ENVIRONMENTAL CONTAMINATION
BY
POLYCHLORINATED BIPHENYLS (PCBs) IN BRITISH COLUMBIA
- A SUMMARY OF CURRENT DATA, 1976

by

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ABSTRACT

This report is a compilation of data from a variety of sources pertaining to the contamination of the British Columbia environment by polychlorinated biphenyls (PCBs). It attempts to evaluate the status of PCB contamination in British Columbia with respect to other parts of Canada and the world, and to recommend areas requiring further investigation.

Data was obtained primarily from government, research and university organizations, and by limited monitoring by the Environmental Protection Service.

From the limited data available, it is evident that significant PCB contamination does exist in the British Columbia environment, but to a lesser extent than in the more heavily industrialized regions of Canada and the rest of the world.

High levels of PCB in many species of fish-eating birds and in river-bottom sediments around the City of Vancouver indicate that British Columbia industry may be an active source of PCB contamination and warrant the need for further investigation in this province.

RÉSUMÉ

Le présent rapport constitue un ensemble de données émanant de diverses sources et portant sur la contamination de l'environnement par les biphényles polychlorés (BPC). Il a pour objet de recueillir tous les renseignements dont on dispose sur ces contaminants propres à la Colombie-Britannique et vise à évaluer le degré de cette contamination dans la province par rapport à d'autres parties du Canada et du monde, et à recommander certains domaines qui devraient faire l'objet d'examens plus approfondis.

Les données ont été recueillies principalement auprès du gouvernement, de bureaux de recherches, d'organismes universitaires ainsi qu'auprès du Service de la protection de l'environnement qui s'est chargé d'une vérification restreinte.

Bien que les données soient très limitées, il est évident que l'environnement en Colombie-Britannique est contaminé par les BPC, mais dans une mesure moindre que dans les régions plus industrialisées du Canada et du reste du monde.

La haute teneur en BPC chez de nombreuses espèces d'oiseaux piscivores et dans les sédiments du fond des cours d'eau aux alentours de Vancouver dénote que l'industrie en C.-B. est probablement une source active de contamination par les BPC, et laisse entrevoir la nécessité d'approfondir les études à ce sujet dans la province.

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CONCLUSIONS

Due to the very limited amount of relevant data, only an estimate of levels and sources of polychlorinated biphenyl (PCB) contamination in the British Columbia environment is possible. Because most of the results were obtained from studies originally designed to investigate other environmental contaminants (such as the organochlorine insecticides), the samples were not necessarily taken from the areas that would normally be subject to high levels of PCB contamination.

It is evident from the available data that PCB contamination is present in British Columbia, although to a lesser extent than in such highly industrialized areas as Southern California and the Great Lakes region, where PCB contamination has, in some places, reached levels considered hazardous to health.

While the agricultural areas of British Columbia appear to be relatively unaffected by PCB contamination, the higher residue concentrations detected in the sediments and biota from the industrial regions around the City of Vancouver indicate that localized sources of PCB entry into the water system do exist, particularly in the lower reaches of the Fraser River and in the Brunette River - Still Creek system on the lower mainland.

Despite the evidence of industrial contamination, and suggestions that even low concentrations of PCB can lead to reproductive failures in fish, potential sources of PCB entry into the environment and areas of accumulation remain virtually unexplored in this province.

The presence of localized areas of high PCB contamination, and indications that fish-eating birds are accumulating significant amounts of residues in the tissues and eggs, demonstrate the need for further study.

Assessment of the relative environmental contamination from industrial sources is necessary in order to make decisions concerning future government legislation affecting the production and use of PCBs.

The high residue levels found in the sediments offshore from Belkin Paperboard Ltd. indicate that paper recycling plants may be discharging significant amounts of PCBs in their effluents. Other large industries including the electrical equipment manufacturing and servicing companies are also suspect as sources of contamination.

The comparatively high residue levels in the biota collected in the vicinity of the Iona Island Sewage Outfall near the mouth of the Fraser River are in accord with the general trend reported for sewage outfall areas in other regions and suggest that sewage and wastewater systems are major contributors to PCB contamination.

The inadequate disposal of PCB-containing compounds in landfills and municipal incinerators ultimately results in further contamination of the environment. Although landfills are not generally considered to be a major source, samples from the Richmond landfill indicate that PCBs may be leached out of the soil and distributed in significant amounts via drainage ditches.

The detectable levels of PCB present only in those birds (Dunlins) collected from the vicinity of the Vancouver International Airport, lend support to theories that emissions from aircraft may have been, at one time, another secondary source of PCB contamination. However, because these data were obtained a number of years ago, further sampling in the area would be necessary to determine the present level. It should be noted that the Iona Island sewage treatment plant, which services a large portion of Greater Vancouver, is located in the same vicinity. It is possible, therefore, that the PCBs detected in the Dunlins are actually due to contamination via this source.

The high levels of PCB contamination found around major port facilities have recently led to suggestions that the release of bilge water from large ships could contribute significant amounts of PCB to active harbours. Samples of bilge water and hydraulic oil from foreign vessels in Vancouver harbour have been analyzed and preliminary results indicate that although the hydraulic fluids do not contain PCBs, the bilge water and deck runoff may contain detectable levels.

The determination of residue concentrations in municipal incinerator gaseous emissions, in the atmosphere, and in precipitation, is of major importance due to indications that atmospheric transport of PCBs is a principal method of distribution.

RECOMMENDATIONS

1. It is recommended that future investigations in British Columbia be conducted by the Environmental Protection Service in co-operation with other resource and research agencies. Such investigations should be organized on a wider scale than past studies, and they should concentrate on identifying sources of entry and areas of accumulation in the environment. Priorities should be given to those areas currently known or suspected to contain major sources of contamination:

   a) Representative sewage treatment plants and surface runoff collection systems from various land-use areas should be monitored:

      i) to determine the relative magnitudes of industrial, residential, commercial, and agricultural contributions;
      ii) to evaluate the efficiency with which PCBs are removed or degraded by specific waste treatment systems in use;
      iii) to determine if the chlorination of effluents produce PCB compounds;
      iv) to determine the degree of contamination in biota in the vicinity of major sewage and/or industrial effluent outfalls.

   b) Industries that are suspect as potential sources of contamination, including the paper recycling plants and electrical equipment companies (particularly those involved in the use, manufacturing and/or servicing of power factor correction type capacitors and transformers), should also be monitored:

i) to determine the quantity and location of equipment presently using compounds containing PCBs;

ii) to determine quantity and modes of accidental loss of contaminated material;

iii) to estimate the relative amount of PCB entering the environment via discharged effluents.

Industries requiring large power facilities, such as the pulp and paper industries and mining and smelting operations, should be included in these investigations.

2. Attempts should be made to identify other industries discharging PCBs into the environment, particularly in those areas known to have significant levels of PCB contamination such as the lower Fraser River and the Brunette River - Still Creek system. Sampling of sewers servicing the major regions of the lower mainland would enable the identification of such industries.

3. Disposal facilities (municipal incinerators and landfills) should be monitored to determine the degree of contamination via these routes. Since the lack of adequate and accessible information and facilities presents a major problem in trying to eliminate the escape of these compounds into the environment, the possibility of establishing disposal guidelines and a regional centre for the disposal of PCB-containing compounds must be investigated.

4. Lower chlorinated biphenyls are less persistent but more toxic to many organisms than are the higher chlorinated biphenyls. Since the PCB formulations presently in use are higher in lower chlorinated biphenyl content than were those used in past years, it is important to conduct further investigations into the presence of lower

chlorinated biphenyls in the environment.

5. It is further recommended that transformer and capacitor dielectric fluids be tested for dibenzofurans and potential breakdown products.

6. Intercalibration among regional laboratories involved in PCB analysis would be helpful in assuring consistency and reliability of analytical procedures.

1 INTRODUCTION

Although in use extensively since 1929, it was not until 1966 that Jensen (1) first attributed a series of previously unidentifiable peaks in tissue samples to the industrial organochlorines known as the polychlorinated biphenyls (PCBs).

The relatively unique physical and chemical characteristics of PCBs, particularly their excellent dielectric properties and thermal and chemical stabilities, make them especially suitable for industrial use. For many years PCBs were used extensively in such products as dielectric fluids, hydraulic fluids, paints, plasticizers, fire retardants, waxes, sealants, asphalts, floor tiles, adhesives, printers' ink, carbonless copy-paper, paper and fabric coatings, heat transfer fluids, water-proofings, synthetic rubber, brake linings, and as carriers for pesticides (2, 3, 4).

Ironically, it is the characteristics of PCBs that are so desirable to industry that present a potential hazard to the environment. Their extreme stability, which prevents them from being destroyed by usual waste disposal methods, and the fact that they are not readily metabolized have lead to their accumulation at higher levels in the food chain. It has been estimated that biological magnification in the food chain can occur by a factor of 10 to 100 at each step, thus exposing organisms at higher trophic levels to significant amounts of PCB. Concentrations in predators at the top of the trophic structure may reach up to 10^7 to 10^8 times those present in ambient waters (2).

PCBs are ubiquitous, having been detected in the atmosphere, water, sediment, and animal tissues, including human milk and adipose tissue. Their distribution in the ecosystem is comparable to that of the organochlorine pesticides (5). While the organochlorines were intended for release into the environment, however, PCBs were not.

It is believed that PCBs enter the environment primarily through the waste water disposal systems, although the importance of atmospheric transport of PCBs is becoming increasingly recognized.

Secondary sources may include industrial solid waste disposal and spills, and to a lesser extent leaching from dumps and landfills.

The persistence of PCBs in the environment, combined with their obvious ubiquity, warrants the placing of this family of chemicals near the top of the list of hazardous chemicals requiring further study. Government regulations for limitations on the production and use of PCBs are currently in preparation, and some controversy exists as to whether the production of these substances should be banned entirely or whether usage in closed systems (i.e., transformers and capacitors) should be permitted on a limited basis.

In the past, the federal government has had little power to demand co-operation in the identification and quantification of potentially hazardous substances now in industrial use. The recently introduced Environmental Contaminants Act, in effect as of April 1, 1976, provides such legislative authority. Users of potentially hazardous substances are required to release all pertinent information to the proper authorities upon request. Importation of products containing prescribed substances are also subject to government regulation.

The major supplier of PCBs to North American markets is Monsanto Company Ltd. Due to increasing awareness of the dangers posed by the release of these chemicals into the environment, Monsanto, in 1971, took voluntary action to help alleviate the problem by limiting sales of PCBs to electrical equipment manufacturers, and by discontinuing production of some of the more persistent formulations.

It is likely that a total ban would be placed on the production and use of these compounds, if not for the fact that their unique properties make them so difficult to replace for industrial purposes. Care must be taken to ensure that replacement substances will possess the chemical and physical properties suitable for industrial use, but lack characteristics that would make them potentially detrimental to the environment.

Monsanto have stated their intention to totally phase out the manufacture of PCBs by October 31, 1977.

Possible alternatives to PCBs for use as dielectric fluids include: diisononyl phthalate, developed by Exxon Chemical Company; Dow - Corning's product, polydimethyl siloxane liquid for transformer use; and Dow Chemical Company's alkylated chlorodiphenyl oxide (DPO) based fluid, which is reportedly effective yet less environmentally persistent and more biodegradable than PCBs, for use in high voltage power capacitors (6, 7).

Since Monsanto's action to restrict PCB use to closed systems, these compounds have been used primarily as dielectric fluids in transformers and capacitors. The major users, the electric power companies, are now aware of the potential hazards posed by the dielectric fluids, and many have instituted measures to minimize accidental loss of these fluids into the environment during both servicing and disposal.

B.C. Hydro and Power Authority, the major power supplier to most of this province, has outlined safety procedures and methods of disposal of PCB contaminated materials in a brochure distributed to service personnel. Within the last few years, B.C. Hydro have altered their past policy of burying transformers and capacitors in the ground, and have begun sealing contaminated material in cement blocks prior to disposal in landfills. B.C. Hydro is no longer ordering PCB-containing transformers, and plans have been made for the construction of a disposal bay where PCB-containing dielectric fluids will be drained from the transformers and capacitors, sealed in labelled 45 gallon steel drums, and shipped to a disposal agency. The drained equipment is encased in concrete blocks of at least 6 inches in thickness and are then transported to the Vancouver City landfill for burial.

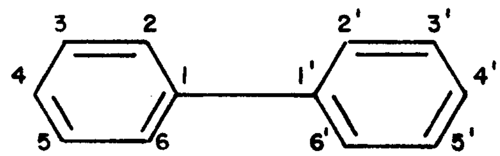
Although these actions have done much to decrease the amount of PCBs currently entering the environment, the persistence of these compounds would indicate that it will be many years before we see a substantial reduction in PCB residue levels in the environment.

For this reason, it is important to set up monitoring programs and baseline studies in various areas to identify sources of present contamination and areas of high PCB levels, and to permit evaluation of the effectiveness of future restrictive actions concerning the production and use of these compounds.

2 LITERATURE REVIEW

2.1 Chemistry of PCBs

PCBs are a class of chlorinated aromatic hydrocarbons, having ten possible sites for chlorine substitution, making possible a total of 209 isomers (8):



The sole North American producer of PCBs, and the major supplier to the North American markets, is Monsanto, whose line of commercial PCB preparations is referred to by the trade name Aroclor.

Aroclor products are designated by a four-digit identification code, in which the first two digits identify the parent molecule (e.g., 12 = biphenyl), while the last two specify the chlorine contained by percentage weight. The exception to the rule is the relatively new product Aroclor 1016, which contains 41 percent chlorine by weight. The other three Aroclor products currently being manufactured are Aroclor 1254 (54% Cl), Aroclor 1242 (42% Cl), and Aroclor 1221 (21% Cl) (3, 8).

PCBs are prepared industrially by the direct chlorination of biphenyl with anhydrous chlorine, using a catalyst of either iron filings or ferric chloride. This procedure is followed by purification and results in a complex mixture of chlorobiphenyl isomers of different chlorine content (3).

The complexity of these industrial PCB preparations poses severe problems for quantitative and qualitative analysis and for the interpretation of physiological effects, since toxicity is dependent on the degree of chlorination and the concentration of each isomer present (9, 10).

Gas chromatography is the technique most commonly employed for PCB residue analysis. Confirmation of results is usually attained by mass spectrometry. Special separation techniques are often required, however, since the similarities in structure and properties between PCBs and the organochlorine insecticides can cause mutual interferences (2, 11, 12).

2.2 Toxicity and Biological Effects

Although it is generally agreed that PCB compounds have a comparatively low acute toxicity to most organisms, there are indications that their chronic toxicity may be substantial (10).

Most studies to date have dealt with the toxic effects of commercial PCB preparations; there is very little available data concerning the toxicity of individual chlorobiphenyls (3). Generally, however, data suggests that the more highly chlorinated PCBs, although being more environmentally persistent, are less toxic to many species than are the more rapidly degraded and more easily metabolized lower chlorinated compounds (2, 13).

Being highly lipophilic, PCBs readily accumulate in the tissues and organs of living organisms with the highest concentrations occurring in fat, liver, and eggs. This accumulation is most pronounced in the case of the more highly chlorinated isomers, with the less chlorinated biphenyls being more easily hydroxylated and excreted (14).

Greb et al (15) explained this variation in the levels of accumulation among the different isomers with the theory that the extra chlorine atoms give the more highly chlorinated isomers increased lipophilic tendencies, and so create the need for a higher degree of hydroxylation. This ultimately results in a slower excretion rate and a gradual accumulation of PCBs in the body tissues.

There is a vast amount of interspecific variation in the toxicity of PCBs. The specific differences in general physiology, including metabolic and excretory rates, are thought to play an important role (16, 17).

Whereas PCBs are relatively non-acutely toxic to most species of birds and mammals, some species exhibit an extreme sensitivity (13). Platonow and Karstad (18) report that mink, when fed a diet of PCB-contaminated Coho Salmon from Lake Michigan, suffered severe reproductive failure, and several died during a six-month experiment. A diet of the salmon, and an additional 30 ppm PCB, resulted in 100 percent mortality within six months.

Many freshwater and estuarine organisms also exhibited extreme susceptibility to PCBs, as indicated by the seven day LC_{50}* test for the following species: Grass Shrimp, 3 ppb; Crayfish, 30 to 100 ppb; and Dragonfly, 800 to 1000 ppb (2). Acute toxicities of various Aroclors to freshwater fish, as determined by 96 hour LC_{50} tests, were reported by Stallings and Mayer (19) and are listed in Table 1.

TABLE 1 96 HOUR LC_{50} VALUES FOR FRESHWATER FISH

Aroclor	Species	96 Hour LC_{50} (ppm)
1221	Cutthroat Trout	1.17
1232	"	2.50
1242	"	5.43
1248	"	5.75
1254	"	42.5
1260	"	60.9
1262	"	50.0
1268	"	50.0
1248	Channel Catfish	6.00
1254	"	12.0
1248	Bluegill	0.28
1254	"	2.74

* 7 day LC_{50} - This term refers to <u>Median Lethal Concentration</u>, or that concentration of a lethal agent required to kill the 50th percentile in a group of test organisms over a time period of 7 days. The 50th percentile is meant to represent the average organism.

There are, however, indications from laboratory bioassays continuing for periods of two weeks or longer, that acute bioassays may underestimate the toxicities of at least Aroclors 1254 and 1016 (20).

In one day, freshwater insects and crustaceans can accumulate PCB in concentrations of up to 24,000 times greater than those present in the ambient water. The exposure of estuarine animals resulted in concentration factors of 85,000 for oysters, 10,000 for shrimp, and 30,000 for fish (21). Data obtained from aquatic organisms collected from Escambia Bay in Florida indicate somewhat higher concentration factors; 100,000 for oysters, 230,000 for shrimp, and 690,000 for fish (20). It appears, therefore, that the bioconcentration potentials of PCBs may also have been underestimated by laboratory evaluations.

Mosser et al (20) indicated that some species of algae were sensitive to PCBs while others were not, and that the addition of PCB to a mixed culture of algae resulted in an altered species composition. He postulates that such stable, yet selective, pollutants could disrupt the species composition of phytoplankton communities, and ultimately affect whole ecosystems.

The toxicity of PSBs to humans has been evident for a number of years (12). General Electric Company has reported that over the last fifteen years, forty-nine cases of allergic dermatitis among workers have been attributed to contact with PCBs (23).

In 1968, over 1000 Japanese contracted an illness later referred to as "Yusho" which was attributed to ingestion of PCB-contaminated rice oil. Although PCB exposure in humans is thought to exert its toxic effects mainly on the skin (in the form of chloracne and dark pigmentation) and on the liver (as an acute yellow atrophy) (3), victims of "Yusho" exhibited a number of other clinical effects, including stillbirths, fetal growth inhibition, bone and joint deformities, anemia, ocular disturbances, and various neurological disorders (6, 23). Recovery is a slow process, and in some cases symptoms were still present three to four years after exposure (13, 24).

Allen (25) noted various reproductive malfunctions in his studies of PCB toxicity to Rhesus Monkeys. Matings of PCB-treated females with normal males resulted in problems similar to those arising in the Yusho disaster, such as decreased fertility, fetal resorption, abortion, and stillborn and undersized infants. Other infants died while nursing and by eight months of age all survivors exhibited signs of hyperactivity (23).

Some commercial mixtures of PCBs, particularly those produced in Europe and Japan (26), have been found to contain trace amounts of extremely toxic impurities including the chlorinated dibenzofurans and dibenzodioxins. It is very difficult to assess the contribution these impurities make to the toxicity of PCBs, but it has been suggested that they are, in fact, responsible for many of the toxic effects formerly attributed to PCBs (9, 27). Zitko (28), however, reports no detectable contamination by dibenzofurans or dibenzodioxins in his analysis of tissues from White Shark, Herring Gull and Double-crested Cormorant eggs, and eels.

Although the actual mechanisms of PCB toxicity are unknown, in recent years a large number of biological effects have become evident:

1. Cecil et al (29) noted reproductive problems in the form of hatchability failures and embryo abnormalities in hens which had ingested PCBs. Oral administration of Aroclor 1242 to rats has been reported to inhibit spermatogonial cells (30), and to cause hepatocellular carcinomas (31).

2. Hays and Risebrough (32) report a number of birth defects among tern colonies on Great Gull Island in Long Island Sound. Deformities, such as loss of flight feathers, stunted extremities, twisted mandibles, and even additional appendages, were attributed to a high level of PCB contamination.

3. Delong et al (33) suspect PCBs to be a contributing factor in the high incidence of premature births in the California Sea Lions from the Channel Islands off the coast of California. Higher PCB residue levels were detected in females exhibiting

premature parturition than in those who carried their young to full term.

4. In at least one instance, chromosome damage has been attributed to PCB ingestion. Ring Doves, fed a diet containing 10 ppm PCB, produced a seemingly normal batch of hatchlings. However, these progeny, when eventually mated, produced third generation embryos with only a 20 percent rate of survival (34).

5. Unlike DDT compounds, PCBs have not been convincingly linked to eggshell thickness (34, 35, 36), although their ability to cause oestradiol degradation through liver enzyme synthesis has been noted by many researchers. The resultant low levels of oestradiol may ultimately lead to delayed breeding, which can be critical for birds with a short breeding season (4, 35, 37).

6. Elevated liver microsomal enzyme activity has been detected in rats ten days after a single dose of PCBs, leading to suggestions that these compounds may affect the natural responses of mammals subjected to environmental chemical stress (38). Indications of actual immunosuppression have been reported following PCB ingestion (39), and chronic PCB exposure has been found to cause increased susceptibility to disease in Pinfish and Spot (40).

7. PCBs also inhibit the synthesis of chlorophyll and growth in the aquatic plant <u>Spirodela oligorhiza</u> (41), and have been found to reduce growth rates in marine diatoms at concentrations as low as 10 to 25 ppb (5).

Controlled laboratory experiments are essential in assessing the potential toxicity of environmental contaminants, but their importance relative to the situation in the environment should not be overrated. Since most organisms in the environment contain detectable levels of several contaminants, experiments designed to test single-factor toxicity may be virtually irrelevant when considering the situation in the natural environment, due to the infinite number of possible interactions between co-contaminants (42).

Because of their mutual persistence and ubiquity, the most common co-contaminants of PCBs are the organochlorine pesticides. Peakall and Lincer (43) report that although PCB toxicity to House Flies is low, it effectively increases the toxic effects of DDT and dieldrin. DDE and PCB, at concentrations too low to exert significant effects when administered singly, acted synergistically to cause severe growth inhibition in marine diatoms (44). PCBs are also reported to increase the insecticidal properties of lindane, carbaryl, and the organophosphate pesticides, in some instances by as much as 100 percent (4, 13).

3 LEVELS IN THE ENVIRONMENT

Although there has never been an extensive study of PCB contamination in British Columbia, limited data on residue levels in tissues, sediments, and water were obtained through various federal and provincial government agencies, university research organizations, and by limited Environmental Protection Service field monitoring. Analyses for the Environmental Protection Service were performed by the B.C. Department of Agriculture Pesticide Analytical Laboratory in Vancouver, except where otherwise indicated. Analytical techniques are described in Appendix I.

It is believed that the following summary includes virtually all available data pertaining to British Columbia, and therefore provides as complete an overview of the current situation in this province as is presently possible.

Data from other geographical locations have been included to complement that obtained from British Columbia and to provide some indication of possible levels in areas where no information was available for British Columbia.

All residue concentrations are listed on wet weight basis unless otherwise indicated.

3.1 Animal Tissues

3.1.1 Terrestrial Vertebrates

3.1.1.1 Birds. Appendix II presents data on PCB residue levels in various species of birds from scattered locations throughout British Columbia. Unpublished information was obtained from the Canadian Wildlife Service and from the British Columbia Fish and Wildlife Branch. Additional data were also included from Friis (45) and from Gilbertson and Reynolds (46). Analyses for Canadian Wildlife Service were performed by the Ontario Research Foundation, while the B.C. Agriculture Pesticide Laboratory analyzed samples for the Fish and Wildlife Branch. It should be noted, however, that some of the data were collected as long ago as 1968, and since PCBs were not detected in tissue samples until 1966, the reliability and accuracy of analytical techniques in these early years should be taken into consideration.

The relatively large interspecific variation in residue levels is to be expected and is influenced by trophic level and by feeding habits. Fish-eating birds from the top of the food chain had particularly high PCB residue levels, a finding consistent with studies throughout the world. Table 2 contains data from some of the more highly contaminated species of British Columbia.

Bald Eagles from Port Hardy, B.C., contained fat residue levels of up to 12.41 ppm, with a mean value of 9.64 ppm, while levels of up to 59.67 ppm were detected in the fat of specimens sampled in the more developed Saanich area of British Columbia. A survey of this species throughout the United States in 1971-1972 yielded a mean carcass residue level of 12 ppm, with individual levels as high as 1200 ppm, indicating that a significant degree of intraspecific variation is possible (47).

These levels, although high, cannot compare to the alarming values that Jensen has recorded for White-tailed Eagles from the Stockholm, Sweden, area where levels in pectoral muscle and fat reached 240 ppm and 17000 ppm, respectively (48).

Heron eggs from Kootenay River, B.C., had PCB residue concentrations of up to 25.9 ppm, while tissue residues in specimens from the Beach Grove area in British Columbia, were very low. Again, Jensen reported much higher concentrations from the Stockholm area, with values of 9400 ppm in fat and 48 ppm in pectoral muscle (48).

Similarly, in the adipose tissues of Merlins sampled in Wisconsin, U.S.A., mean PCB levels of 196 ppm detected in the lipid fraction were much higher than residue levels of 8.64 ppm dry weight in Merlin eggs collected in British Columbia (49).

The residue levels in gull eggs from British Columbia (0.364 to 2.83 ppm) were far lower than those found in the major industrial centres in the Great Lakes area, where mean values have reached

TABLE 2 PCB RESIDUES IN THE MORE HEAVILY CONTAMINATED SPECIES OF BRITISH COLUMBIA BIRDS

Species	Location	Date	Tissue	Mean PCB Content (ppm wet wt.)
Fork-tailed Petrel[3]	Skedans Island	June, 1970	Egg	15.2
Common Murre[2]	Danger Reef	February, 1972	Fat	26.55
Pelagic Cormorant[3]	Mittlenatch Island	August, 1970	Egg	5.36
Brandt's Cormorant[2]	Ganges Harbour	February, 1972	Fat	43.45
Double-crested Cormorant[3]	Mandarte Island	July, 1970	Egg	14.0
Western Grebe[3]	Duck Lake	May, 1969	Fat	46.5
Western Grebe[2]	Captain Passage	February, 1972	Fat	44.65
Great Blue Heron[3]	Kootenay River	May, 1969	Egg	12.97
Great Blue Heron[2]	Victoria	January, 1972	Liver	13.28
Merlin[4]	Lower Mainland	-	Egg	8.64
Peregrine Falcon[3]	Langara Island	June, 1968 & April/May, 1969	Egg	7.03
			Chick	3.24
Bald-headed Eagle[1]	Port Hardy	August, 1974, January, 1975	Subcut. Fat	9.64
			Visceral Fat	4.80
Bald-headed Eagle[2]	Saanich	January, 1972	Subcut. Fat	22.84
			Visceral Fat	59.67

1 B.C. Fish and Wildlife Branch, Unpublished Data
2 Friis (45)
3 Canadian Wildlife Service, Unpublished Data
4 Gilbertson and Reynolds (46) (expressed in ppm dry weight)

134.3 ppm at Lake Ontario and 249.0 ppm at Lake Michigan (50). The British Columbia data more closely resemble the less extreme contamination levels found in gulls collected in the St. Lawrence and Bay of Fundy areas, where mean values of 6.0 ppm and 5.34 to 12.6 ppm, respectively, have been recorded (42). PCB residue levels of 14.0 ppm found in British Columbia Double-crested Cormorant eggs, and 43.45 ppm found in the adipose tissue of Brandt's Cormorants were also comparable to those from the St. Lawrence (9.83 to 13.2 ppm) and Bay of Fundy areas (15.0 to 45.0 ppm) (42).

Other fish-eating species from British Columbia with exceptionally high PCB residue levels include Fork-tailed Petrels, with egg concentrations of 15.2 ppm, and Western Grebes and Common Murres, with levels of 46.5 ppm and 26.55 ppm, respectively, in adipose tissue. Peregrine Falcons from Langara Island, B.C., were also significantly contaminated, with mean residue levels of 7.03 ppm in the eggs. High values in Peregrine Falcons are not uncommon, although they depend primarily on sea birds for food rather than fish. Risebrough et al (49) reported values of 52.2 $\pm$ 32.3 ppm in extractable lipid from adipose tissue in Wisconsin specimens.

Shorebirds, like Plover and Dunlin, feed mainly on insects and other small marine invertebrates and, therefore, would not normally be expected to accumulate PCBs to any significant extent. It should be noted, however, that detectable PCB levels in Dunlins were found in almost every sample from the vicinity of the Vancouver Airport/Iona Island sewage treatment plant, while no PCBs were detected in specimens from other nearby areas.

As could be predicted from their general biology and feeding habits, owls, hawks, Passerines, and Galliformes, all of which would contact PCBs only in abnormal circumstances, contained very low or undetectable amount of PCB.

3.1.1.2 Mammals. B.C. Fish and Wildlife Branch data for ungulates from the Cache Creek area indicated that, with the exception of one Mule Deer, PCB residues were below detectable levels in the tissues of all specimens. Since ungulates are herbivorous, these observations are not surprising. However, no consideration has been given to the investigation of PCB levels in some of the fish-eating mammals of British Columbia. Levels in mink would be of particular interest since this species has been found to be extremely sensitive to PCBs (18).

Measureable levels of PCB have been detected in mammals from most areas of the world, including the Arctic regions, where Bowes and Jonkel (51) found Polar Bear muscle lipid to contain up to 80.6 ppm while Clausen et al (17) reported levels of 21.0 ppm in Polar Bears, 2.8 ppm in Arctic Fox and 1.2 in sheep (Ovis aries) from Greenland.

3.1.2 Aquatic Vertebrates

3.1.2.1 Fish. In the past, most PCB residue analyses of fish-tissues have been conducted on the edible portion only. These data were used to determine the suitability for human consumption of fish from various waters and were the basis for enforcing tolerance limits (2 ppm in Canada and 5 ppm in the United States).

However, according to Aulerich et al (50), who reported the toxic effects of Lake Michigan Coho Salmon fed to mink, it is the 'canning by-products' (i.e., the non-edible portions) that contain particularly high concentrations of PCB. Many researchers have noted that liver, kidneys, and gonads of fish concentrate PCBs to a greater extent than does muscle tissue (38, 53, 54, 55, 56). Although these tissues are discarded during preparation for human consumption, they are readily ingested by animal predators. Consequently, analysis of whole fish, rather than the edible portion, would be more relevant and less misleading when assessing potential toxic effect to wild populations.

PCB residue values for various species of fish collected from the lower Fraser River (Figure 1), from British Columbia coastal waters, and from the Okanagan Lake were obtained from the Westwater Research Centre; Fisheries and Marine Service Fish Inspection Branch; and the B.C. Fish and Wildlife Branch (Tables 3 and 4).

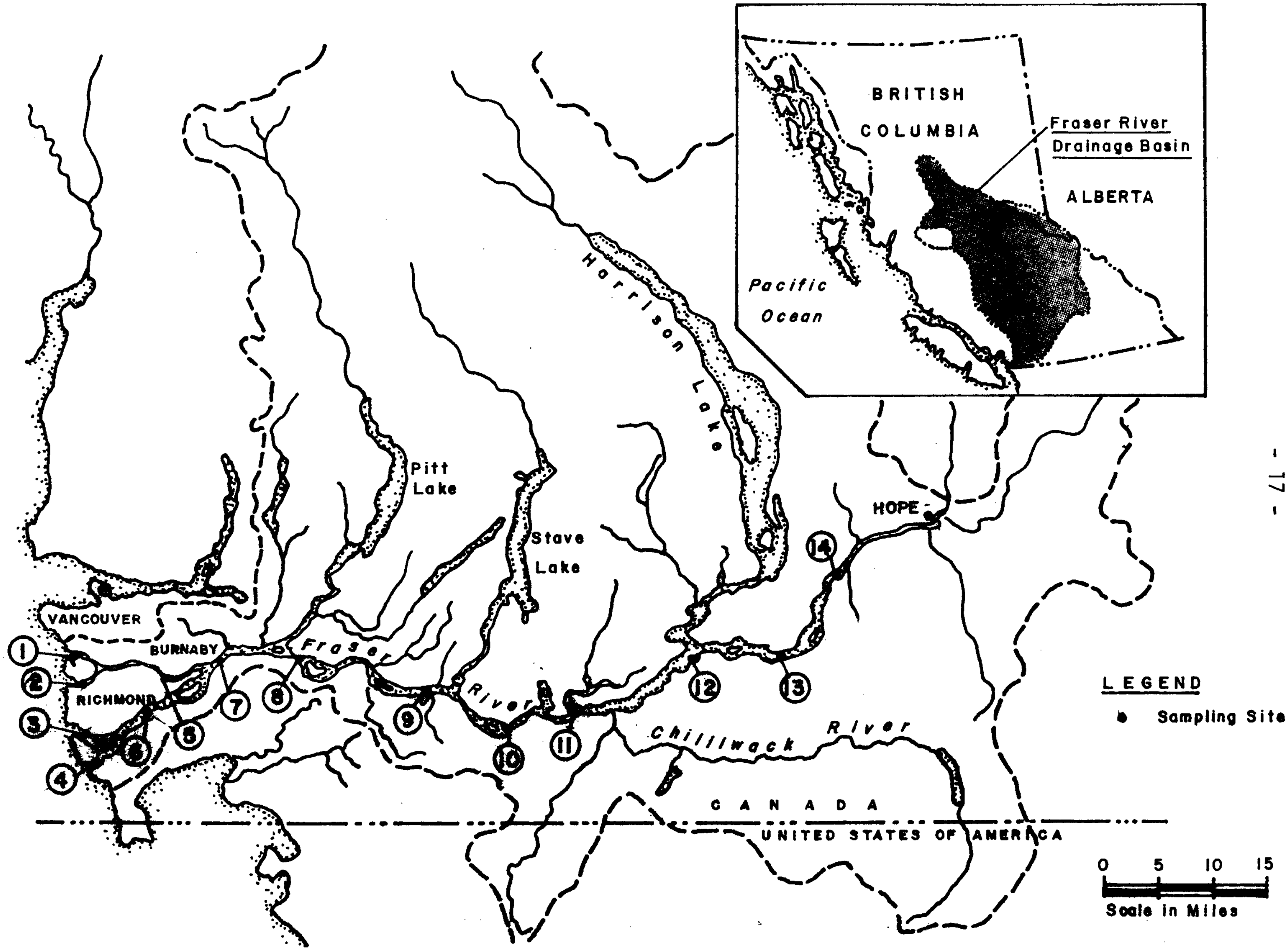


FIGURE I WESTWATER RESEARCH SAMPLING SITES FOR FISH FROM THE LOWER FRASER RIVER SYSTEM (Adapted from Johnston *et al* (55)

TABLE 3 PCB RESIDUE IN FISH FROM WESTWATER RESEARCH CENTRE SAMPLING SITES ALONG THE LOWER FRASER RIVER* (1972-1973)

Species	Station														Total Station Mean ± Standard Deviation
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
White Sturgeon			0.150 (N.D.to 0.318)		0.167 (0.137 to 0.198)	0.143 (N.D.to 0.287)	N.D.	N.D.	N.D.	N.D.		(N.D. to trace)		0.041 (N.D. to 0.165)	0.099 ±0.114
Largescale Sucker			0.154 (N.D.to 0.251)		0.091 (N.D.to 0.199)	0.171 (N.D.to 0.259)		0.623	3.695	0.147 (N.D.to 0.294)	N.D.	N.D.	0.350	0.138 (N.D.to 0.590)	0.258 ±0.643
Peamouth Chub	0.527		0.091 (N.D.to 0.272)				N.D.	N.D.	N.D.		N.D.	N.D.	N.D.	N.D.	0.053 ±0.149
Northern Squawfish			0.755 (0.608 to 0.903)	0.122 (N.D. to 0.483)	1.040 (0.427 to 1.653)	0.748 (0.204 to 1.894)		N.D.		0.084 N.D.to 0.168)	N.D.	(N.D. to trace)	0.204 (N.D to 0.527)	0.075 (N.D.to 0.244)	0.208 ±0.415
Rainbow Trout		0.117 (Trace to 0.314		0.139	0.129 (0.065 to 0.193)		0.143 (0.058 to 0.193)		N.D.	0.062 (N.D. to 0.106)	(Trace to N.D.)		0.059 (N.D.to 0.229	0.037 (Trace to -0.072)	0.071 ± 0.079
Cutthroat Trout			0.119 (0.102 to 0.135)				0.128 (0.077 to 0.209)				N.D.			Trace	0.094 ±0.069
Dolly Varden					N.D.					0.164					0.082 ±0.116
Sockeye Salmon			N.D.												N.D. ±0.0
Chinook Salmon			0.087 (0.084 to 0.090)												0.087 ±0.005
Mountain Whitefish								N.D.			N.D.	N.D.		N.D.	N.D. ±0.0
Brown Bullhead													0.235		0.235
Carp					0.934								N.D.		0.467 ±0.660

* Residue levels [mean (range)] expressed in ppm wet weight based on edible portion only (Johnson *et al* (55)

TABLE 4 PCB RESIDUES IN MATURE FISH FROM MARINE COASTAL WATERS OF BRITISH COLUMBIA* (1973-1974)

Species	No. Samples	PCB Content (ppm wet weight)	
		Mean	Range
Dogfish	8	0.540	0.160 - 1.717
Dogfish liver	2	2.846	0.356 - 5.336
Skate	6	0.009	0.004 - 0.017
Halibut	28	0.061	0.012 - 0.182
Sole	11	0.018	0.006 - 0.045
Flounder	2	0.011	0.011 - 0.011
Grey Cod	10	0.010	0.001 - 0.016
Ling Cod	9	0.051	0.051 - 0.184
Sablefish	7	0.163	0.024 - 0.513
Rockfish	14	0.043	0.006 - 0.233
Tuna	2	0.028	0.023 - 0.032
Herring	6	0.261	0.157 - 0.492
Whiting	1	0.005	
Eulachon	1	0.057	
Ratfish	1	0.031	
Salmon, Chum	10	0.012	0.007 - 0.020
Salmon, Coho	10	0.055	0.013 - 0.103
Salmon, Pink	12	0.019	0.011 - 0.028
Salmon, Sockeye	10	0.021	0.009 - 0.031
Salmon, Steelhead	10	0.052	0.022 - 0.096

* Fisheries and Marine Service, Fish Inspection Laboratory, Unpublished data

For the past two years, B.C. Fish and Wildlife Branch monitoring has indicated the mean PCB residue concentrations in Rainbow Trout from Okanagan Lake to be 0.25 $\pm$ 0.09 ppm and 0.26 $\pm$ 0.18 ppm. Although higher than the mean value found in this species in the lower Fraser River, PCBs in Okanagan trout were more than an order of magnitude below the values recorded for Lake Michigan Rainbow Trout (mean concentration of 2.70 ppm). In fact, almost all trout and salmon specimens more than 12 inches in length from the Lake Michigan area were found to contain PCB residues in excess of the 5.0 ppm United States tolerance limit (57). In contrast, to date, only one British Columbia fish (a Large-scale Sucker from the lower Fraser River) has been found to exceed the Canadian guideline of 2.0 ppm.

While the highest levels of contamination in British Columbia fish were found in suckers (up to 3.695 ppm) and Squawfish (up to 1.894 ppm) from the Fraser River, the mean values of 0.258 ppm and 0.208 ppm, respectively, were only a fraction of those recorded for these species in the Columbia River system (1.040 ppm and 1.190 ppm, respectively) (58). Other areas of high contamination include Escambia Bay in Florida and New York, where mean levels for various species ranged between 4.5 and 20.0 ppm (59) and 0.5 to 26.2 ppm (whole fish), respectively (60).

As noted by the Westwater Research Centre, the residue concentrations in a number of species were higher in the more industrial estuarine portions of the Fraser River than farther upstream. This observation supports the theory that PCB contamination is concentrated mainly in the more heavily industrial areas, and further demonstrates that local industrial outputs are major contributors to PCB contamination in this region.

Although fish collected in British Columbia and adjacent coastal waters show relatively low PCB contamination levels when compared to fish from more heavily industrialized areas, most species have been found to contain concentrations in the 0.1 to 0.9 ppm range. When British Columbia data are compared to data from non-industrial areas such as Manitoba and Saskatchewan and the Arctic regions, it is obvious that British Columbia industry is either currently or has in the past contributed to PCB contamination in the province.

It should also be noted that an absence of extreme levels of PCB contamination is not necessarily indicative of the absence of a potential environmental hazard. For instance, in the Saint John River in New Brunswick, PCBs are suspect in the low spawning success of the Striped Bass. Although residue levels in the fish tissues are not unusually high, the levels detected in the eggs (up to 1.8 ppm in some cases) are thought to be sufficient to cause breakage prior to hatching (61).

3.1.2.2 Marine mammals. Since subcutaneous fat constitutes a large proportion of the body weight of aquatic mammals, and because in most cases their diet consists mainly of fish, they are among the most likely organisms to accumulate large amounts of lipophilic environmental contaminants, including PCBs.

No analyses of aquatic mammal tissues have been performed in British Columbia, but studies elsewhere have confirmed their propensity for accumulation of these compounds and indicate the need for investigation.

Taruski (62) analyzed the blubber of several species of cetaceans from the West Indies and from the northwestern Atlantic and found significant levels of PCB in most samples. Concentrations detected in dolphins (37 to 147 ppm) were found to be slightly higher than those recorded for whales (0.7 to 114 ppm). Measureable quantities were found in every sample of Odontoceti including the Short-finned Pilot Whale and Long-snouted Dolphin from the Lesser Antilles. Concentrations ranged from 0.69 to 5.00 ppm in blubber and 0.03 to 0.54 ppm in muscle (63). A mean value of 6.7 ppm dry weight was detected in tissues of the Common Porpoise from Greenland (17).

Substantial levels of PCBs have also been detected in seals from Greenland and the Arctic regions. Mean levels in Greenland species were: Bearded Seal, 1.8 ppm; Ringed Seal, 0.9 ppm; and Hooded Seal, 2.7 ppm dry weights (17). Ringed Seal and Square Flipper Seals from the Arctic regions contained 0.792 ppm and 0.664 ppm, respectively (51).

In the Channel Islands, off the coast of California, a high degree of premature seal births have occurred and analyses of both premature parturition and full-term females showed higher PCB concentrations in the former(85 to 145 ppm as compared to 12 to 25 ppm). Brain tissue of premature pups was higher in PCB content than that of full-term pups with residue levels of 0.23 to 1.05 ppm and 0.12 to 0.23 ppm, respectively (33).

3.1.3 Marine Invertebrates. Data of PCB residue levels in the marine invertebrates of British Columbia (Table 5) were obtained from the Westwater Research Centre (Figure 2) and from limited Environmental Protection Service field monitoring.

PCB residue concentrations in *Cancer magister* were highest near collection stations in the vicinity of the Iona Island sewage outfall with contamination levels decreasing with increasing distance from this area (64, 65). Similar observations have been reported regarding sewage outfall areas in other regions and have led to suggestions that sewage and wastewater systems may be major sources of PCB entry into the aquatic environment (54, 59).

Mussels from Southern California, collected near municipal wastewater discharge areas, were reported to contain 0.38 to 0.52 ppm PCBs (54) as compared to residue levels of 0.1 to 0.4 ppm in specimens from industrial regions (42) and 0.014 to 0.026 ppm in mussels collected from areas removed from the urban centres. Unfortunately, data on mussels from British Columbia waters are too limited to permit comparison.

Data in Table 5 indicate that organisms from waters adjacent to the less urban or industrial centres had lower levels of PCB contamination. For example, PCBs were not detected in clams and mussels from Kye Bay, a predominantly agricultural district located south of Campbell River, but were detected in these organisms from more urban-industrialized areas.

TABLE 5 PCB RESIDUES IN INVERTEBRATES FROM BRITISH COLUMBIA MARINE WATERS[1] (1972)

Species	Collection Location[2]	PCB Content (ppm dry weight) Mean ± S.D. (Range)
Phylum Mollusca		
Class Pelecypoda - Mussels, oysters, clams		
Mytilus edulis	Sturgeon Bank (Area 3)	Trace
	Kye Bay (Vancouver Island)	N.D.*
Crassostrea gigas	Sturgeon Bank (Area 2)	0.32
	Roberts Bank (Area 5)	2.72
Cardium corbis	Roberts Bank (Area 6)	0.19
	Cowichan Bank (Vancouver I.)	1.96
	Kye Bay (Vancouver Island)	N.D.*
Phylum Arthropoda		
Class Crustacea - Shrimp, crab		
Callianassa californiensis	Sturgeon Bank (Area 3)	0.03
	Roberts Bank (Area 5)	1.85
Cancer magister	Fraser River (Area 1)	1.05
	Sturgeon Bank (Area 2)	0.84 ± 0.56 (0.15 - 1.61)
	Sturgeon Bank (Area 4)	0.78 ± 0.75 (0.23 - 2.10)
	Roberts Bank (Area 6)	0.56 ± 0.40 (0.17 - 1.38)
	Kitimat Arm	0.25 ± 0.09 (0.14 - 0.39)
Cancer magister and Cancer productus	Cowichan Bay (Vancouver I.)	0.78 ± 0.44 (0.11 - 1.51)

[1] Data marked with an asterisk was obtained through Environmental Protection Service field monitoring; all other data from Albright et al (64), and Bawden et al (65).

[2] See Figure 2.

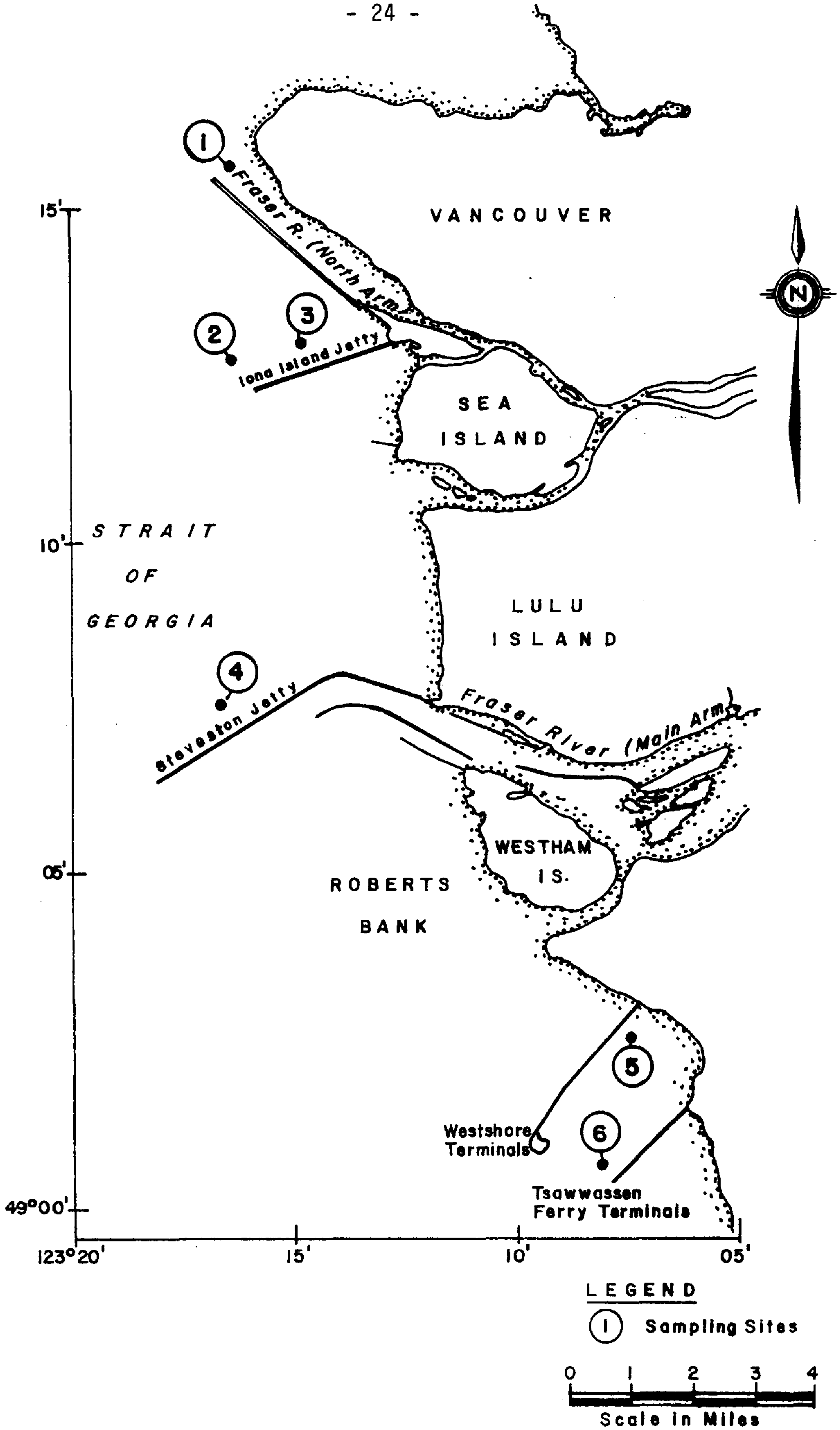


FIGURE 2 WESTWATER RESEARCH INVERTEBRATE SAMPLING SITES IN THE FRASER RIVER ESTUARY (Adapted from Albright et al. (64) and Bawden et al. (65).

The mean concentration in Cancer magister from a more urban area of Georgia Strait in the vicinity of the Iona Island outfall (Area 2 in Figure 2) was 0.84 ppm (dry weight). Southern California, however, with its greater population and industrialization has much higher levels of contamination than the Georgia Strait area, and mean concentrations of PCB in crab tissue have ranged from 0.09 ppm to 2.2 ppm (wet weight) (54).

McDermott et al (54) also report that PCB concentrations in harbour mussels were many times greater than those in mussels from nearby coastal sites, with highest values being detected in specimens collected from regions of heaviest vessel activity.

3.1.4 Plankton and Algae. Because of the extreme sensitivity of some species of algae to PCB compounds, it is possible that high levels of these contaminants in the environment could ultimately result in the disruption of the aquatic food chain or the entire ecosystem. The importance of monitoring levels of contamination in these organisms is obvious and yet there is very little relevant data available.

Algae samples collected from various stations in the vicinity of Kootenay Lake (Figure 3) in interior British Columbia by the Inland Waters Directorate during 1975 were analyzed for PCBs and were found to contain levels below a maximum detection limit of 40 ppb. This region is almost exclusively forest and agricultural land, and is therefore not indicative of the situation in the more urban areas of the province.

Planktonic samples from highly polluted areas in other countries such as the Bristol Channel in England, Firth of Clyde in Scotland, and southwest coast of Finland have been found to contain levels of up to 7000, 17 (66), and 77 ppm (67) PCB, respectively, based on lipid weight. Measureable levels of 0.007 to 0.450 ppm have been reported in samples taken from the open Atlantic Ocean (42).

3.2 Human Tissues

Substantial levels of PCBs have been found in human tissues throughout the world. In Europe, PCBs were detected in concentrations of 0.103 ppm in human milk, and 5.7 ppm in adipose tissue (68).

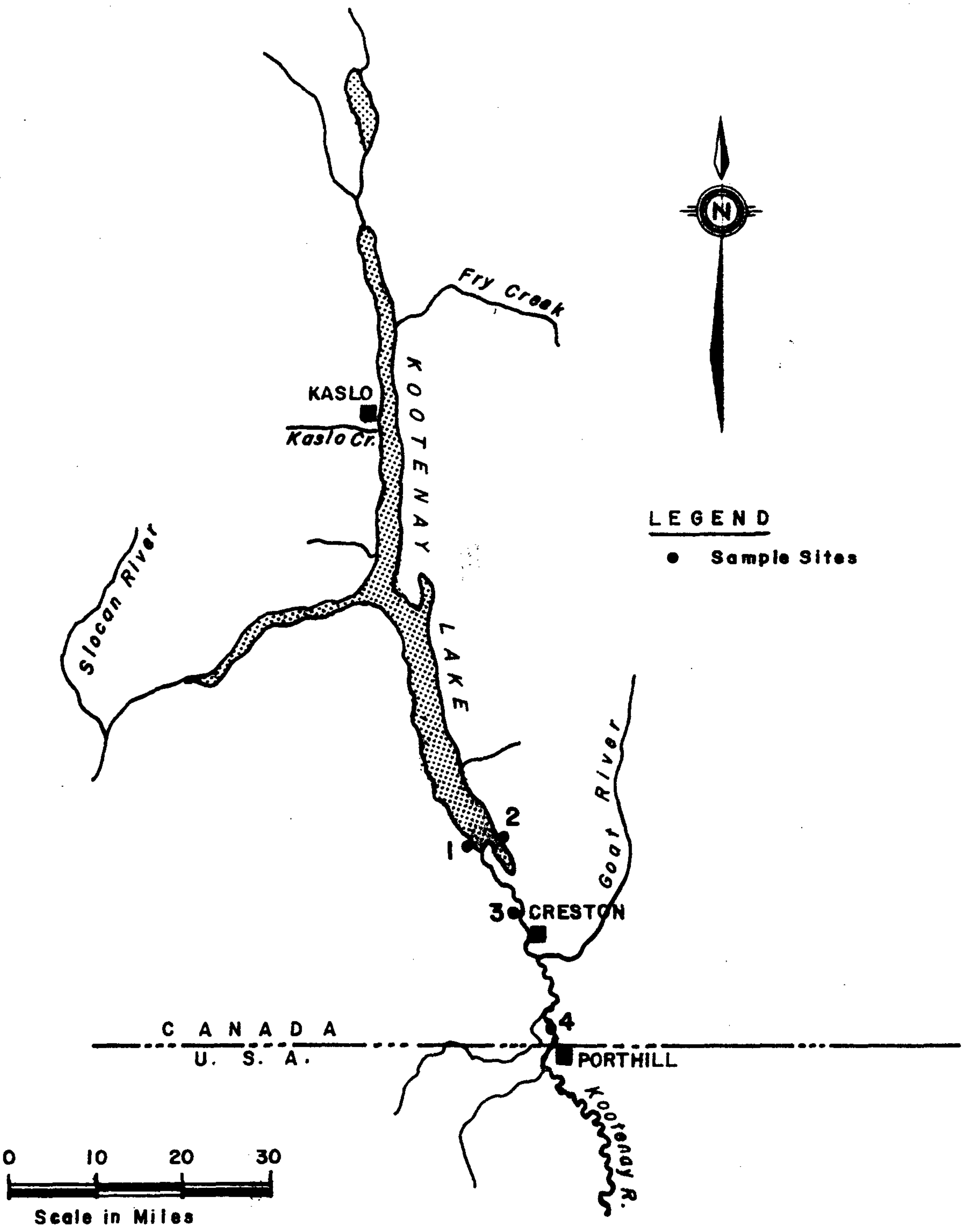


FIGURE 3 INLAND WATERS DIRECTORATE SEDIMENT AND ALGAE SAMPLING SITES IN THE KOOTENAY LAKE AND RIVER DISTRICT, B.C.

The Environmental Protection Agency in the United States estimates that a large percentage of people in the U.S. have levels of between 1 and 3 ppm in their adipose tissue (69). This finding was confirmed by a cross-sectional survey of the American public by the National Institute for Occupational Safety and Health, which revealed that thirty-one percent of the population had concentrations of 2 ppm in their adipose tissue (23).

PCB residues in the whole blood of residents of Tokyo ranged from 1.9 to 5.8 ppb, with a mean value of 3.2 ppb (70). In 1974, PCB concentrations in the samples of adipose tissue from victims of the 1968 Yusho incident were found to be slightly higher than those of unexposed persons. Gas chromatographic analysis of the tissues indicated that the hexa or hepta-chlorobiphenyls can remain in the body for at least 4 years (24).

Analysis of Canadian human adipose tissue revealed detectable levels of PCBs in all samples. The national average has been reported as 0.907 ppm, with the following regional average levels: 0.727 ppm in the Atlantic provinces, 0.969 ppm in Quebec, 1.070 ppm in Ontario, 0.499 ppm in Saskatchewan and Manitoba, and 0.898 ppm in Alberta and British Columbia. The general trend was toward a higher residue concentration in the tissues of men (1.020 ppm) than in those of women (0.685 ppm) (71).

PCB residue data for British Columbia human tissues is limited to a study by the Health Protection Branch of Health and Welfare Canada (Table 6) and another by Oloffs <u>et al</u> (72).

TABLE 6 PCB RESIDUES (ppm) IN HUMAN ADULT ADIPOSE TISSUE SAMPLED IN BRITISH COLUMBIA (1972)

	No. of Samples	PCB Content (Mean ± S.D.)
Male	13	0.74 ± 0.37
Female	5	0.72 ± 0.28
Combined Samples	18	0.74 ± 0.34

Oloffs et al (72) detected the PCB Aroclor 1260 in 32 of 52 samples of human adipose tissue during screening procedures prior to analysis for organochlorine insecticides. To be detected during screening procedures, the PCB contaminants had to be present in substantial concentrations, so the fact the PCB residues were not detected in the remaining 20 samples does not necessarily indicate a total absence of these compounds. Unfortunately, PCB residues were not quantified during this study and conclusions could not be drawn on contamination levels.

It is possible, however, that the PCBs detected by Oloffs et al (72) were present in concentrations higher than those reported by National Health and Welfare. Dissimilarity of data could be due to an age factor, since all of the samples in the study by Oloffs et al were taken from people that were over 60 years of age at the time of their death. There is some documented evidence that age could be a factor in PCB residue levels in human tissues (73). In addition, the overall health of the people just prior to death could be another possible factor. All data from the National Health and Welfare survey were obtained from the tissues of accident victims, while Oloffs et al (72) based their study on tissue samples from hospitalized individuals who had died from various causes, including terminal diseases.

3.3 Sediments and Street Surface Contaminants

The Great Lakes region is known to be among the most polluted in North America. PCBs in Hamilton harbour sediments have been detected at levels of up to 1300 ppb in the canal region, 2000 to 3000 ppb along heavily industrialized waterfront, and 10,000 ppb at a sewage treatment plant. Mean values for other areas of the Great Lakes include: 20 to 300 ppb in Lake Erie, 10 ppb or less in Lake Huron, and trace amounts to 90 ppb in Lake Superior, with one sediment sample from the Marathon area containing 1300 ppb (71).

Sediment levels from heavily contaminated Escambia Bay in Florida ranged from less than 30 ppb to 1700 ppb. One sample from the sewage outfall area contained 486 ppm but was later attributed to the accidental leakage of heat exchange fluid of a local industry into the plant's effluent (59). Southwest Finland sediments from coastal regions near Turku did not exceed 20 ppb (67).

Some British Columbia sediments have been found to contain substantial concentrations of PCBs, comparable, in fact, to the most highly contaminated areas in North America.

Investigations into the more heavily industrialized Brunette River system in Burnaby by the Westwater Research Centre (74) (Figure 4) indicated levels of up to 780 ppb dry weight in Still Creek (Table 7). Substantial levels of PCBs were detected in every sample and the numerous industries in the vicinity, including electrical equipment manufacturers and a B.C. Hydro and Power Authority transformer storage yard, are possible sources of contamination.

Another industry suspected of being a major source of PCB entry into the environment is the paper recycling industry. In February of 1976 and again in April of 1976, sediment samples were taken by the Environmental Protection Service at various stations along the Fraser River in the areas of Scott Paper Limited, Island Paper Mills, and Belkin Paperboard Limited (Figure 5). Levels of up to 1002 ppb dry weight in the first study and 704 ppb in the second study were detected in sediments collected offshore from Belkin Paperboard Limited. (Table 8).

The plants' effluents were sampled at points immediately prior to their discharge into the river and a concentration of 454 ppt PCB was detected in the effluent from Belkin Paperboard Limited. (Table 9). These results indicate that paper recycling plants may still exist as significant sources of PCB release.

Sediment samples from the Kootenay River and Lake system (Figure 3) collected by the Inland Waters Directorate were found to be relatively free of PCBs with all samples containing concentrations below the detection limit of 30 ppb. These results are to be expected since this is a predominantly agricultural district with little local industry.

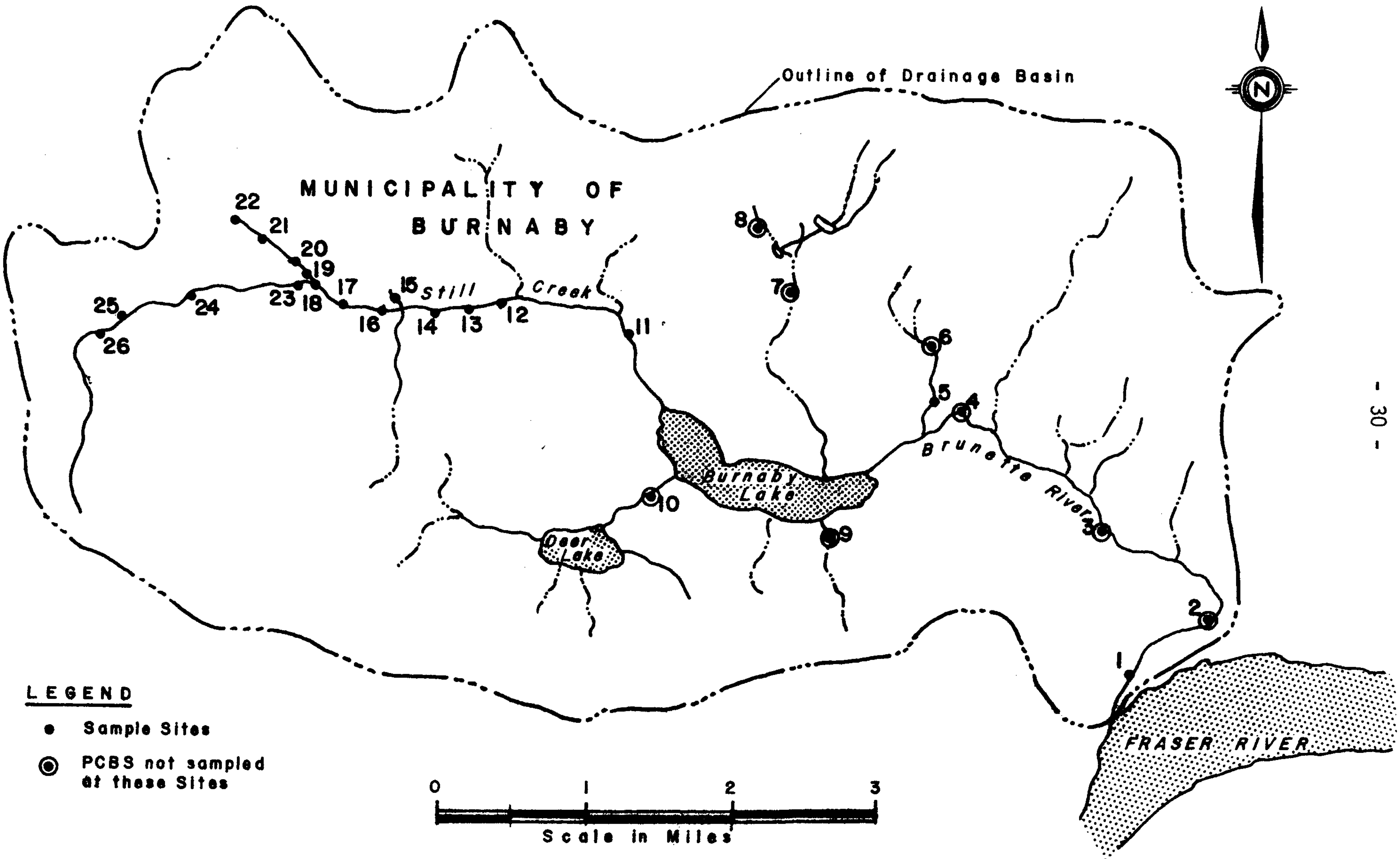


FIGURE 4 WESTWATER RESEARCH SEDIMENT SAMPLING SITES IN THE BRUNETTE RIVER DRAINAGE SYSTEM, BURNABY, B.C. (Adapted from Hall et al. (74)

TABLE 7 PCB RESIDUES IN THE SEDIMENTS OF THE BRUNETTE RIVER - STILL CREEK SYSTEM* (1974)

Station Number**	PCB Content (Aroclor 1254) (ppb dry weight)
1	N.D.
5	N.D.
11	(75)***
12	380 (64)
13	400
14	310
15	540
16	320 (150)
17	780
18	710
19	120
20	37
21	200 (230)
22	120
23	640
24	49
25	55 (<10)
26	44

* Hall _et al_ (74)
** Description of station locations listed in Appendix III
*** Bracketed values are from samples collected in February; all other samples collected in June.

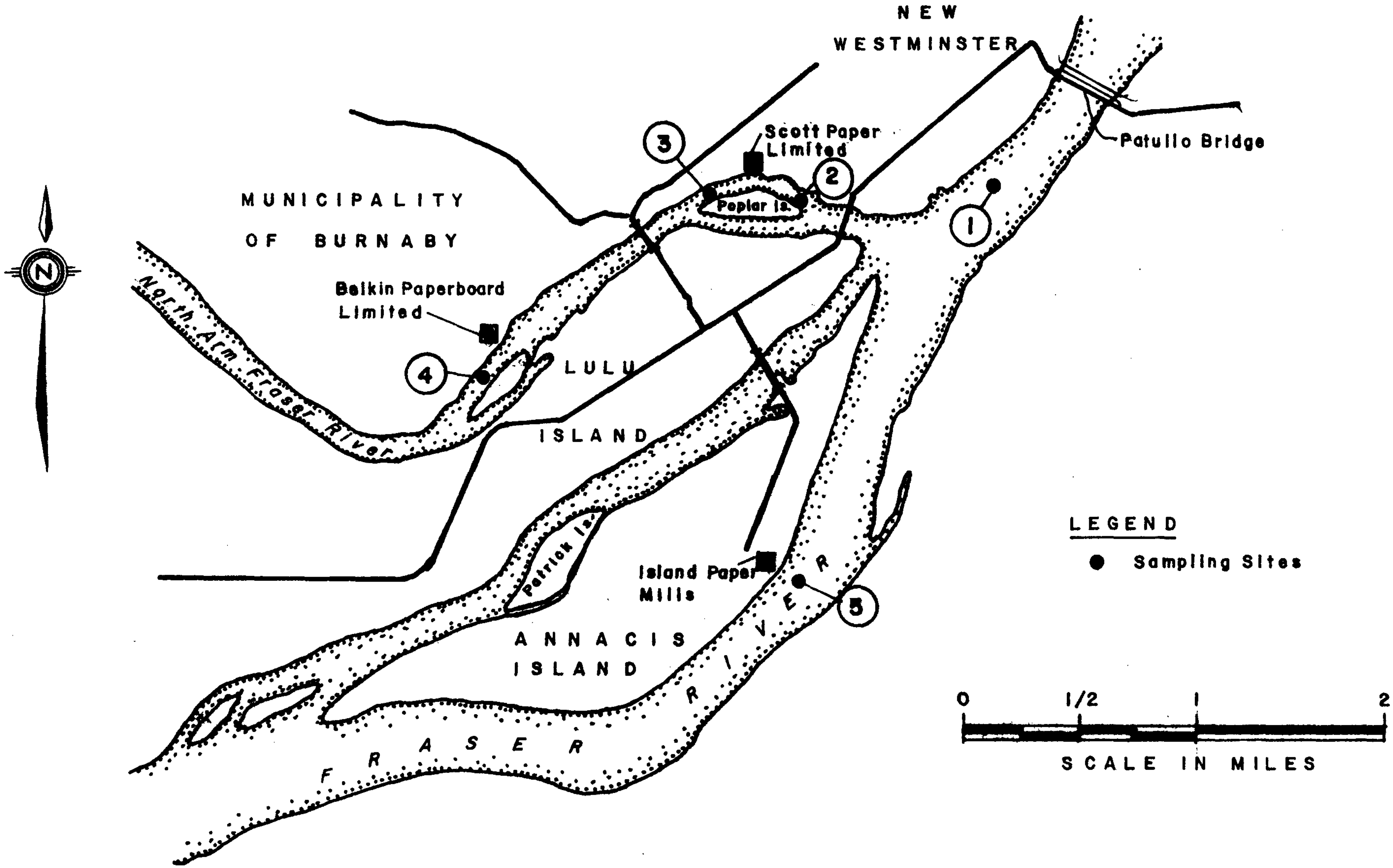


FIGURE 5 E.P.S. SEDIMENT SAMPLING SITES IN FRASER RIVER OFFSHORE FROM LOCAL PAPER PRODUCTS INDUSTRIES

TABLE 8 PCB RESIDUES IN THE SEDIMENTS OF THE FRASER RIVER IN THE VICINITY OF THE EFFLUENT DISCHARGE FROM PAPER PRODUCTS INDUSTRIES (1976)

Station Number[1]	Replicates	Location	PCB (ppb dry weight)
February Survey			
1 Control	i	Downstream from Patullo Bridge	N.D.[2]
	ii		N.D.[2]
2 Control	i	Upstream from Scott Paper Ltd.	N.D.[2]
	ii		N.D.[2]
3	i	Scott Paper Ltd.	N.D.[2]
	ii		N.D.[2]
4	i	Belkin Paperboard Ltd.	1002[2]
	ii		543[2]
5	1	Island Paper Mills	230[2]
	ii		200[2]
April Survey[3]			
1 Control		Downstream from Patullo Bridge	N.D.
2 Control		Upstream from Scott Paper Ltd.	N.D.
3		Scott Paper Ltd.	N.D.
4		Belkin Paperboard Ltd.	
		a) collected off effluent pipe	704
		b) collected midstream just downstream from effluent pipe	50
5		Island Paper Mills	
		a) collected offshore just downstream from effluent pipe	N.D.
		b) collected midstream downstream from effluent pipe	N.D.

1 See Figure 5

2 Values converted from wet weight to dry weight based on an average moisture content of 30%.

3 Analysis performed by Inland Waters Directorate Water Quality Laboratory

TABLE 9 PCB RESIDUES IN THE EFFLUENTS OF PAPER PRODUCTS MILLS ON THE FRASER RIVER (1976)

Location	PCB (ppt)
Belkin Paperboard Ltd.	454
Scott Paper Ltd.	N.D.
Island Paper Mills	N.D.

While studies indicate that soils with high clay content retain PCBs in greater concentrations than do other soil types, it is generally agreed that they are not readily leached from soils of most types (75). For this reason, it is generally assumed that landfills do not play a major role in PCB contamination; however, since they do exist as a potential secondary source, monitoring of these areas would be worthwhile.

Sediment samples taken from the Richmond landfill by the Environmental Protection Service contained from 20 to 30 ppb PCB. A leachate sample obtained from a drainage ditch in another area of the landfill contained 20 ppb PCB. Although this value seems surprisingly high considering the values reported for leachates from Ontario landfills (N.D. to 1.2 ppb) in 1975 (71), the fact that old transformers have been found there may be a partial explanation. It is difficult to determine the contribution that landfill leachates make to total PCB contamination without further sampling in this and similar areas or without an estimation of flow rate in groundwater and drainage ditches.

Westwater Research Centre has found high concentrations of PCBs in samples of street surface sediments (Table 10). Samples were taken at various residential, green space, industrial, and commercial sites. The highest mean value (141 ppb) was found in samples from the commercial areas, while the lowest mean value (50 ppb) was from green space areas (76).

The presence of relatively high levels in all samples indicates that street surface runoff could be a major contributor of PCBs into the environment.

3.4 Water

Data were not available for marine waters in British Columbia, but extensive monitoring by the Inland Waters Directorate indicates that many of the freshwater systems throughout British Columbia (listed in Appendix V) contain PCB residues in concentrations below 0.100 ppb (exact concentrations are not available due to technical limitations).

TABLE 10 PCB RESIDUES IN STREET SURFACE SEDIMENTS FROM THE GREATER VANCOUVER AREA (1974)*

Station Number**	Type of Area		PCBs (ppb dry weight)
R1	Residential		255
R2			40
R3			67
R4			127
R5			31
R6			70
R7			35
R8			102
		Mean Concentration	91
G1	Green Space		30
G2			87
G3			32
		Mean Concentration	50
I1	Industrial		57
I2			126
I3			140
I4			208
I5			96
I6			34
I7			56
I8			48
		Mean Concentration	96
C1	Commercial		57
C2			240
C3			184
C4			71
C5			136
C6			156
		Mean Concentration	141

* Hall, K.J. (76)
** Description of Sampling Station locations listed in Appendix IV.

Detection limits for water samples vary widely with some researchers claiming to be able to detect concentrations as low as a few parts per trillion (ppt), while others list detection limits at 100 ppt. Such disparity makes comparison between various areas inconclusive.

Since no exact figures were available for British Columbia waters, it is difficult to make comparisons with other urban or more industrial areas. However, comparisons between the aquatic biota from British Columbia and various other urban or more industrial regions indicate that British Columbia waters are not as contaminated as are those from known areas of high contamination. Biota from Escambia Bay in Florida, for example, has tissue residues well above those reported for British Columbia. Water concentrations of PCBs in Escambia Bay range from non-detectable levels up to 275.0 ppb at a sewage outfall area (59).

The Environmental Protection Agency objective for acceptable level of PCB contamination in United States waterways is 1 ppt (77). It is probable that many water systems near urban centres do not meet this standard. Analyses of Scottish streams and rivers in 1971 indicated that even streams with no evidence of industrial or heavy sewage contamination contained PCB levels of 2 to 20 ppt. Measureable quantities of PCBs have been detected in the Atlantic Ocean at depths of 3000 metres (78).

3.5 Atmosphere and Rain

As greater restrictions are placed on the production and use of PCBs, the amounts entering the environment through sewage waste systems or other terrestrial sources will gradually diminish, and atmospheric entry will probably take over as the dominant source of PCB contamination of the terrestrial and aquatic environments. The presence of PCBs in open ocean and in Arctic ecosystems has been attributed mainly to atmospheric transport.

As products containing PCBs outlive their usefulness, many will ultimately be taken to municipal dumps or incinerators for burning.

PCBs, because of their thermal stability, require incineration at temperatures of 2000^{O}F (with 3% excess oxygen in stack gas), or 2700^{O}F (with 2% oxygen in stack gas) with dwell times of 2 seconds and 1.5 seconds, respectively, in specially equipped incineration facilities to achieve complete thermal destruction (79).

Disposal in municipal dumps and attempts at destruction in conventional incinerators may result in vaporization of PCBs and subsequent emission into the atmosphere. Wind currents would carry these aerosols for considerable distances, contaminating areas many miles from the source in amounts partially dependent upon regional rainfall (51, 78).

Rainwater samples collected from agricultural watersheds in Ontario containing PCB concentrations in the range 0.01 to 0.1 ppb (71), and samples from four different sites in Scotland in 1972 ranging from 20 to 40 ppt (66), indicate that rainfall may be a significant source of PCB entry into the aquatic environment.

There is a dearth of information on PCB concentrations in air and rainwater and there are no known investigations of this problem in the British Columbia environment.

Data collected from Eastern Canada in 1974 and 1975 by the Ontario Research Foundation under contract to the Ministry of the Environment confirm suspicions that municipal incinerators release measureable amounts of PCBs into the atmosphere. The majority of PCB was found to be in gaseous form rather than associated with particulate matter, and total PCB concentrations were 1.32 ng/m^3 in a research community, 0.82 to 2.88 ng/m^3 in a heavily urban-industrialized area, and 1.85 to 9.30 ng/m^3 downwind from a municipal incinerator (71).

Harvey and Steinhauer (80) took atmospheric samples from four stations over the western Atlantic Ocean. Results indicated that PCB concentrations in the atmosphere at sea decreases exponentially with increasing distance from industrial centres of the mainland. Concentrations at the various sampling stations were: 3.9 to 5.3 ng/m^3 in Vineyard Sound, Massachusetts; 0.58 to 1.60 ng/m^3 at Georgia Bank, Massachusetts; 0.15 to 0.5 ng/m^3 at Bermuda, and 0.05 to 0.16 ng/m^3 at Grand Banks, Newfoundland. These stations are located 150 to 250 km, 500 km, 1000 km, and 2000 km, respectively, from the Boston-Hartford-New York-New Jersey industrial complex.

3.6 Food Products and Packaging

Health and Welfare Canada has set the following limits for PCB residues in products intended for human consumption; 2.0 ppm in fish (as compared to 5.0 in the United States), 0.2 ppm for dairy products, 0.5 ppm for poultry, and 0.1 ppm for eggs.

There has been concern over the high content of PCBs in recycled paper used in food packaging materials. Questions concerning the possibility of the migration of PCBs into packaged food substances have been raised. A federal survey of food packaging material and packaged food products confirms this possibility. Of the numerous packages analyzed, 15% were found to contain between 1 and 10 ppm, while 3.4% contained more than 10 ppm PCB. Paperboard and paper packages contained the highest levels (81).

Two types of packaged food were found to contain residue levels in excess of 1 ppm. Packaged dried fruit contained 4.5 ppm, and packaged rice contained 2.1 ppm PCB. Three hundred and sixty-six samples of meat were examined, and eight samples of beef were found to contain 0.04 to 1.7 ppm, while six samples of chicken contained 0.29 to 0.38 ppm. In extensive sampling on staple foods, including milk, eggs, vegetables, and oils, only one sample of chicken fat contained a detectable level of PCB residue (81).

Since the discontinuation of the use of PCBs in packaging and in other non-closed systems, monitoring programs indicate that PCBs now contaminate far fewer types of food than they did formerly, and that "the rate and level of occurrence of PCBs have declined very drastically in all categories except fish" (77).

Limited data on PCB residue levels in British Columbia food products for 1974-1975 were obtained from the Health Protection Branch of Health and Welfare Canada in Ottawa (Table 11).

TABLE 11 PCB RESIDUES IN BRITISH COLUMBIA FOOD PRODUCTS

Commodity		PCBs (ppm)
Apple	(fresh)	0.048
	(fresh)	0.063
Clam	(whole)	0.058
	(dehydrated)	0.097
	(dehydrated)	0.230
Oyster	(canned)	0.270
Smoked shellfish		0.026
Trout	(whole)	0.4
	(whole)	0.3
	(whole)	0.3
	(whole)	0.3
	(whole)	0.3
	(whole)	0.2
	(whole)	0.3
	(whole)	0.3
	(whole)	0.2
	(whole)	0.3
	(whole)	0.1
	(whole)	0.1
	(whole)	0.2
Tuna	(cut up)	0.080

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APPENDIX I

EXTRACTION, CLEANUP, AND ANALYTICAL PROCEDURES FOR PCB RESIDUES IN SEDIMENTS (BRITISH COLUMBIA DEPARTMENT OF AGRICULTURE, PESTICIDE LABORATORY, VANCOUVER, B.C.)

APPENDIX I EXTRACTION, CLEANUP, AND ANALYTICAL PROCEDURES FOR PCB RESIDUES IN SEDIMENTS (BRITISH COLUMBIA DEPARTMENT OF AGRICULTURE, PESTICIDE LABORATORY, VANCOUVER, B.C.)

A. Extraction and Cleanup

5 grams (wet weight) of each sediment sample were extracted in a 50:50 acetone:hexane solution in the presence of excess anhydrous sodium sulfate, using a high speed "Polytron" blender. Solids were removed by filtration through a filter pad of "Hi Flo Super Cel." The filtration was then concentrated nearly to dryness.

The residue from evaporation was eluted through 20 grams of Florisil 80/100 mesh with 5% water using 200 ml hexane. The eluate was concentrated nearly to dryness and was then diluted to 10 mls for gas chromatographic analysis.

B. Gas Chromatography

Electron capture GLC analysis was performed on a Microtek TRACOR 550 and on a Microtek TRACOR 220. A 183 cm x 0.3 cm I.D. glass column was packed with a mixture of 4% OV 101 and 6% OV 210 on Chromosorb W "H.P." 80/100 mesh. N_2 carrier gas at a flow rate of 80 ml/min was used. Injector, oven, and detector temperatures were 225^{o}C, 185^{o}C, and 325^{o}C, respectively.

APPENDIX II

PCB RESIDUE IN BIRDS FROM VARIOUS AREAS IN BRITISH COLUMBIA

APPENDIX II . PCB RESIDUE IN BIRDS FROM VARIOUS AREAS IN BRITISH COLUMBIA

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
ORDER CHARADRIIFORMES					
Black-legged Kittiwake[1]	Saltspring Isl.	Oct. 19/74	Muscle	N.D.	
			Liver	N.D.	
Black-legged Kittiwake[2]	Cape Beale	Sept. 1973	Muscle	N.D.	
			Liver	0.88	
Fork-tailed Petrel[3]	Skedans Isl.	June 11/70	Egg	15.2	
Leach's Petrel[3]	Cleland Isl.	June 1970	Egg	1.09	
Glaucous-winged Gull[2]	Bowle's Point (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
	Langara Island	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
			Ovary	N.D.	
	Rainy Isl. (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
			Ovary	N.D.	
Glaucous-winged Gull[3]	Cleland Isl.	June 1970	Egg	2.58	
	Mandarte Isl.	July 7/70	Egg	2.49	
	Mittlenatch Isl.	May 22/70	Egg	1.53	
	Stevenson Islets	June 17/70	Egg	2.83	
	Lucy Isl.	June 7/70	Egg	0.567	
	Skedans Isl.	June 11/70	Egg	0.487	
	Bonita Isl.	June 6/70	Egg	0.364	

(continued)

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
continued					
Hermann's Gull[2]	Barkley Sound	Aug. 1972	Muscle	N.D.	
			Liver	0.03 ± 0.04	N.D.-0.05
			Visc. Fat	N.D.	
Ancient Murrelet[1]	Queen Char. Isl.	June 1975	Brain	0.04 ± 0.08	N.D.-0.13
			Muscle	2.00 ± 1.64	0.35-4.26
			Liver	1.40 ± 0.88	0.26-2.39
Ancient Murrelet[2]	Marble Isl.	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
			Ovary	N.D.	
	Frederick Isl.	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
			Ovary	N.D.	
			Egg	N.D.	
	Howay Isl.	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
			Ovary	N.D.	
			Crop Content	N.D.	
Ancient Murrelet[3]	Langara Isl. (1/4 mi. N.N.W. Iphiganta Light)	June 7/69	Chick	0.517	
	Langara Isl. (West of Furry Bay)	June 10/69	Chick	1.40	
	Queen Char. Isl.	-	Whole body	1.03	

(continued)

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
continued					
Marbled Murrelet[1]	Queen Char. Isl.	June 1975	Brain	0.54 ± 1.12	N.D.-3.05
			Muscle	0.99 ± 0.89	N.D.-2.56
			Liver	1.01 ± 0.88	N.D.-2.56
Marbled Murrelet[2]	Tanu Isl. (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	0.21	
			Ovary	N.D.	
			Crop Contents	N.D.	
Marbled Murrelet[2]	Athlow Bay (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	0.25 ± 0.35	N.D.-0.50
			Fat	0.64 ± 0.66	0.17-1.10
			Ovary	N.D.	
Marbled Murrelet[3]	Langara Isl.	Aug. 1969	Fat	1.41 ± 0.55	0.775-1.77
Common Murre[2]	Captain Passage	Feb. 1972	Liver	1.10	
	Danger Reef	Feb. 1972	Muscle	0.25	
			Liver	1.45	
			Fat	26.55	
Common Murre[3]	Queen Char. Isl.	-	Whole bird	1.04	
	Semiahmoo Bay	-	Liver	1.18 ± 0.01	1.17-1.19
Pigeon Guillemot[2]	Collision Bay (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
			Ovary	N.D.	
	Anthony Isl.	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	Trace	
			Ovary	N.D.	

(continued)

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
continued					
Pigeon Guillemot[2]	Langara Isl.	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
			Ovary	N.D.	
			Crop Contents	N.D.	
Pigeon Guillemot[3]	Skedans Isl.	June 11/70	Eggs	0.421	
	Cleland Isl.	June 28/70	Eggs	2.56	
	Mittlenatch Isl.	July 15/70	Eggs	3.54	
Cassin's Auklet[1]	Queen Char. Isl.	June 1975	Brain	2.52 ± 1.93	0.34-3.98
			Breast Muscle	1.68 ± 0.91	1.13-2.74
			Liver	1.37 ± 0.62	0.74-1.97
Cassin's Auklet[3]	Queen Char. Isl.	-	Whole body	0.399±0.17	0.279-0.518
			Eggs	0.600	
Rhinoceras Auklet[1]	Queen Char. Isl.	June 1975	Brain	1.02 ± 1.44	N.D.-2.04
			Breast Muscle	1.14 ± 1.61	N.D.-2.28
			Liver	1.21 ± 1.70	N.D.-2.41
Rhinoceras Auklet[2]	Lyell Isl. (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	Trace	
	Flamingo Inlet (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	Trace	
	Marble Isl. (Queen Char. Isl.)	May 1971	Muscle	Trace	
			Liver	N.D.	
			Fat	Trace	

(continued)

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
continued					
Rhinoceras Auklet[3]	Langara Isl.	Aug. 14/70	Fat	3.65 ± 3.35	1.28-6.02
	Lucy Isl.	June 7/70	Egg	2.01	
	Moore Isl.	May 31/70	Egg	1.73	
	Queen Char. Isl.	-	Whole bird	2.86 ± 1.06	2.11-3.61
Puffin[1]	Queen Char. Isl.	June 1975	Brain	0.22 ± 0.16	0.10-0.33
			Breast Muscle	0.28 ± 0.40	N.D.-0.56
			Liver	1.25 ± 1.77	N.D.-2.50
Tufted Puffin[1]	Queen Char. Isl.	June 1975	Brain	0.28	
			Breast Muscle	0.41	
			Liver	0.24	
Tufted Puffin[2]	Bowles Point	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
			Ovary	N.D.	
	Marble Isl. (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
			Ovary	N.D.	
	Knox Isl. (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
			Ovary	N.D.	
Tufted Puffin[3]	Cleland Isl.	Jan. 27/70	Egg	0.660	
	Queen Char. Isl.	May 12/71	Whole bird	1.03 ± 0.37	0.77-1.29

(continued)

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
continued					
Killdeer[3]	Sea Island	Mar. 5/68	Brain	N.D. ± 0.00	
			Muscle	N.D. ± 0.00	
	Sea Island & Reifel Isl.	Mar. 7/68	Brain	N.D. ± 0.00	
			Muscle	0.026±0.01	0.021-0.03
Wandering Tattler[3]	Queen Char. Isl.	-	Whole bird	N.D.	
Dunlin[3]	Boundary Bay	Mar. 5/68	Brain	N.D. ± 0.00	
			Muscle	N.D. ± 0.67	N.D.-Trace
	Sea Island	Mar. 8/68	Brain	N.D. ± 0.00	
			Muscle	0.0089±0.01	N.D.-0.038
	Sea Island Airport	-	Breast Muscle	1.03 ± 0.99	N.D.-3.19
Oystercatcher[1]	Queen Char. Isl.	June 1975	Brain	0.79 ± 0.08	0.73-0.85
			Breast Muscle	1.26 ± 0.33	1.03-1.49
			Liver	0.13 ± 0.18	N.D.-0.25
ORDER PELECANIFORMES					
Pelagic Cormorant[3]	Mandarte Isl.	July 5/70	Eggs	2.64	
	Mittlenatch Isl.	Aug. 7/70	Eggs	5.36	
Pelagic Cormorant[2]	Langara Isl. (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
	Rainy Islands (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	

(continued)

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
continued					
Brandt's Cormorant[2]	Ganges Harbour	Feb. 1972	Muscle	0.87	
			Liver	2.56	
			Fat	43.45	
Double-crested Cormorant[3]	Mandarte Isl.	July 5/70	Eggs	14.0	
ORDER PROCELLARIOFORMES					
Socty Shearwater[3]	Queen Char. Isl.	May 14/71	Whole body	0.339	
ORDER ANSERIFORMES					
American Widgeon[3]	Boundary Bay	Mar. 5-6/68	Brain	N.D. ± 0.00	
			Muscle	N.D. ± 0.00	
Green-winged Teal[3]	Sea Island	Mar. 8/68	Brain	N.D. ± 0.00	
			Muscle	N.D. ± 0.00	
	Reifel Island	Mar. 5/68	Brain	N.D. ± 0.00	
			Muscle	N.D. ± 0.00	
Greater Scaup[3]	Reifel Island	Mar. 6/68	Brain	N.D.	
			Muscle	N.D.	
Bufflehead[3]	Lower Mainland	Nov. 1969	Breast Muscle	1.39	
Oldsquaw[3]	Beach Grove	Mar. 8/68	Brain	N.D. ± 0.00	
			Muscle	N.D. ± 0.00	
Common Scoter[3]	Beach Grove	Mar. 8/68	Brain	N.D.	
			Muscle	N.D.	
Surf Scoter[3]	Beach Grove	Mar. 6/68	Brain	N.D. ± 0.00	
			Muscle	N.D. ± 0.00	

(continued)

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
continued					
Snow Goose[3]	Sea Island	Mar. 8/68	Brain	N.D. ± 0.00	
			Muscle	N.D. ± 0.00	
ORDER PODICIPEDIFORMES					
Western Grebe[3]	Duck Lake	May 18/69	Brain	1.29	
			Breast Muscle	2.11	
			Fat	46.5	
			Egg	1.70	
Western Grebe[2]	Captain Passage (Vancouver Island)	Feb. 1972	Muscle	2.50	
			Liver	2.22	
			Fat	44.65	
ORDER GAVIIFORMES					
Arctic Loon[2]	Hidden Island (Queen Char. Isl.)	May 1971	Muscle	N.D.	
			Liver	N.D.	
			Fat	N.D.	
Arctic Loon[3]	Semiahmoo Bay	Jan. 5/71	Liver	2.44 ± 2.09	0.96-3.91
ORDER CICONIIFORMES					
Great Blue Heron[3]	Beach Grove	Mar. 6/68	Brain	0.006 ± 0.01	N.D.-0.012
			Muscle	N.D. ± 0.00	
	Kootenay River	May 1969	Eggs	12.97 ± 18.29	0.036-25.9
Great Blue Heron[2]	Victoria	Jan. 1972	Muscle	2.22	
			Liver	13.28	

(continued)

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
continued					
ORDER GRUIFORMES					
Sora Rail[3]	Westham Isl.	Aug. 5/69	Brain	0.151	
ORDER FALCONIFORMES					
Osprey[3]	Kootenay River	May 18/69	Egg	0.3395±0.02	0.328-0.351
Osprey[2]	Victoria	Oct. 1973	Muscle	N.D.	
			Liver	N.D.	
			Visc. Fat	N.D.	
Peregrine Falcon[3]	Langara Isl.	June 1968 & Apr.-May/69	Egg	7.03 ± 3.32	4.38-12.7
		June 11/69	Nestling-breast muscle	0.19 ± 0.27	N.D.-0.387
			Nestling-liver	0.629 ± 0.77	0.088-1.17
			Nestling-brain	0.503 ± 0.14	0.403-0.602
		May 21/69	Chick - 1 day	3.24	
Red-tailed Hawk[1]	Victoria	Nov. 2/74	Muscle	0.21	
			Liver	0.05	
Red-Tailed Hawk[3]	Fraser Delta	April 1969	Egg	0.374	
	Ladner Delta	-	Chick brain	0.024	
Cooper's Hawk[1]	Metchosin	Feb. 1/74	Muscle	N.D. ± 0.00	
			Liver	N.D. ± 0.00	
	Saltspring Isl.	Oct. 19/74	Muscle	N.D.	
			Liver	N.D.	

(continued)

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
continued					
Cooper's Hawk[2]	Victoria	Feb. 1973	Muscle	3.18	
			Liver	10.10	
	Ten Mile Point (Victoria)	Oct. 1973	Muscle	N.D.	
			Liver	N.D.	
Snarp-shinned Hawk[2]	Victoria	Oct. 1973	Muscle	N.D.	
			Liver	N.D.	
Merlin[2]	Victoria	Nov. 1973	Muscle	N.D.	
			Liver	N.D.	
Merlin[4]	Lower Mainland	-	Brain	0.003	
			Egg	8.64	
Bald-headed Eagle[1]	Port Hardy	Aug.74-Jan.75	Pectoral Muscle	0.70 ± 0.29	0.49-0.90
			Liver	0.20 ± 0.03	N.D.-0.39
			Subcut.Fat	9.64 ± 2.63	7.19-12.41
			Visc. Fat	4.80	
Bald-headed Eagle[2]	Alberni Valley	Dec. 1970	Muscle	N.D.	
			Liver	N.D.	
			Fat	2.43	
	Saanich	Jan. 1972	Muscle	9.76	
			Liver	2.04	
			Visc. Fat	59.67	
			Subcut.Fat	22.84	
ORDER STRIGIFORMES					
Great-horned Owl[1]	Victoria	Nov. 12/74	Muscle	N.D.	
			Liver	N.D.	
			Fat	1.41	

(continued)

Species	Location	Date	Tissue	PCB CONTENT (ppm wet weight) Mean ± S.D.	Range
continued					
Great-horned Owl[2]	Mt. Lehman	Oct. 1971	Muscle	N.D.	
			Liver	N.D.	
			Visc. Fat	N.D.	
Short-eared Owl[3]	Fraser Delta	-	Brain	0.014	
			Muscle	0.019	
ORDER GALLIFORMES					
Ruff Grouse[1]	Cache Creek	-	Muscle	N.D.	
Blue Grouse[1]	Cache Creek	-	Muscle	N.D. ± 0.00	
Franklin Grouse[1]	Cache Creek	-	Muscle	N.D. ± 0.00	
ORDER PASSERIFORMES					
Robin[3]	Reifel Island	Mar. 6/68	Brain	N.D. ± 0.00	
			Muscle	0.01 ± 0.01	N.D.-0.032
Starling[3]	Dawson Creek	Apr. 24/69	Breast Muscle	0.065±0.03	0.030-0.125
Crow[2]	Langara Island	May 1971	Muscle	N.D.	
			Liver	N.D.	

1 B.C. Fish and Wildlife Branch, unpublished data.

2 from Friis. (45)

3 Canadian Wildlife Service, unpublished data.

4 from Gilbertson and Reynolds (46) (expressed in ppm dry weight)

APPENDIX III

DESCRIPTION OF WESTWATER RESEARCH CENTRE SEDIMENT SAMPLING LOCATIONS IN THE BRUNETTE RIVER - STILL CREEK SYSTEM

APPENDIX III DESCRIPTION OF WESTWATER RESEARCH CENTRE SEDIMENT SAMPLING LOCATIONS IN THE BRUNETTE RIVER - STILL CREEK SYSTEM

Station No.	Location	Remarks
1	Brunette River at Spruce Ave.	At mouth of river, wood products industries
5	Small creek north of freeway	Urban dwelling, storm drainage
11	Small creek crosses Government Road east of Brighton	Rechanneling of stream, new industrial construction
12	Upstream of Station 11 at Production Way	Stream discharge from industrial park area
13	Eagle Creek near Piper Ave. and Winston St.	Residential area, near Burnaby Lake
14	Eagle Creek at East Broadway	Below golf course, landfill area
15	Tributary of Eagle Creek	Below oil tank form on Burnaby Mt.
16	Tributary of Eagle Creek near Phillips Avenue	Above golf course in deciduous woods
17	Robert Burnaby Creek	Near exit from Robert Burnaby park
18	Small creek south of Burnaby Lake	Residential area near freeway
19	Deer Creek at Glencairn Dr.	North of freeway and south of Burnaby Lake
20	Deer Creek at Canada Way	Residential area
21	Small stream near Gilpin Ave.	Discharge from Forest Lawn Memorial Cemetary
22	Small stream at Bond St. and Sussex Ave.	Residential area - flows to Deer Lake
23	Still Creek at Sperling Ave.	Wodded shores, creek backed up from Burnaby Lake

(continued)

Station No.	Location	Remarks
continued		
24	Small creek, Sperling at Jordan Drive	Residential, creek shoreline is wooded
25	Small creek at Goring Ave.	Industrial - transport and aluminum company
26	Upstream of Station 25 at Lougheed Highway	Residential

APPENDIX IV

LOCATION OF WESTWATER RESEARCH CENTRE
SAMPLING STATIONS FOR STREET SURFACE CONTAMINANTS

APPENDIX IV LOCATION OF WESTWATER RESEARCH CENTRE SAMPLING STATIONS FOR STREET SURFACE CONTAMINANTS

Station Number	Location (Burnaby, B.C.)
Residential	
R1	East 14th Ave. (block east of Renfrew St.)
R2	East 16th Ave. (between Renfrew and Rupert Sts.)
R3	Smith Ave. at Spruce Ave.
R4	Whitsell Ave. at Williams Ave.
R5	2400 Duthie St.
R6	Mahon at Eglington
R7	Mayfield and Canada Way
R8	Lee and 10th Ave.
Green Space	
G1	Forest Lawn Cemetary
G2	Robert Burnaby Park
G3	Gaglardi Way at Esterbrook
G4	Phillips and Halifax (near golf course)
Industrial	
I1	Rupert St. (between Grandview and Broadway)
I2	Boundary Rd. and Myrtle Ave.
I3	Gilmore Ave., north of Still Creek
I4	Willingdon Ave., north of "401" interchange
I5	Douglas Rd. at Still Creek
I6	Industrial Park (Lake City)
I7	Spruce Ave. opposite Labatts
I8	Spruce Ave. opposite Capilano Lumber
Commercial	
C1	Canada Way at Boundary Rd.
C2	Willingdon at Lougheed (Brentwood Shopping Center)
C3	Austin at Lougheed (Lougheed Shopping Center)
C4	North Rd. at Lougheed
C5	Sperling at Canada Way
C6	Braid at Columbia St.

APPENDIX V

LIST OF INLAND WATERS DIRECTORATE FRESHWATER SAMPLING STATIONS IN BRITISH COLUMBIA (1974-1975)

APPENDIX V LIST OF INLAND WATERS DIRECTORATE FRESHWATER SAMPLING STATIONS IN BRITISH COLUMBIA (1974-1975)

Peace River at Hwy 29 Bridge
Hudson Hope, B.C.

Peace River at Clayhurst Ferry near
B.C.-Alta. Border

Bulkley River at Highway Bridge,
Quick

Skeena River at USK Ferry

Squamish River at Hwy 99 Bridge 3
miles north of Brackendale

Cowichan River at Duncan

Nanaimo River at pumphouse below Hwy
1 Bridge, Cassidy

Campbell River at John Hart
Generating Station 3 miles west of
Campbell River

Nechako River at Dept. of Highways
Ferry crossing 0.5 mile north of Isle Pierre

Stuart River at Hwy 27 Bridge 2 miles
south of Fort St. James

Fraser River at Shelley

Fraser River at Hwy 97 bridge
Quesnel

South Thompson River at intake
to Kamloops City Treatment Plant

North Thompson River at Hwy 5 Bridge
McLure

Thompson River at Hwy 1 bridge
Spences Bridge

Fraser River at Ferry Crossing 2 miles
north of Marguerite

Fraser River at Hwy 1 Bridge, Hope

Harrison River at Hwy 7 Bridge

Fraser River at Mission City

Pitt River at Hwy 7 Bridge above
Port Coquitlam

Sumas River at pumping station about
0.9 mile above confluence of Vedder
Canal

Still Creek at Gilmore Avenue
Burnaby

Vedder Canal at Hwy 401

Sumas River at International Boundary

Salmon River at 72nd Avenue
Langley

Salmon River at Rawlinson Crescent

Salmon River at 96th Avenue Bridge
about 0.35 mile above mouth

Chilliwack Creek below the confluence
of Atchelitz Creek

Lonzo Creek at North Parallel Road
about 0.3 mile above mouth

Deer Creek at Glencairn Drive
New Westminster

Brunette River at Braid Street
New Westminster

Sinclair Creek at Canyon Campground

Columbia River below Mica Dam

Columbia River below Trail 2 miles
north of Waneta Power Dam

Columbia River at Castlegar Ferry

Pend D'Oreille River 1500 feet below
Remac Mine

Pend D'Oreille River below Waneta Power
Dam at Railway Bridge

Pend D'Oreille River 3000 feet below
Remac Mine

Kootenay River at Kootenay crossing

Kootenay River near South Park Boundary

Kootenay River above confluence of Vermilion
River, Kootenay National Park

Kootenay River above confluence of Cross
River, Kootenay National Park

Kootenay River above Nixon Creek
Kootenay National Park

Vermilion River near Mouth
Kootenay National Park

Vermilion River above Wardle Creek
Kootenay National Park

Simpson River near mouth
Kootenay National Park

Vermilion River above Vermilion Crossing
Kootenay National Park

Vermilion River above Floe Creek
Kootenay National Park

Vermilion River above Ochre Creek
Kootenay National Park

Ochre Creek near mouth
Kootenay National Park

Tokumm Creek near mouth
Kootenay National Park

Vermilion River above Marble Canyon
Kootenay National Park

Vermilion River below Vermilion Crossing
Kootenay National Park

Haffner Creek near mouth at Hwy 93

Hawk Creek near mouth at Hwy 93

Vermilion River opposite
Hector Gorge picnic site

Kootenay River at Fort Steele

Duncan River below Duncan Dam 2400
feet above confluence with Lardeau River

Kootenay River at Creston Ferry

John Creek northwest of Marblehead

Goat River near junction with Kootenay
River

Summit Creek at north end of Nick's
Island near Leach Lake

Kootenay River at Summit Creek

Old Goat River Channel near Wyndell

Kootenay River east channel near
Wyndell

Elk River at Elko

Similkameen River at Hwy 3 Bridge
Princeton

Similkameen River at Hwy 3 Bridge
4 miles west of Hedley

Tulameen River at Route #5 bridge
Princeton

Okanagan River at No. 12 Road bridge
Oliver

Okanagan River at Road Bridge
Penticton

Kettle River at Cascade

Kettle River at Grand Forks

Buttle Lake near Outlet

Duck Lake at Drywash Creek

Duck Lake at pumping outlet

Kootenay Lake at Kuskonook

Okanagan Lake 1 mile north of
Penticton
