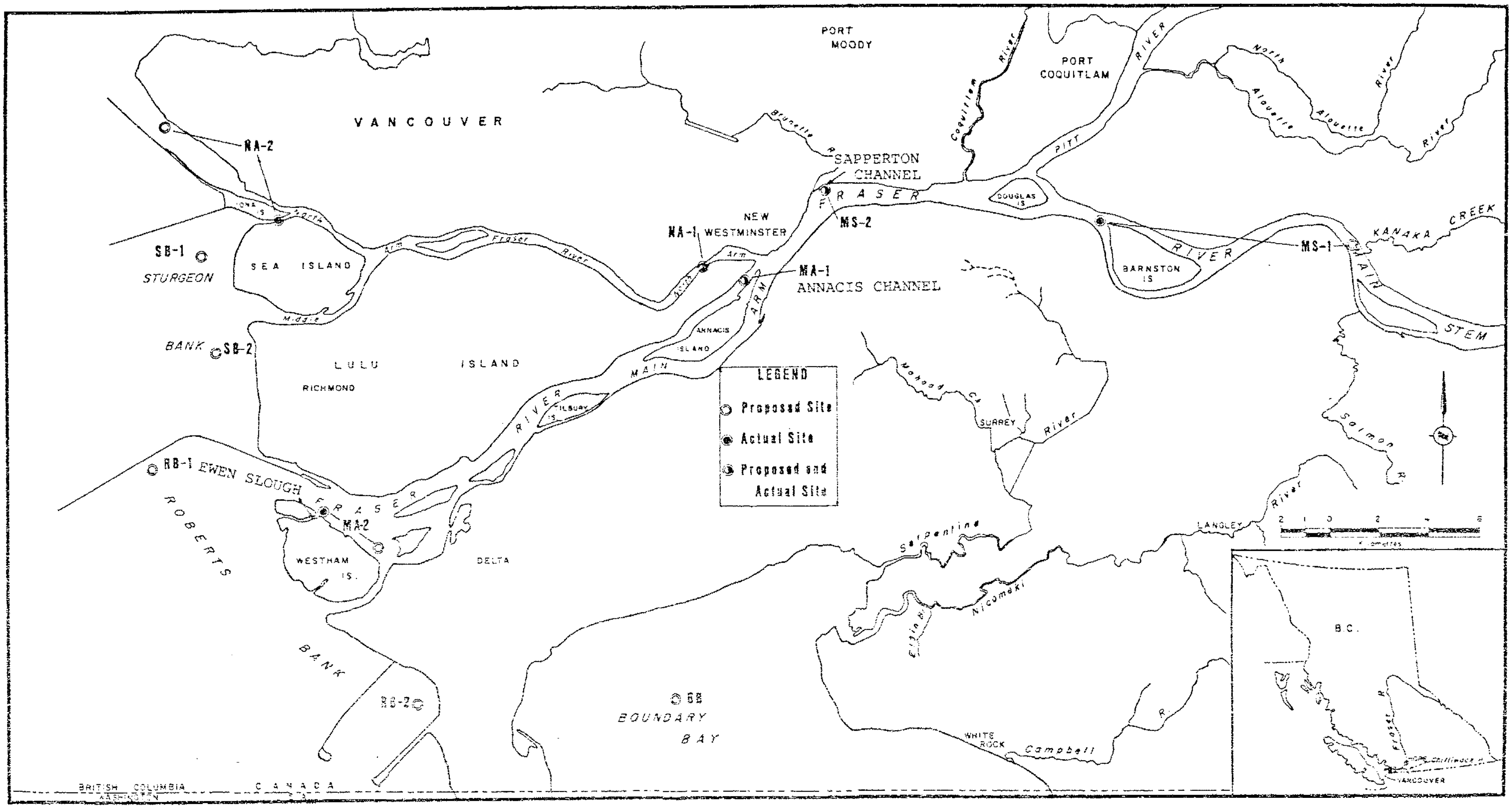

FIGURE 1 PROPOSED AND ACTUAL MONITORING SITES

TABLE 1

PARTICLE SIZE DISTRIBUTION

AND MISCELLANEOUS ANALYSES IN SEDIMENTS

		MS-1 BARNSTON ISLAND			MS-2 SAPPERTON CHANNEL	
	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 1	SAMPLE 2	SAMPLE 3
Total Volatile Residue % (w/w)	2.9	2.7	2.6	4.1	3.9	4.0
Total Organic Carbon (µg/g)	7 350	9 760	5 060	12 800	8 190	14 700
Total Inorganic Carbon (µg/g)	2 030	1 940	3 400	1 260	4 410	3 620
Total Carbon (µg/g)	9 380	11 700	8 460	14 100	12 600	18 300
Total Phosphorus (µg/g)	538	595	569	680	609	620
Particle Size (% passing)						
Sieve Size 16 (1.2 mm)	100.0	99.9	100.0	99.8	99.9	99.8
30 (0.6 mm)	99.9	99.8	99.9	99.3	99.6	99.5
50 (0.3 mm)	95.5	94.4	96.3	99.1	99.4	99.1
100 (0.15 mm)	74.6	70.5	68.3	91.2	90.5	87.7
140 (0.106 mm)	71.7	61.1	66.5	85.3	82.0	71.6
200 (0.075 mm)	57.2	48.7	45.0	69.8	68.2	48.2
270 (0.053 mm)	47.6	41.5	36.2	61.0	54.1	42.2
400 (0.038 mm)	39.3	29.9	27.6	52.4	43.3	32.9
Summary (%)						
Coarse and Medium Sand (>0.3 mm)	4.5	5.5	3.7	0.7	0.5	0.7
Fine Sand (0.075-0.3 mm)	38.3	45.7	51.3	29.3	31.2	50.9
Silt and Clay (<0.075 mm)	57.2	48.7	45.0	69.8	68.2	48.2

TABLE 1 (Continued)

	NA-1 UPPER NORTH ARM					NA-2 LOWER NORTH ARM		
	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 1	SAMPLE 2	SAMPLE 3
Total Volatile Residue % (w/w)	5.7	5.3	5.1	5.5	4.9	5.3	4.3	3.9
Total Organic Carbon (µg/g)	16 400	14 300	17 700	14 200	15 200	8 530	10 600	8 170
Total Inorganic Carbon (µg/g)	503	3 320	< 500	3 040	2 690	2 870	579	871
Total Carbon (µg/g)	16 900	17 600	17 700	17 200	17 900	11 400	11 200	9 040
Total Phosphorus (µg/g)	688	681	665	675	649	654	604	638
Particle Size (% passing)								
Sieve Size 16 (1.2 mm)	99.9	99.9	100.1	100.0	100.2	99.8	99.6	100.0
30 (0.6 mm)	99.7	99.8	100.0	99.9	100.0	97.0	96.6	98.6
50 (0.3 mm)	95.8	97.9	99.0	98.4	97.1	91.7	84.0	91.0
100 (0.15 mm)	92.0	95.5	96.8	95.8	94.1	83.8	78.8	85.0
140 (0.106 mm)	90.8	92.3	94.7	94.2	89.7	82.0	76.7	76.1
200 (0.075 mm)	83.1	87.5	88.6	86.1	83.8	78.8	70.4	69.2
270 (0.053 mm)	71.7	82.2	83.5	77.6	78.9	76.1	63.9	65.0
400 (0.038 mm)	63.4	68.5	69.6	65.4	64.4	68.4	56.7	58.5
Summary (%)								
Coarse and Medium Sand (>0.3 mm)	4.1	2.0	1.1	1.6	3.2	8.1	15.6	9.0
Fine Sand (0.075-0.3 mm)	12.7	10.4	10.4	12.3	13.3	12.9	13.6	21.8
Silt and Clay (<0.075 mm)	83.1	87.5	88.6	86.1	83.8	78.8	70.4	69.2

TABLE 1 (Continued)

	MA-1 ANNACIS CHANNEL			MA-2 EWEN SLOUGH		
	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 1	SAMPLE 2	SAMPLE 3
Total Volatile Residue % (w/w)	4.9	4.7	4.9	5.7	5.4	5.5
Total Organic Carbon (μg/g)	15 400	14 100	15 500	14 200	15 800	15 400
Total Inorganic Carbon (μg/g)	3 520	1 150	2 560	< 500	< 500	< 500
Total Carbon (μg/g)	18 900	15 200	18 100	14 200	15 800	15 400
Total Phosphorus (μg/g)	774	718	720	757	789	770
Particle Size (% passing)						
Sieve Size 16 (1.2 mm)	100.0	100.0	100.0	99.7	99.8	99.9
30 (0.6 mm)	99.9	100.0	100.0	99.5	99.3	99.8
50 (0.3 mm)	99.8	99.9	99.9	98.5	97.6	99.0
100 (0.15 mm)	99.7	99.6	99.8	97.9	96.6	98.6
140 (0.106 mm)	99.4	99.1	99.6	97.1	95.9	98.1
200 (0.075 mm)	98.8	98.7	99.4	95.9	94.6	97.0
270 (0.053 mm)	97.4	97.6	97.9	93.4	92.3	95.1
400 (0.038 mm)	92.6	90.0	95.0	91.3	88.6	93.9
Summary (%)						
Coarse and Medium Sand (>0.3 mm)	0.2	0.1	0.1	1.2	2.2	0.9
Fine Sand (0.075-0.3 mm)	1.0	1.2	0.5	2.6	3.0	2.0
Silt and Clay (<0.075 mm)	98.8	98.7	99.4	95.9	94.6	97.0

TABLE 2

ANALYTICAL RESULTS

BOTTOM SEDIMENTS

(µg/g dry weight except where noted)

CHARACTERISTIC	BARNSTON ISLAND (MS-1)					SAPPERTON CHANNEL (MS-2)				
	SAMPLE 1	SAMPLE 2	SAMPLE 3	MEAN	STANDARD DEVIATION	SAMPLE 1	SAMPLE 2	SAMPLE 3	MEAN	STANDARD DEVIATION
% Moisture (%)	25	24.9	23.9	24.6	0.6	30.1	34.5	38.1	34.2	4.0
Aluminum	8 800	8 150	8 270	8 407	346	10 800	10 100	9 140	10 013	833
Barium	79	72	73	74.7	3.8	105	93	92	96.7	9.8
Calcium	6 010	6 330	7 390	6 576	722	7 220	7 700	8 360	7 760	572
Cadmium	0.20	0.20	0.20	0.20	0	0.35	0.30	0.30	0.32	0.03
Cobalt	15	14	10	13	2.6	16	18	16	16.7	1.2
Chromium	29	27	27	27.7	1.2	33	32	29	31.3	2.1
Copper	27	28	25	26.7	1.5	33	29	30	30.7	2.1
Iron	19 800	18 800	19 600	19 400	529	24 200	23 800	22 000	23 330	1 170
Mercury	0.06	0.06	0.05	0.056	0.006	0.05	< 0.05	<0.05	<0.05	-
Magnesium	8 510	8 250	8 620	8 460	190	9 550	9 570	9 220	9 450	200
Manganese	432	402	389	408	22	497	450	436	461	32
Molybdenum	7	6	6	6.3	0.6	7	8	7	7.3	0.6
Nickel	36	34	34	34.7	1.2	40	42	39	40.3	1.5
Lead	28	19	16	21	6.2	15	19	18	17.3	2.1
Strontium	33	31	32	32	1	37	39	40	38.7	1.5
Titanium	237	207	182	208.7	27.5	211	351	232	264.7	75.5
Thallium	25	23	<20	22.7	2.5	<20	27	35	27.3	7.5
Vanadium	26	24	23	24.3	1.5	31	28	27	28.7	2.1
Zinc	48	46	46	46.7	1.2	59	55	50	54.7	4.5
Total Phosphorus	538	595	569	567.3	28.5	680	609	620	636.3	38.2

TABLE 2

ANALYTICAL RESULTS

BOTTOM SEDIMENTS

(µg/g dry weight except where noted)

CHARACTERISTIC	ANNACIS CHANNEL (MA-1)					EWEN SLOUGH (MA-2)				
	SAMPLE 1	SAMPLE 2	SAMPLE 3	MEAN	STANDARD DEVIATION	SAMPLE 1	SAMPLE 2	SAMPLE 3	MEAN	STANDARD DEVIATION
% Moisture (%)	41.2	35.7	40.7	39.2	3.0	38.4	40.0	38.4	38.9	0.9
Aluminum	13 000	13 400	13 800	13 400	400	13 500	12 800	12 500	12 933	513
Barium	110	110	115	111.7	2.9	81	69	72	74	6.2
Calcium	7 080	7 530	7 710	7 440	324	6 310	6 160	5 970	6 147	170
Cadmium	0.35	0.35	0.35	0.35	0	0.40	0.40	0.35	0.38	0.03
Cobalt	16	16	13	15	1.7	20	18	16	18	2
Chromium	36	36	36	36	0	37	37	35	36.3	1.2
Copper	40	37	40	39	1.7	40	41	44	41.7	2.1
Iron	32 500	30 600	31 200	31 433	971	31 100	29 300	29 300	29 900	1 039
Mercury	0.06	0.05	0.07	0.06	0.01	0.07	0.08	0.07	0.07	0.01
Magnesium	11 200	11 200	11 100	11 167	58	11 600	11 300	11 000	11 300	300
Manganese	501	515	539	518	19	618	548	614	593	39
Molybdenum	8	8	7	7.7	0.6	9	8	8	8.3	0.6
Nickel	44	43	43	43.3	0.6	42	41	41	41.3	0.6
Lead	21	22	20	21	1	21	23	27	23.7	3.1
Strontium	40	39	38	39	1	38	38	37	37.7	0.6
Titanium	265	301	294	287	19	336	286	226	283	55
Thallium	<20	<20	<20	<20	0	<20	<20	<20	<20	0
Vanadium	34	34	32	33.3	1.2	34	33	34	33.7	0.6
Zinc	75	72	73	73.3	1.5	71	69	69	69.7	1.2
Total Phosphorus	774	718	720	737	32	757	789	770	772	16

TABLE 2

ANALYTICAL RESULTS

BOTTOM SEDIMENTS

(ug/g dry weight except where noted)

CHARACTERISTIC	UPPER NORTH ARM (NA-1)							LOWER NORTH ARM (NA-2)				
	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	MEAN	STANDARD DEVIATION	SAMPLE 1	SAMPLE 2	SAMPLE 3	MEAN	STANDARD DEVIATION
% Moisture (%)	-	-	28.4	46.3	34.5	36.4	9.1	29.1	-	28.0	28.6	0.8
Aluminum	11 100	11 100	11 100	10 200	10 600	10 800	410	11 100	9 660	8 910	9 890	1 110
Barium	85	93	91	83	89	88	4	56	47	36	46	10
Calcium	6 460	6 430	6 970	6 300	6 480	6 530	255	4 540	5 200	4 540	4 760	360
Cadmium	0.32	0.31	0.23	0.35	0.39	0.32	0.06	0.34	0.27	0.26	0.29	0.04
Cobalt	11	18	12	15	16	14.4	2.9	14	11	10	11.7	2.1
Chromium	31	32	31	30	32	31.2	0.8	35	28	29	30.7	3.8
Copper	38	39	39	36	38	38	1.2	39	30	28	32.3	5.9
Iron	25 500	26 600	26 000	24 400	25 300	25 560	820	24 500	21 500	19 900	21 970	2 340
Mercury	0.08	0.07	0.08	0.07	0.07	0.074	0.005	0.09	0.06	0.07	0.073	0.015
Magnesium	9 440	9 670	9 640	9 220	9 500	9 490	180	9 960	8 900	8 760	9 210	650
Manganese	422	418	448	446	418	430	15	300	293	259	284	22
Molybdenum	6	8	7	7	8	7.2	0.8	7	6	5	6	1
Nickel	37	40	38	38	40	38.6	1.3	43	35	38	38.7	4
Lead	22	30	24	26	24	25.2	3	22	15	23	20	4
Strontium	36	36	36	34	34	35.2	1.1	30	28	26	28	2
Titanium	269	264	255	190	229	245	37	237	209	158	201	40
Thallium	<20	21	<20	<20	<20	<20	-	<20	<20	<20	<20	0
Vanadium	30	30	29	28	29	29.2	0.8	30	28	25	28	2
Zinc	101	98	97	97	97	98	2	81	61	70	70.7	10
Total Phosphorus	688	681	665	675	649	672	15	654	604	633	630	25

TABLE 3

ANALYTICAL RESULTS

BENTHIC ORGANISMS

(μg/g dry weight except where noted)

Characteristic	BARNSTON ISLAND				SAPPERTON CHANNEL			UPPER NORTH ARM	LOWER NORTH ARM		
	Chironomids	Lampreys	Oligochaetes	Crustacea	Diptera	Oligochaetes	Lampreys	Chironomids	Amphipods	Polychaetes	Pelecypoda
Aluminum	1 220	1 910	5 010	1 510	2 470	3 730	122	1 020	1 630	4 150	2 280
Boron	< 1	< 1	27	31	3	4	17	7	15	< 1	< 1
Barium	19	22	73	109	39	103	10	26	91	31	41
Calcium	5 410	3 860	10 400	90 400	5 560	7 500	3 250	3 540	63 600	5 220	227 000
Cadmium	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chromium	5	4	35	26	14	14	14	9	8	12	6
Copper	55	37	188	271	46	56	156	91	81	57	21
Iron	2 760	3 140	10 400	4 170	7 950	8 930	2 920	3 320	5 190	11 600	6 600
Magnesium	1 650	1 310	4 140	2 010	2 240	3 180	541	1 590	5 380	4 850	2 140
Manganese	268	239	770	1 010	300	354	203	165	236	172	110
Molybdenum	< 1	< 1	< 1	< 1	< 1	2	< 1	< 1	< 1	3	3
Nickel	< 5	7	< 5	< 5	15	18	< 5	< 5	7	16	8
Lead	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	15
Tin	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	10
Strontium	23	13	39	343	31	30	14	17	978	58	988
Tellurium	<20	<20	<20	<20	<20	20	<20	<20	<20	<20	28
Titanium	43	58	355	72	125	117	12	54	51	115	73
Thallium	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	61
Vanadium	4	4	20	< 1	14	14	< 1	7	7	16	8
Zinc	177	115	180	211	108	179	1 870	172	165	190	68
Total Phosphorus	7 010	4 090	5 610	11 900	6 840	7 340	4 340	6 450	12 400	4 200	971
Total PCB's (wet)	< 0.1	< 0.1	-	-	-	-	-	-	-	<0.1	< 0.1
Pentachlorophenol (wet)	0.06	0.05	-	-	-	-	-	-	-	0.8	0.01
Tetrachlorophenol (wet)	0.03	<0.01	-	-	-	-	-	-	-	1.7	0.02

TABLE 3 (Continued)

Characteristic	ANNACIS CHANNEL					EWEN SLOUGH	
	Lampreys	Leeches	Oligochaetes	Chironomids	Pelecypoda	Amphipods	Polychaetes
Aluminum	693	929	3 810	3 030	570	2 220	3 060
Boron	< 1	87	8	< 1	6	< 1	< 1
Barium	13	44	96	58	132	207	36
Calcium	4 100	6 370	11 500	5 700	339 000	19 400	8 220
Cadmium	< 1	< 1	< 1	4	< 1	1	5
Chromium	4	48	17	11	7	8	14
Copper	43	125	108	93	19	154	87
Iron	2 110	5 160	8 440	8 150	4 320	5 820	11 000
Magnesium	874	1 240	2 670	2 640	305	3 110	3 260
Manganese	247	453	475	445	2 470	1 590	306
Molybdenum	< 1	< 1	< 1	2	5	3	5
Nickel	8	96	< 5	12	< 5	19	12
Lead	<10	<10	<10	<10	24	<10	<10
Tin	< 5	< 5	< 5	< 5	16	< 5	< 5
Strontium	14	23	37	27	358	352	83
Tellurium	<20	<20	<20	<20	<20	<20	20
Titanium	25	47	151	90	22	67	102
Thallium	<20	<20	<20	<20	97	<20	<20
Vanadium	6	< 1	14	11	5	7	11
Zinc	158	814	259	178	31	157	298
Total Phosphorus	4 530	8 170	5 690	4 670	1 140	9 190	7 200
Total PCB's (wet)	-	-	-	-	-	< 0.1	<0.1
Pentachlorophenol (wet)	-	-	-	-	-	< 0.01	0.04
Tetrachlorophenol (wet)	-	-	-	-	-	< 0.01	0.07

TABLE 4

ANALYTICAL RESULTS

FISH MUSCLE

(µg/g dry except where noted)

Characteristic	BARNSTON ISLAND (MS-1)		SAPPERTON (MS-2)	UPPER NORTH ARM (NA-1)		LOWER NORTH ARM (NA-2)		
	Peamouth Chub 24.5 cm 153.6 g	Dolly Varden 24.8 cm 129 g	Sculpin (prickly) 5.7 cm 56 g	Rainbow Trout 76 cm 4 440 g	Cutthroat Trout 40.5 cm 66 g	Staghorn Sculpin 30.5 cm 417.1 g	Staghorn Sculpin 27 cm 291.5 g	Staghorn Sculpin 29.5 402.2 g
Moisture Content (%)	80.4	81.1	83.5	76.2	77.6	84.3	83.8	85.4
Aluminum	5	2	7	3	7	8	2	8
Calcium	1 650	374	2 570	122	308	456	872	738
Chromium	1.62	1.05	1.72	0.44	0.49	1.73	1.69	1.87
Copper	2	2	2	4	4	2	2	3
Iron	26	19	29	31	36	25	24	44
Lead	1	1	< 1	< 1	< 1	1	1	1
Magnesium	1 340	1 290	1 240	1 170	1 150	1 260	1 210	1 330
Manganese	< 1	< 1	1	< 1	< 1	1	1	1
Mercury (wet)	0.20	0.10	1.36	0.12	0.11	0.25	0.15	0.24
Molybdenum	< 1	< 1	< 1	< 1	1	< 1	< 1	< 1
Strontium	2	< 1	4	< 1	< 1	1	2	2
Zinc	30	20	43	17	16	26	32	37
Total Phosphorus	9 950	10 900	10 600	9 420	9 370	10 300	10 200	11 000
Total PCB's (wet)	< 0.1	< 0.1	-	< 0.1	<0.1	< 0.1	< 0.1	<0.1
Pentachlorophenol (wet)	0.03	0.02	-	0.03	0.03	0.02	0.02	0.03
Tetrachlorophenol (wet)	0.01	< 0.01	-	0.03	0.01	0.01	< 0.01	0.02

TABLE 4 (Continued)

ANALYTICAL RESULTS

FISH MUSCLE

(µg/g dry weight except where noted)

Characteristic	LOWER NORTH ARM (NA-2)			
	Staghorn Sculpin 26.5 cm 260.5 g	Staghorn Sculpin 26 cm 227.2 g	Staghorn Sculpin	
			Mean	Standard Deviation
Moisture Content (%)	85.4	84.5	84.7	0.7
Aluminum	9	28	11	9.9
Calcium	5 350	1 470	1 777	2 031
Chromium	1.49	1.71	1.70	0.14
Copper	3	4	2.8	0.8
Iron	49	59	35.8	22.6
Lead	1	1	1	0
Magnesium	1 290	1 310	1 280	47
Manganese	1	1	1	0
Mercury (wet)	0.26	0.10	0.20	0.07
Molybdenum	< 1	< 1	< 1	0
Strontium	20	5	6	8
Zinc	50	36	36.2	8.8
Total Phosphorus	12 200	10 800	10 900	800
Total PCB's (wet)	-	< 0.1	< 0.1	0
Pentachlorophenol (wet)	-	0.02	0.02	0.005
Tetrachlorophenol (wet)	-	0.01	0.01	0.005

TABLE 4 (Continued)

ANALYTICAL RESULTS

FISH MUSCLE

(µg/g dry weight except where noted)

Characteristic	ANNACIS CHANNEL (MA-1)								EWEN SLOUGH (MA-2)	
	Dolly Varden	Cutthroat Trout	Cutthroat Trout	Cutthroat Trout	Cutthroat Trout	Cutthroat Trout	Cutthroat Trout		Dolly Varden	Rainbow Trout
	34 cm 286 g	23.1 cm 123 g	27.3 cm 203 g	33.6 cm 395 g	32.3 cm 336 g	36.6 cm 496 g	Mean	Standard Deviation	30.8 cm 163 g	66.5 cm 2217 g
Moisture Content (%)	74.2	78.9	77.4	78.9	78.3	79.6	78.6	0.8	78.6	74.7
Aluminum	< 2	< 2	< 2	< 2	< 2	< 2	< 2	0	< 2	< 2
Calcium	294	1 930	632	626	12 000	415	3 120	5 000	366	182
Chromium	1.07	1.22	1.19	1.5	1.41	1.37	1.34	0.13	1.3	1.03
Copper	2	2	2	2	2	2	2	0	2	2
Iron	21	18	19	27	19	29	22.4	5.2	23	20
Lead	1	< 1	< 1	1	< 1	< 1	< 1	0	< 1	< 1
Magnesium	1 290	1 500	1 400	1 420	1 510	1 250	1 416	105	1 520	1 350
Manganese	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0	< 1	< 1
Mercury (wet)	0.11	0.15	0.08	0.19	0.07	0.17	0.13	0.05	0.09	0.07
Molybdenum	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0	< 1	< 1
Strontium	< 1	2	2	1	3	< 1	1.8	0.8	< 1	< 1
Zinc	19	20	15	16	15	21	17.4	2.9	21	14
Total Phosphorus	9 910	11 500	11 200	11 000	11 500	10 900	11 220	277	11 900	10 400
Total PCB's (wet)	< 0.1	< 0.1	<0.1	< 0.1	< 0.1	< 0.1	< 0.1	0	< 0.1	< 0.1
Pentachlorophenol (wet)	< 0.01	< 0.01	<0.01	0.01	< 0.01	< 0.01	< 0.01	0	< 0.01	< 0.01
Tetrachlorophenol (wet)	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	< 0.01	0	< 0.01	< 0.01

TABLE 5
ANALYTICAL RESULTS
FISH LIVERS
(µg/g dry weight except where noted)

Characteristic	BARNSTON ISLAND	UPPER NORTH ARM (NA-1)		LOWER NORTH ARM (NA-2)						
	Dolly Varden 24.8 cm 129 g	Rainbow Trout Duplicate	Rainbow Trout Duplicate	Staghorn Sculpin 30.5 cm 417.1 g	Staghorn Sculpin 27 cm 291.5 g	Staghorn Sculpin 29.5 cm 402.2 g	Staghorn Sculpin 26.5 cm 260.5 g	Staghorn Sculpin 26 cm 227.2 g	MEAN	Standard Deviation
Moisture Content (%)	79.4	76.9	78	75.5	72	74.9	77.3	77.6	75.5	2.3
Aluminum	8	12	11	6	6	< 2	< 2	< 2	3.6	2.2
Boron	5	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0
Calcium	238	304	243	119	98	123	117	194	130	37
Cadmium	0.31	3	0.27	0.22	< 0.2	0.5	0.61	0.52	0.41	0.19
Chromium	2	0.91	1.09	0.89	0.81	1.5	1.37	1.9	1.29	0.45
Copper	113	80	29	8	10	3	6	21	9.6	6.9
Iron	311	684	683	79	116	145	200	153	139	45
Lead	5	1	2	2	< 1	1	1	4	1.8	1.3
Magnesium	923	1 020	1 120	1 020	974	1 060	561	1 200	963	240
Manganese	6	8	5	4	4	5	3	6	4.4	1.1
Mercury (wet)	-	0.09	0.09	0.12	0.11	0.13	0.09	0.08	0.11	0.02
Molybdenum	< 1	3	< 1	<1	< 1	< 1	< 1	< 1	< 1	0
Nickel	5.43	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0
Selenium	<10	15	<10	<10	<10	<10	<10	<10	<10	0
Strontium	< 1	1	< 1	< 1	< 1	< 1	1	< 1	< 1	0
Titanium	< 1	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0
Vanadium	< 1	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0
Zinc	157	137	84	117	205	93	213	222	170	60
Total Phosphorus	16 400	15 300	17 300	15 800	14 400	15 800	8 560	24 000	15 710	5 515

TABLE

ANALYTICAL RESULTS

FISH LIVERS

(µg/g dry weight except where noted)

Characteristic	ANNACIS CHANNEL (MA-1)								EWEN SLOUGH (MA-2)	
	Dolly Varden	Cutthroat Trout	Cutthroat Trout	Cutthroat Trout	Cutthroat Trout	Cutthroat Trout	Cutthroat Trout		Dolly Varden	Rainbow Trout
	34 cm 286 g	23.1 cm 123 g	27.3 cm 203 g	33.6 cm 395 g	32.3 cm 336 g	36.6 cm 496 g	Mean	Standard Deviation	30.8 cm 163 g	66.5 cm 2 217 g
Moisture Content (%)	71.6	67	77.2	76.9	78.1	76.3	75.1	4.6	77	75.2
Aluminum	< 2	8	7	3	2	4	4.8	2.6	6	< 2
Boron	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0	< 1	< 1
Calcium	146	227	259	278	287	219	254	30	423	333
Cadmium	< 0.2	0.37	0.29	0.44	< 0.2	0.33	0.33	0.09	0.24	3
Chromium	1.2	2.7	1.46	1.74	1.72	0.55	1.63	0.77	1.5	0.84
Copper	32	67	140	84	23	83	79.4	42	47	86
Iron	296	367	343	610	435	1 060	563	297	986	561
Lead	< 1	2	9	< 1	< 1	< 1	2.8	3.5	< 1	< 1
Magnesium	652	801	1 190	1 230	1 340	1 140	1 140	203	1 020	1 100
Manganese	3	5	8	7	6	6	6.4	1.1	4	8
Mercury (wet)	-	-	-	0.13	< 0.05	0.12	0.1	0.04	-	0.06
Molybdenum	< 1	< 1	< 1	< 1	< 1	1	< 1	0	1	< 1
Nickel	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0	< 1	< 1
Selenium	<10	21	16	16	<10	20	16.6	4.3	<10	12
Strontium	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0	2	1
Titanium	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0	< 1	< 1
Vanadium	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0	< 1	< 1
Zinc	121	97	133	102	100	96	105.6	15.5	202	112
Total Phosphorus	11 000	15 600	19 700	17 900	19 000	17 900	18 020	1 555	13 600	16 200

TABLE 6
A COMPARISON OF LEVELS OF SELECTED CHARACTERISTICS IN INVERTEBRATES
TO LEVELS FROM PREVIOUS STUDIES

DATA FROM THIS STUDY: JANUARY/FEBRUARY, 1985

		Cd	Cu	Fe	Pb	Ni	Zn	PCB's
Barnston Island	Chironomids	1	55	2 760	<10	< 5	177	0.09
	Lampreys	<1	37	3 140	<10	7	115	0.05
	Oligochaetes	<1	188	10 400	<10	< 5	180	-
	Crustacea	<1	271	4 170	<10	< 5	211	-
Sapperton	Diptera	<1	46	7 950	<10	15	108	-
	Oligochaetes	<1	56	8 930	<10	18	179	-
	Lampreys	<1	156	2 920	<10	< 5	1 870	-
Upper N. Arm	Chironomids	<1	91	3 320	<10	< 5	172	-
Lower N. Arm	Amphipods	<1	81	5 190	<10	7	165	-
	Polychaetes	<1	57	11 600	<10	16	190	2.5
	Pelecypoda	<1	21	6 600	15	8	68	0.03
Annacis Channel	Lampreys	<1	43	2 110	<10	8	158	-
	Leeches	<1	125	5 160	<10	96	814	-
	Oligochaetes	<1	108	8 440	<10	< 5	259	-
	Chironomids	4	93	8 150	<10	12	178	-
	Pelecypoda	<1	19	4 320	24	< 5	31	-
Ewen Slough	Amphipods	1	154	5 820	<10	19	157	<0.01
	Polychaetes	5	87	11 000	<10	12	248	0.11
MINISTRY OF ENVIRONMENT (1978/1979) (SEE REFERENCE 4)								
Barnston Island	Oligochaetes 80% Chironomids 20%	<1 - 1.0	21 - 34	3030-6680	4 - 10	10 - 13	127 - 130	-
Poplar Island Upper N. Arm	Oligochaetes 90% Chironomids 10%	<1	15	3010	10	<7	152	-
Mitchell Island Lower N. Arm	Oligochaetes 90% Chironomids 10%	<1	11 - 22	2680-5680	8 - 12	< 5 - 10	82 - 150	-
D/S Annacis Island	Oligochaetes 90% Chironomids 10%	<1	21 - 34	2870-8120	3 - 12	7 - 14	143 - 160	-

DATA FROM CHAPMAN ET AL.* AND HALL**
(See Tables 3-22 and 3-24, Reference 4)

		Cd	Cu	Fe	Pb	Ni	Zn	PCB's
New* Westminster	Oligochaetes	<1 - 5.1	11.8 - 35.3	1030-5400	4.1 - 72	3 - 13	82.4 - 153	-
	Chironomids	<2 - <36	26.5 - 46.4	1330-2750	12.5 - <90	<3 - <90	70.2 - 206	-
Oak* Street	Oligochaetes	<1 - 5.1	8.9 - 25.2	905-4500	5.5 - 21.6	2.5 - 12	47.1 - 125	-
	Chironomids	<8 - 166	27.5 - 41.9	1840-7780	<10 - 52.1	<17 - <66	120 - 205	-
Ladner** Side Channel	Oligochaetes	<0.2-<0.5	19 - 40	-	3.2 - 7.1	-	40 - 96	-
	Chironomids	1.2	19	-	5.1	-	152	-