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Environmental Conservation
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ABSTRACT

Dioxins and furans were analysed in bed sediments and fish collected upstream and downstream of four non-chlorine bleaching pulp and/or paper mills and one petroleum refinery in inland British Columbia. Areas sampled were the Peace and Pine Rivers, Kitimat River and the lower Fraser River. The results showed that all bed sediment samples collected upstream of the mills and refinery were below the analytical detection limit for dioxins and furans. Most bed sediment samples collected downstream of the mills and refinery were also below the analytical detection limit. Exceptions were, one sample collected in the Kitimat River which had detectable levels of hexachlorodibenzodioxin and samples collected from the lower Fraser River which showed the presence of dioxins and furans, principally, octachlorodibenzodioxin.

The levels of dioxins and furans in all fish samples (composed of composites of muscle tissue) from the Peace, Pine and Kitimat Rivers were below the detection limit, with the exception of one sample. This sample, collected from the Kitimat River downstream of the pulp mill, had a detectable concentration of tetrachlorodibenzofuran (T4CDF). Fish samples collected from the lower Fraser River, upstream and downstream of the two pulp and/or paper mills, exhibited detectable levels of mainly T4CDF. The highest levels of T4CDF were measured in the northern squawfish (*Ptychocheilus oregonensis*) and peamouth chub (*Mylocheilus caurinus*) samples.

RÉSUMÉ

Des échantillons de matériau du lit et de poissons ont été prélevés en amont et en aval de quatre usines de pâtes et/ou de papier (n'utilisant pas le chlore pour le blanchiment) et d'une raffinerie de pétrole, toutes situées à l'intérieur de la Colombie-Britannique; ces échantillons ont été analysés pour les dioxines et les furannes. Les sites d'échantillonnage étaient situés dans les rivières de la Paix, Pine et Kitimat et dans le bas du fleuve Fraser. Tous les échantillons de matériau du lit prélevés en amont des usines et de la raffinerie ont donné des valeurs qui étaient sous les limites de détection pour les dioxines et les furannes. La plupart des échantillons de matériau du lit prélevés en aval ont montré les mêmes résultats, sauf un échantillon pour la rivière Kitimat qui contenait des niveaux détectables d'hexachlorodibenzodioxines et certains échantillons pour le bas-Fraser qui montraient la présence de dioxines et de furannes, surtout l'octachlorodibenzodioxine.

Pour tous les échantillons de poisson (en fait des échantillons composites de tissu musculaire prélevé chez plusieurs individus) provenant des rivières de la Paix, Pine et Kitimat, les niveaux de dioxines et de furannes étaient sous les limites de détection, sauf pour un échantillon. Cet échantillon, prélevé en aval de l'usine de pâte de Kitimat, a montré un niveau détectable de tétrachlorodibenzofurannes totaux (T4CDF). Certains échantillons de poissons prélevés dans le bas-Fraser, en amont comme en aval des deux usines de pâte et/ou de papier, ont montré des niveaux détectables de T4CDF. Les niveaux les plus élevés ont été mesurés chez la sauvagesse du nord (*Ptychocheilus oregonensis*) et le méné deux-barres (*Mylocheilus caurinus*).

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INTRODUCTION

In 1988, Environment Canada and the Department of Fisheries and Oceans began a program to sample for dioxins and furans in sediment and biota from the vicinity of pulp and paper mills in British Columbia (B.C.). The objectives of this program were to determine levels of dioxins and furans and to identify areas of concern.

Sampling conducted in 1988 by Environmental Conservation (formerly Inland Waters) of Environment Canada concentrated on areas in the vicinity of chlorine bleaching mills in inland B.C. The results of this sampling are reported in Mah et al. (1989). In general, fish had elevated levels of tetrachlorodibenzo-para-dioxin (T4CDD) and tetrachlorodibenzofuran (T4CDF). Sediments collected downstream of the mills had elevated levels of mainly T4CDF. Of the ten mills sampled, eight utilize the chlorine bleached kraft process and two use the thermo-mechanical process. The two thermo-mechanical mills were sampled because they were located close to a chlorine bleaching mill.

Similar sampling was conducted by Environmental Protection of Environment Canada and the Department of Fisheries and Oceans in the vicinity of coastal kraft pulp mills using chlorine bleaching. The results showed that certain fish, shellfish, bivalves and sediment (Harding and Pomeroy 1990) had elevated levels of dioxins and furans. A cross-Canada survey on dioxins and furans in sediment collected downstream of pulp mills using chlorine bleaching showed elevated concentrations of dioxins and furans in the sediments (Trudel 1991). Other studies have shown that dioxins and furans are associated with chlorine bleached pulp mill effluent (Amendola et al. 1987) and in environmental samples collected from the vicinity of chlorine bleaching pulp mills (Koistinen et al. 1990; Rappe et al. 1989).

Dioxin and furan contamination from non-chlorine bleaching mills

may occur through the use of chlorophenol contaminated woodchips (Elliot et al. 1989) and recycled paper (Beck et al. 1988). In addition, a Finnish study suggested that the chlorination of process water for disinfection and decolourising may be a source of dioxins and furans precursors in some non-chlorine bleaching mills (Kitunen and Salkinoja-Salonen 1990).

In 1988, Environmental Conservation completed its program to sample for dioxins and furans in fish and bed sediments from the vicinity of ten inland B.C. pulp and/or paper mills. This report presents the results of sampling in the vicinity of the four interior pulp and/or paper mills sampled in 1989.

Sampling was conducted near an unbleached kraft mill at Kitimat, a recycled paper converting mill at Burnaby, an unbleached groundwood pulp mill at New Westminster and a bleached chemical thermo-mechanical mill at Taylor. None of these four mills utilizes chlorine bleaching in their process.

Samples were also collected from the vicinity of the Petro-Canada Products petroleum refinery; due to its close proximity to the pulp mill at Taylor, and because dioxins and furans have been detected in petroleum refinery wastewater (MISA 1988).

METHODS

A detailed description of methods is given in Mah et al. (1989).

Sampling Locations and Timing

Bed sediments and fish were sampled in the vicinity of: Paperboard Industries Corporation, Scott Paper Limited, Eurocan Pulp and Paper Company, Fibreco Pulp Incorporated and the Petro-Canada Products petroleum refinery (Figure 1). At each site, samples were collected upstream and downstream of the discharges. The upstream samples were collected 30 to 160 km upstream of the effluent discharges in order to avoid contamination from other potential sources of dioxins and furans (for example, wood treatment facilities). Downstream sampling was conducted in areas considered most affected by effluent. Sites containing fine grain sediments were preferentially selected for sediment sampling. The exact locations of the bed sediment and fish sampling sites are shown in Figures 2 through 7.

Sampling commenced in August 1989 and continued to October 1989. At each site sediment and fish sampling was conducted at the same time.

Sediment Sampling

Three composite bed sediment samples were collected from upstream and downstream of the discharges. Composite bed sediment samples consisted of a minimum of three grabs of the Ekman or Ponar dredge. On two occasions, samples were collected using a stainless steel spoon or ladle. In all cases only the top 2-4 cm were used. Once collected, the samples were mixed well in a stainless steel bucket and subsamples were placed into labelled Teflon jars and frozen.

Figure 1. Locations of the Four Pulp and/or Paper Mills and One Petroleum Refinery Sampled.

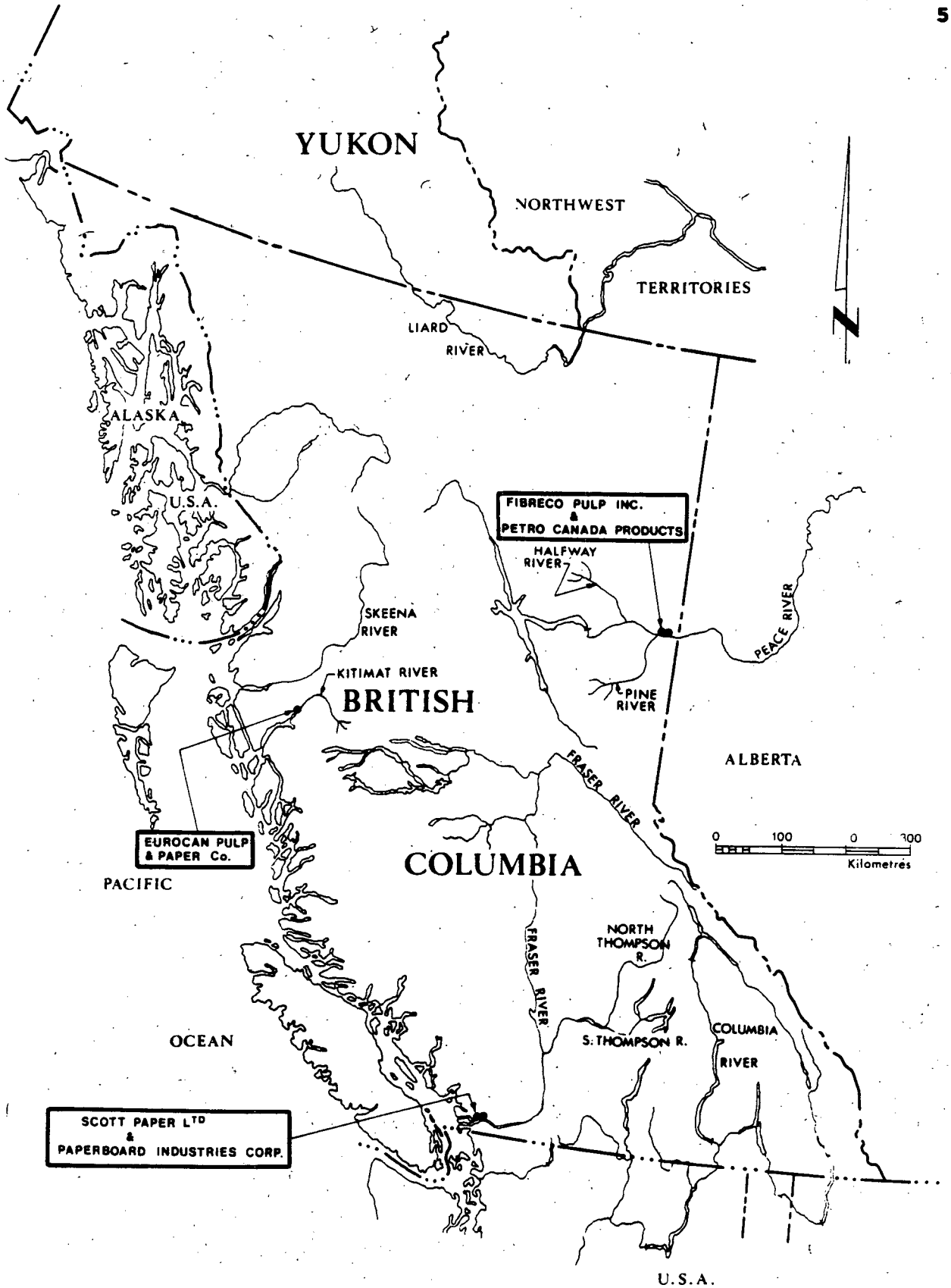

YUKON
NORTHWEST
TERRITORIES
LIARD
RIVER
ALASKA
U.S.A.
FIBRECO PULP INC.
&
PETRO CANADA PRODUCTS
HALFWAY
RIVER
SKEENA
RIVER
KITIMAT RIVER
BRITISH
PEACE RIVER
PINE
RIVER
ALBERTA
FRASER RIVER
EUROCAN PULP
& PAPER Co.
PACIFIC
COLUMBIA
0 100 0 100
Kilometres
NORTH
THOMPSON
R.
FRASER RIVER
OCEAN
S. THOMPSON R.
COLUMBIA
RIVER
SCOTT PAPER LTD
&
PAPERBOARD INDUSTRIES CORP.
U.S.A.

Figure 2. Locations of Areas Sampled in the Pine and Peace Rivers.
Details "A" and "B" are shown in Figure 3.
Details "C" and "D" are shown in Figure 4.

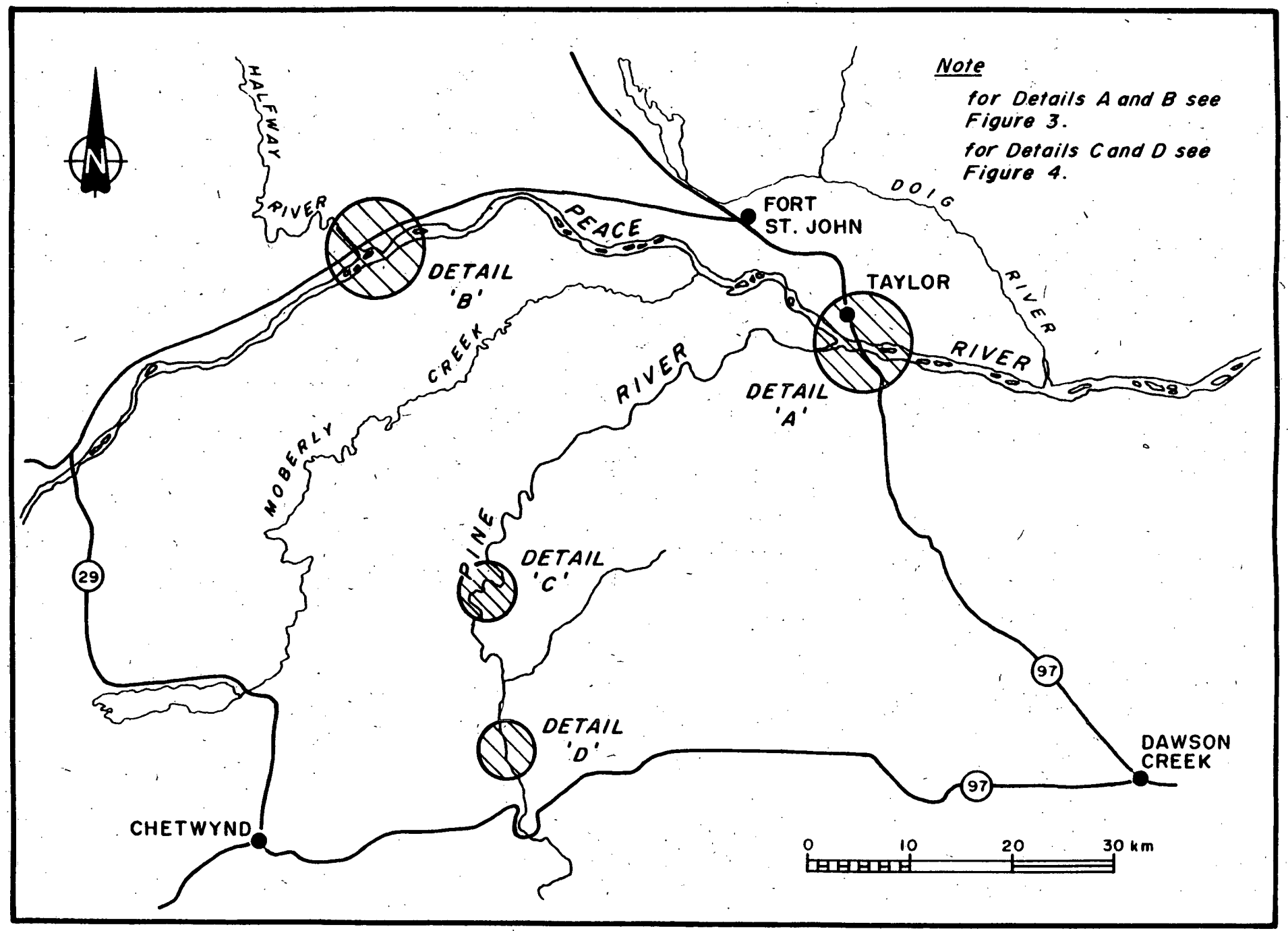

Note
for Details A and B see Figure 3.
for Details C and D see Figure 4.
N
HALFWAY RIVER
PEACE
FORT ST. JOHN
DOIG RIVER
DETAIL 'B'
TAYLOR
RIVER
CREEK
MOBERLY
RIVER
DETAIL 'A'
PINE
DETAIL 'C'
29
97
DETAIL 'D'
DAWSON CREEK
CHETWYND
0 10 20 30 km

Figure 3. Detail A: Locations of Fish and Sediment Sampling Sites near Fibreco Pulp Incorporated and Petro-Canada Products Limited.

Detail B: Locations of Fish and Sediment Sampling Sites Upstream on the Peace River.

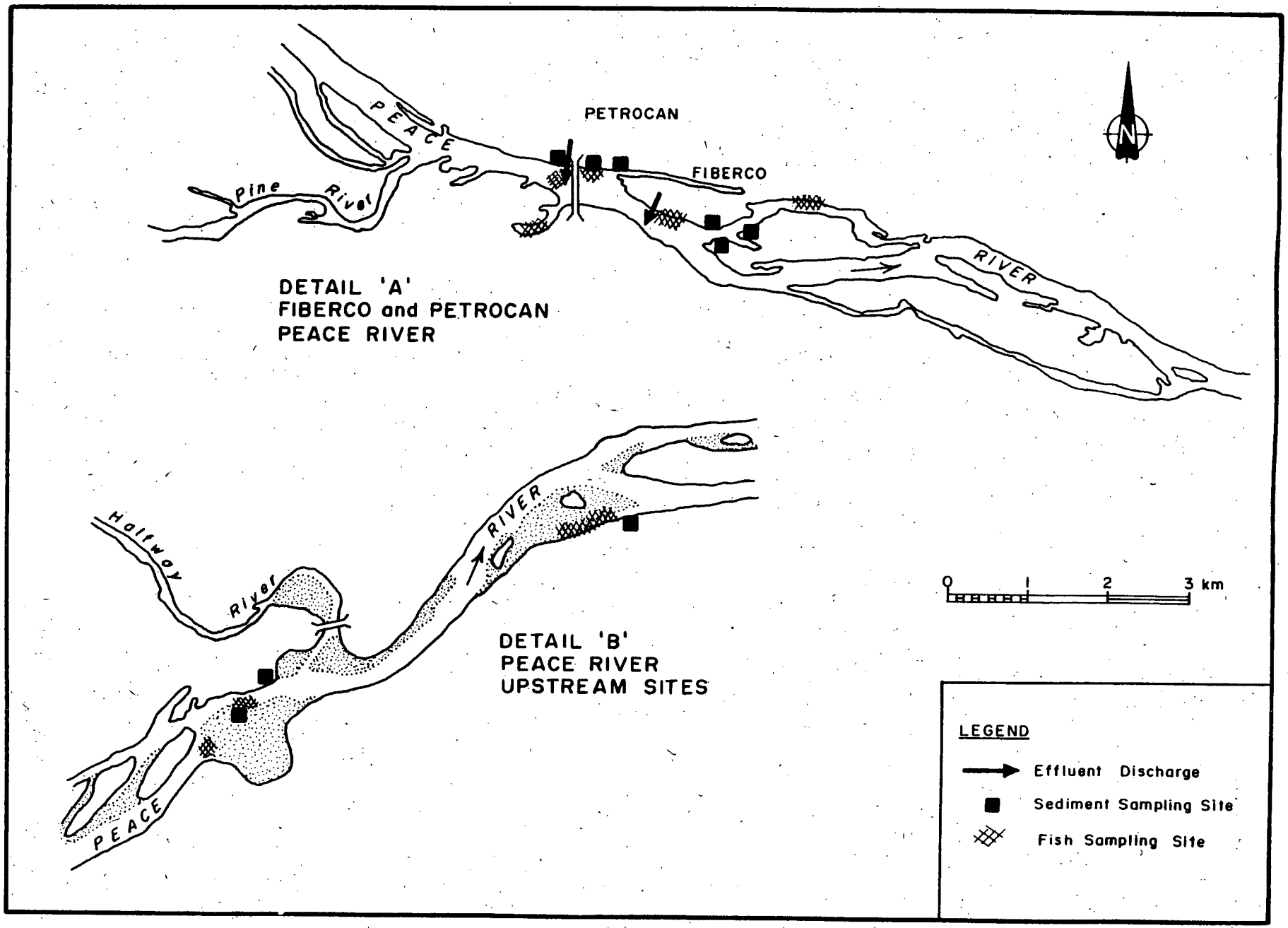

PETROCAN
FIBERCO
PEACE
Pine River
RIVER
DETAIL 'A'
FIBERCO and PETROCAN
PEACE RIVER
Halfway River
RIVER
PEACE
DETAIL 'B'
PEACE RIVER
UPSTREAM SITES
N
0 1 2 3 km
LEGEND
Effluent Discharge
Sediment Sampling Site
Fish Sampling Site

Figure 4. Detail C: Locations of Fish Sampling Sites on the Pine River near Graveyard Creek.

Detail D: Locations of Fish and Sediment Sampling Sites on the Pine River.

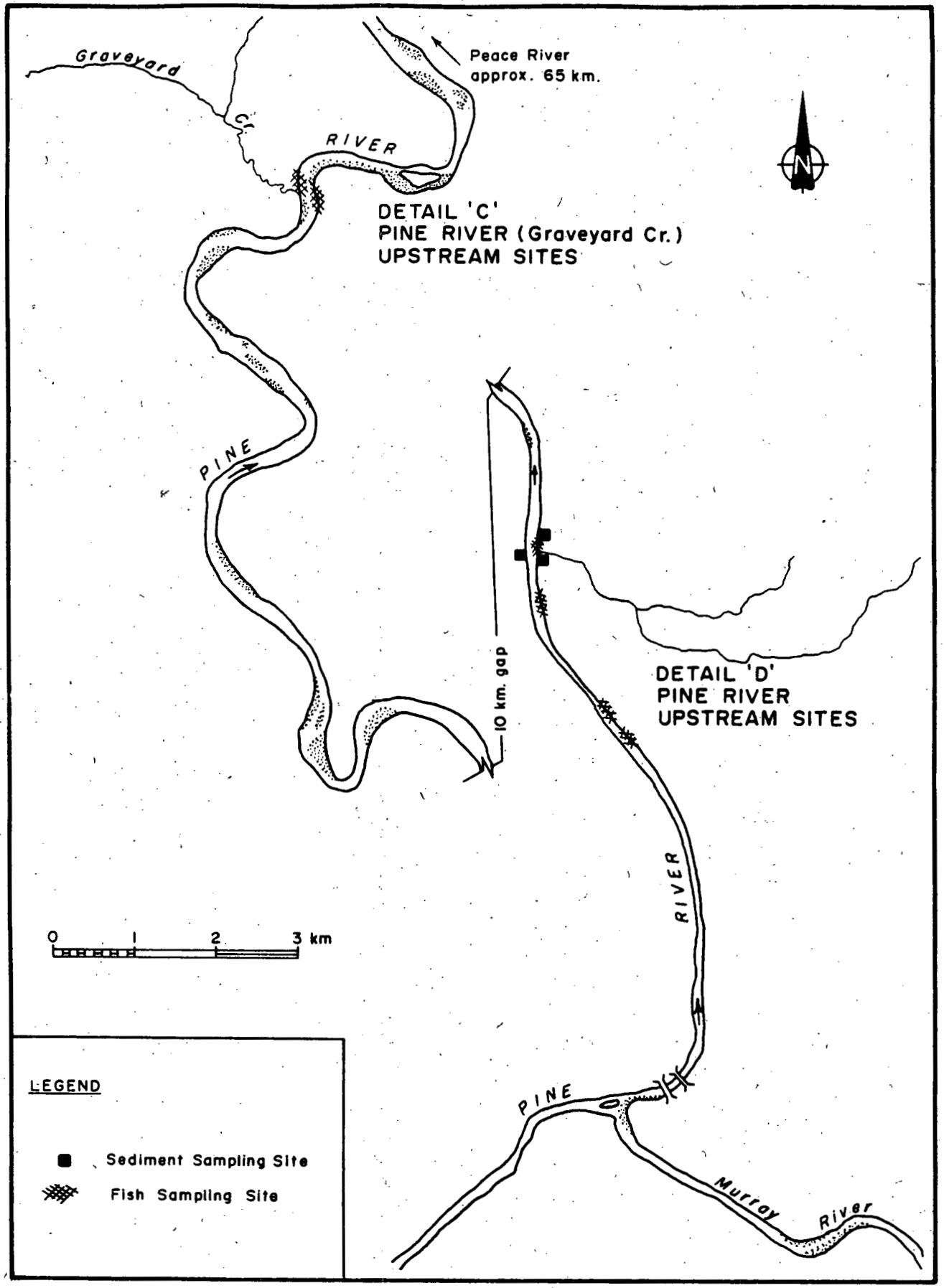

Graveyard Cr.
RIVER
Peace River
approx. 65 km.
N
DETAIL 'C'
PINE RIVER (Graveyard Cr.)
UPSTREAM SITES
PINE
10 km. gap
DETAIL 'D'
PINE RIVER
UPSTREAM SITES
RIVER
0 1 2 3 km
LEGEND
Sediment Sampling Site
Fish Sampling Site
PINE
Murray River

Figure 5. Locations of Fish and Sediment Sampling Sites in the Kitimat River Upstream and Downstream of Eurocan Pulp and Paper Company.

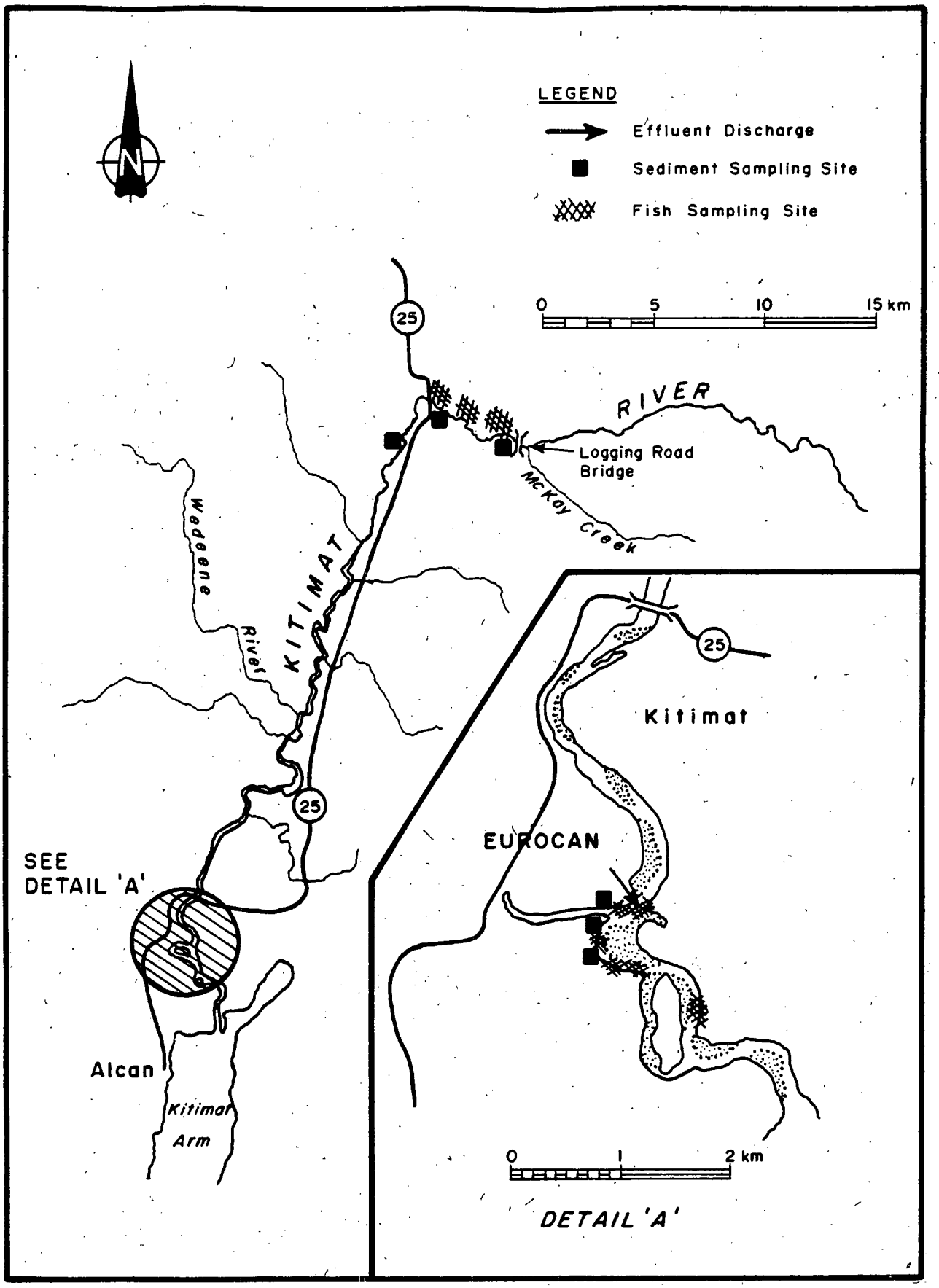

LEGEND
Effluent Discharge
Sediment Sampling Site
Fish Sampling Site
N
0 5 10 15 km
25
RIVER
Logging Road Bridge
McKay Creek
Wedgeene River
KITIMAT
SEE DETAIL 'A'
Alcan
Kitimat Arm
Kitimat
EUROCAN
0 1 2 km
DETAIL 'A'

Figure 6. Locations of Areas Sampled in the Lower Fraser River. Details "A" and "B" are shown in Figure 7.

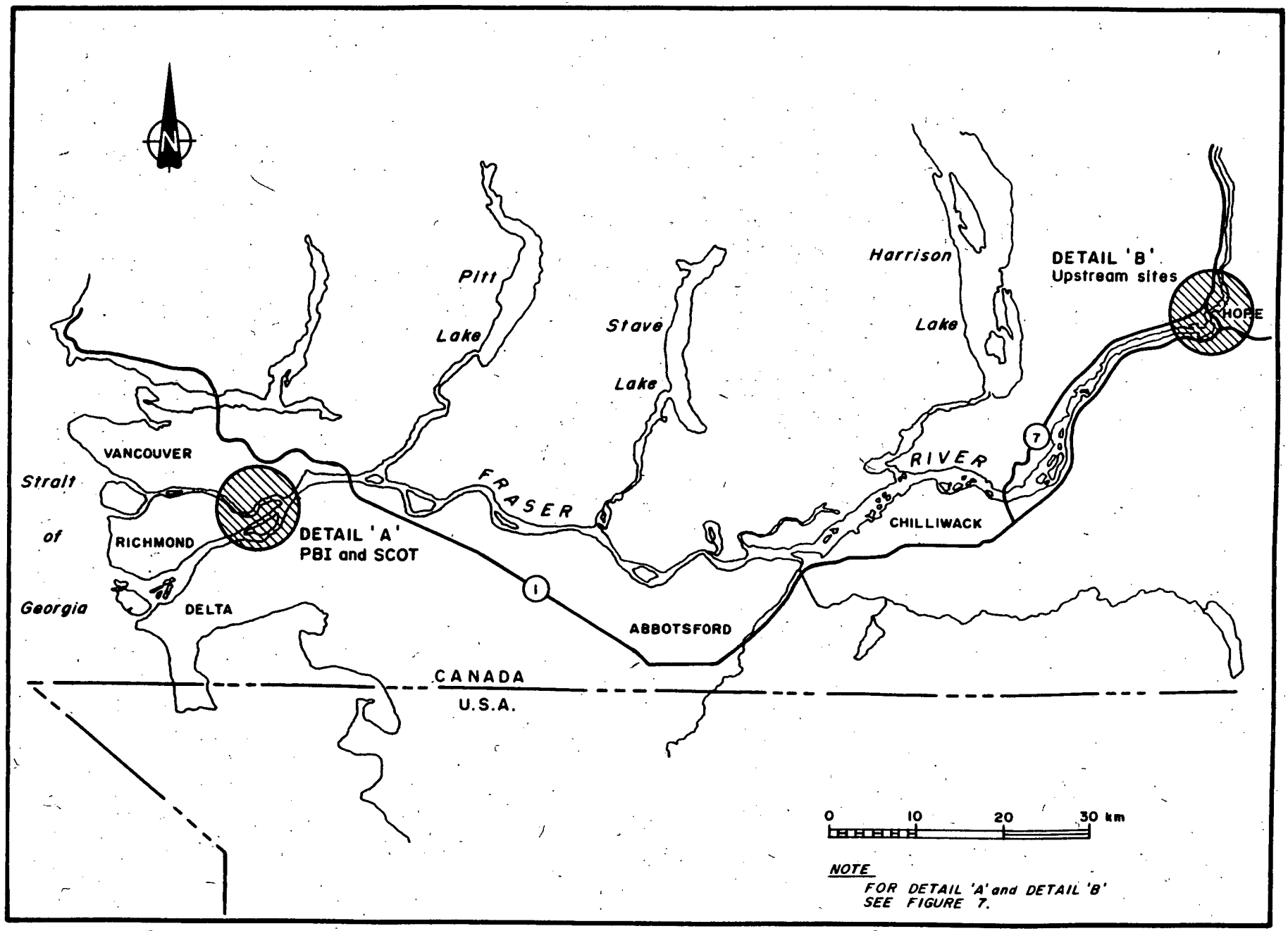
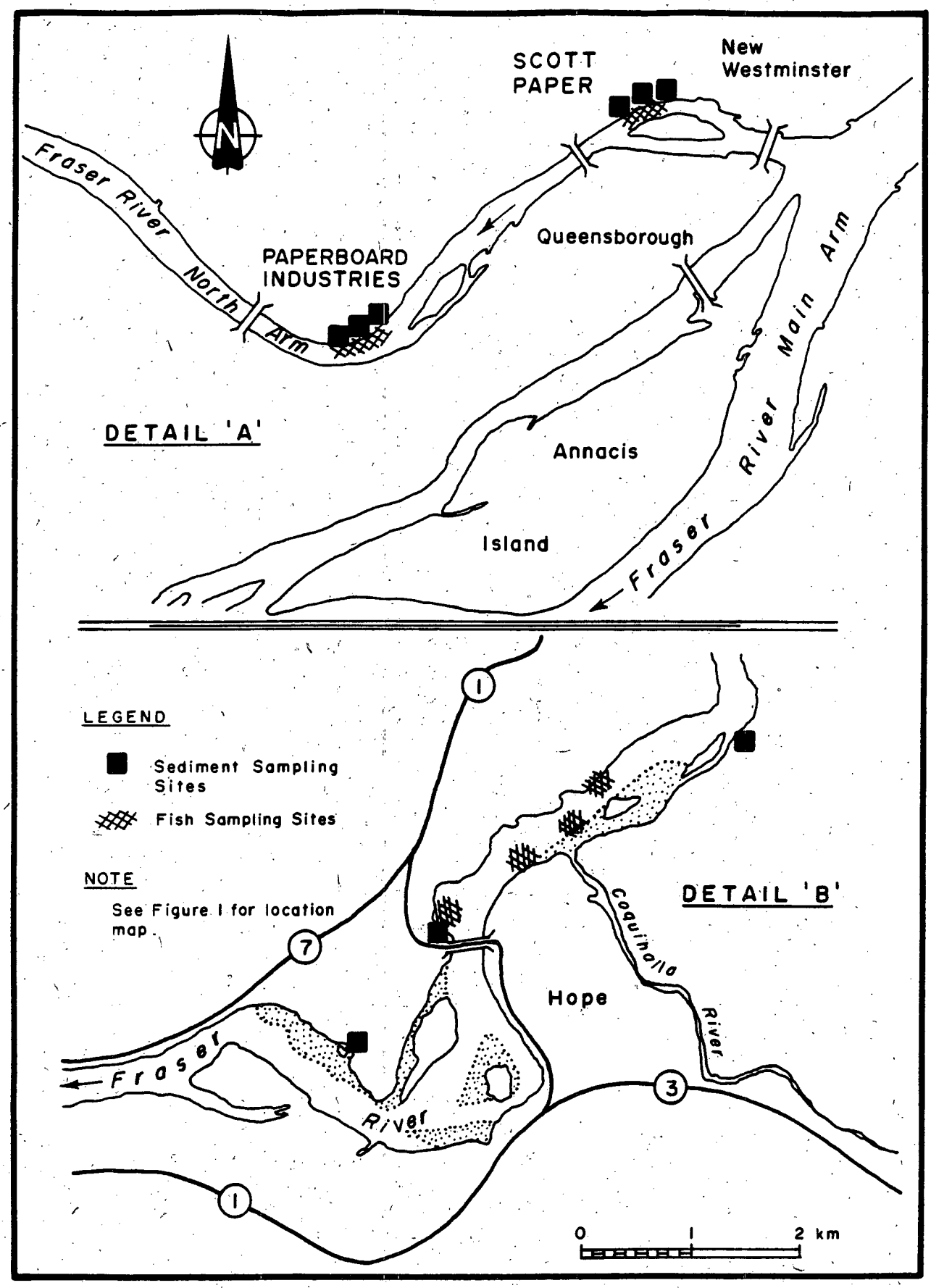

N
Pitt
Lake
Stave
Lake
Harrison
Lake
DETAIL 'B'
Upstream sites
HOPE
VANCOUVER
Strait
of
Georgia
RICHMOND
DETAIL 'A'
PBI and SCOT
DELTA
FRASER
RIVER
CHILLIWACK
ABBOTSFORD
CANADA
U.S.A.
7
1
0
10
20
30 km
NOTE
FOR DETAIL 'A' and DETAIL 'B'
SEE FIGURE 7.

Figure 7. Detail A: Locations of Fish and Sediment Sampling Sites near Paperboard Industries Corporation and Scott Paper Limited.

Detail B: Locations of Fish and Sediment Sampling Sites near Hope.


SCOTT PAPER
New Westminster
Fraser River North Arm
PAPERBOARD INDUSTRIES
Queensborough
DETAIL 'A'
Annacis Island
Fraser River Main Arm
LEGEND
Sediment Sampling Sites
Fish Sampling Sites
NOTE
See Figure 1 for location map.
DETAIL 'B'
Coquihalla River
Hope
Fraser River
1
7
3
0 1 2 km

Fish Sampling

Fish were collected using minnow traps, beach seines and sinking gill nets (mesh sizes from 3.8 cm to 11.4 cm). Captured fish were placed into stainless steel basins or buckets and kept cool until field processing. Field processing consisted of:

- identifying the species,
- recording the length,
- assigning labels,
- wrapping in oven baked aluminum foil,
- and freezing with dry ice.

Details of the fish sampling locations, dates and sampling methods are presented in Table 1.

Fish Preparation and Ageing

In the laboratory the fish were thawed, weighed and re-identified to confirm field identification. The fish were then skinned, and an equal amount of epaxial muscle tissue was removed from several fish of the same species to make one composite sample. Usually, the composite sample consisted of seven fish; however, this number varied from five to sixty. The tissue was then homogenized using a blender followed by a Polytron ultrasonic dispersator and mixed well. Subsamples were placed into labelled Teflon jars and frozen. For some samples, composite liver and kidney samples were similarly prepared for future analyses.

Otoliths, pectoral fins and pelvic fins were removed and retained from each fish for age determination. Scales were retained for ageing from some species. Fish age was determined by examining annuli present in the structures listed above. The analysis was conducted at the Fish Age Determination Unit, Department of

TABLE 1. LOCATIONS OF FISH SAMPLING SITES, SAMPLING DATES AND COLLECTION METHODS

SITE LOCATION	GENERAL LOCATION	SPECIFIC SITE	SAMPLING DATE	SAMPLING METHOD
Fibreco Pulp Inc. Upstream Peace River	Near Halfway River Confluence, 58 km upstream of Fibreco	Landslide site at right bank and at confluence of the Halfway and Peace Rivers	21/08/89	beach seine gill nets 6.3, 11.4 cm
		Behind the high water island, right bank, 6 km downstream of the Halfway River	22/08/89 23/08/89 27/08/89	beach seine gill nets 6.3, 11.4 cm
Fibreco Pulp Inc. Upstream Pine River	Pine River, 80 km upstream of Fibreco	Right bank, approximately 500 m downstream of proposed Louisiana Pacific discharge site	18/08/89	beach seine
		Right bank, approximately 1 km downstream of proposed Louisiana Pacific discharge site	18/08/89 19/08/89	beach seine gill nets 3.8, 6.3, 11.4 cm
		Right bank, across from proposed Louisiana Pacific discharge site	18/08/89 19/08/89	gill nets
		Left bank, 1 km downstream of proposed Louisiana Pacific discharge site	19/08/89	beach seine
	Pine River near mouth of Graveyard Creek, 54 km upstream of Fibreco	Left bank , 26 km downstream of Louisiana Pacific discharge site	20/08/89* 04/10/89*	gill nets 8.9 cm
		Right bank, 26 km downstream of Louisiana Pacific discharge site	04/10/89* 05/10/89* 07/10/89*	gill nets 8.9 cm

TABLE 1. LOCATIONS OF FISH SAMPLING SITES, SAMPLING DATES AND COLLECTION METHODS (Cont'd)

SITE LOCATION	GENERAL LOCATION	SPECIFIC SITE	SAMPLING DATE	SAMPLING METHOD
Petro–Canada Products Downstream	Peace River, at Taylor, 1 km upstream of Fibreco	Left bank, back eddy 3 m from Petrocan discharge	25/08/89 26/08/89	gill nets 11.4 cm
	"	Right bank, across Peace River from Petrocan discharge, mouth of side channel from Pine River	26/08/89	gill nets 6.3, 11.4 cm
	"	Left bank, 200 m downstream of Petrocan discharge	26/08/89	gill nets 6.3, 11.4 cm
Fibreco Pulp Inc. Downstream	Peace River near Taylor	Left bank, in backwater behind island, 3 km downstream of Fibreco discharge	24/08/89 25/08/89	gill nets 6.3, 11.4 cm
	"	10 m downstream of Fibreco discharge, toward left bank	25/08/89 26/08/89 27/08/89	gill nets 6.3, 11.4 cm
	"	Left bank, 800 m downstream from Fibreco discharge	25/08/89	beach seine
Eurocan Pulp & Paper Co. Upstream	Kitimat River, approximately 31 km upstream of Eurocan	Left bank in deep pools near Highway 25 bridge	07/09/89	minnow traps
	"	Right bank, near mouth of Chist Creek	08/09/89	minnow traps
	"	Right bank, just downstream of McKay Creek	09/09/89 to 14/09/89	minnow traps

TABLE 1. LOCATIONS OF FISH SAMPLING SITES, SAMPLING DATES AND COLLECTION METHODS (Cont'd)

SITE LOCATION	GENERAL LOCATION	SPECIFIC SITE	SAMPLING DATE	SAMPLING METHOD
Eurocan Pulp & Paper Co. Downstream	Kitimat River, near Eurocan Pulp Mill	Right and left banks, from 150 m to 2 km downstream of Eurocan discharge	07/09/89 to 14/09/89	minnow traps
	*	Directly in effluent on right bank, 1 to 3 m downstream of discharge	14/09/89	beach seine
Lower Fraser River Mills Upstream	Fraser River at Hope	Left bank, at mouth of Coquihalla River	12/10/89	gill nets 3.8, 6.3 cm
	*	Left bank, 500 m downstream of Coquihalla River	12/10/89	gill nets 3.8, 6.3 cm
	*	Right bank, 1.2 km downstream of Coquihalla River	12/10/89	gill nets 3.8, 6.3 cm
	*	Right bank, 600 m upstream of Coquihalla River	12/10/89	gill nets 3.8, 6.3 cm
Scott Paper Limited Downstream	North Arm of the Fraser River, New Westminster	Right bank, 50 to 100 m downstream of Scott Paper discharge	05/10/89 06/10/89	gill nets 3.8, 6.3, 11.4 cm
	*	Right bank, 3 m from the Scott Paper discharge	05/10/89	gill nets 3.8, 6.3, 11.4 cm
Paperboard Industries Corp. Downstream	North Arm of the Fraser River, near Burnaby Bend	Right bank, 20 to 300 m downstream of discharge	05/10/89 06/10/89 10/10/89	gill nets 3.8, 6.3 cm

* Collected by EVS Consultants

Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C.

Sediment Particle Size Distribution

The particle size distribution of sediment samples was determined by hydrometer, bottom withdrawal or sieve analysis methods using procedures described in Environment Canada (1988a).

Particulate Organic Carbon Determination

The procedure for determining particulate organic carbon was identical to NAQUADAT 06903 (Environment Canada 1979; 1988b) except that the dried, acid washed sediment was pressed into a capsule and no catalyst was added.

Lipids in Fish

The lipid content was determined by extracting the fish sample with 50% methylene chloride/hexane as described in Mah et al. (1989).

Determination of Dioxins and Furans

The analytic methods used for the determination of dioxins and furans in fish and sediment, as well as the quality assurance and quality control procedures, are presented in Mah et al. (1989).

RESULTS and DISCUSSION

Bed Sediment Results

Refer to Table 2 for the bed sediment sampling locations, sampling dates and particle size distributions. Table 3 presents concentrations of dioxins and furans, moisture content and organic carbon content.

Quality Assurance (QA) and Quality Control (QC)

As part of the QA/QC procedures, composite bed sediment samples from two different locations were split into three subsamples. Each subsample was assigned a unique label and submitted for analysis. The results of the bed sediment splits (Table 4) are similar since all results were below the detection limit. However, detection limits varied among splits. Laboratory analytical QA/QC procedures are those of Mah et al., (1989). The laboratory QA/QC results for dioxin analysis on bed sediments are presented in Table 5.

Pine and Peace River Bed Sediments

Bed sediments were collected from the Pine and Peace Rivers upstream and downstream of Fibreco Pulp Incorporated and the Petro-Canada Products refinery. No detectable residues of dioxins or furans were measured except for one Pine River sample (Pine-03). Initial analysis of the Pine-03 sample showed the presence of hexachlorodibenzodioxin (H6CDD), hexachlorodibenzofuran (H6CDF) and heptachlorodibenzofuran (H7CDF) residues. Since the Pine-03 sample was collected from an upstream location with no apparent source of dioxins or furans, a re-analysis of this sample was performed. The

TABLE 2. SPECIFIC SAMPLING LOCATIONS, SAMPLING DATES AND PARTICLE SIZES OF BED SEDIMENT SAMPLES

SAMPLE NO.	SITE LOCATION	SAMPLING LOCATION	SAMPLING DATE	PARTICLE SIZE *			
				% GRAVEL	% SAND	% SILT	% CLAY
PRUS–01	Fibreco Pulp Inc. Upstream Peace River	Peace River, just upstream of Halfway River Confluence, left bank	21/08/89	0.0	57.2	27.8	15.0
PRUS–02		Peace River, just upstream of Halfway River Confluence across river at landslide site, right bank	21/08/89	0.2	72.1	19.1	8.6
PRUS–03		Peace River, 6 km downstream of Halfway River, right side in backwater area	21/08/89	0.0	49.0	40.0	11.0
PINE–01	Fibreco Pulp Inc. Upstream Pine River	About 80 km upstream from Fibreco, right bank, approximately 1 km downstream of proposed Louisiana Pacific discharge	18/08/89	0.0	54.2	38.8	7.0
PINE–02		Pine River, left bank, approximately 1 km downstream of proposed Louisiana Pacific discharge	19/08/89	0.0	64.0	24.0	12.0
PINE–03		Pine River, right bank, approximately 1.1 km downstream of proposed Louisiana Pacific discharge	19/08/89	0.0	58.8	32.2	9.0
PETR–01	Petro–Canada Products Downstream	Peace River at Taylor, 10 m downstream of discharge, left side	24/08/89	0.0	35.7	53.8	10.5
PETR–02		Peace River at Taylor, 150 m downstream of discharge, just downstream of bridge, left bank	24/08/89	0.0	49.1	41.7	9.2
PETR–03		Peace River at Taylor, 600 m downstream of discharge, at tip of island	24/08/89	0.0	37.3	52.4	10.3

TABLE 2. SPECIFIC SAMPLING LOCATIONS, SAMPLING DATES AND PARTICLE SIZES OF BED SEDIMENT SAMPLES (Cont'd)

SAMPLE NO.	SITE LOCATION	SAMPLING LOCATION	SAMPLING DATE	PARTICLE SIZE *			
				% GRAVEL	% SAND	% SILT	% CLAY
FIBR–01	Fibreco Pulp Inc. Downstream	Peace River at Taylor, 650 m downstream of discharge	24/08/89	0.0	61.4	31.3	7.3
FIBR–02		Peace River at Taylor, 500 m downstream of discharge, left bank	24/08/89	0.0	23.6	61.9	14.5
FIBR–03		Peace River at Taylor, approximately 1 km downstream of discharge	24/08/89	0.0	12.9	71.6	15.5
KITU–01	Eurocan Pulp & Paper Co. Upstream	Kitimat River, 3.5 km downstream of Hwy 25 bridge (31 km upstream of Eurocan) in side channel by right bank	08/09/89	0.0	71.1	23.6	5.3
KITU–02		Kitimat River, just upstream of Hwy 25 bridge, left bank	08/09/89	0.2	55.9	36.9	7.0
KITU–03		Kitimat River, at logging road bridge, 4 km upstream of Hwy 25 bridge, left bank	08/09/89	0.2	84.3	11.3	4.2
EUR–01	Eurocan Pulp & Paper Co. Downstream	Kitimat River, right bank, 175 m downstream of discharge	09/09/89	0.0	63.6	31.1	5.3
EUR–02		Kitimat River, right bank, 750 m downstream of discharge	09/09/89	0.1	77.6	16.9	5.4
EUR–03		Kitimat River, right bank, 1 km downstream of discharge	09/09/89	0.0	25.4	62.6	12.0
HOPE–01	Lower Fraser River Mills Upstream	Fraser River, just upstream of Highway 1 bridge, behind rocks, in backwater by right bank	12/10/89	0.0	68.5	25.3	6.2

TABLE 2. SPECIFIC SAMPLING LOCATIONS, SAMPLING DATES AND PARTICLE SIZES OF BED SEDIMENT SAMPLES (Cont'd)

SAMPLE NO.	SITE LOCATION	SAMPLING LOCATION	SAMPLING DATE	PARTICLE SIZE *			
				% GRAVEL	% SAND	% SILT	% CLAY
HOPE–02		Fraser River, 2 km upstream of Coquihalla River confluence, left bank	12/10/89	0.0	58.5	34.9	6.6
HOPE–03		Fraser River, downstream of Croft Island (3 km downstream of Hwy 1 bridge), right bank	12/10/89	0.0	12.0	77.7	10.3
SCOT–01	Scott Paper Limited Downstream	Fraser River, near discharge, close to shore	06/10/89	3.6	59.4	30.8	6.2
SCOT–02		Fraser River, halfway between discharge pipe and edge of Scott property (about 80 m downstream of discharge)	06/10/89	0.0	46.0	43.8	10.2
SCOT–03		Fraser River, at downstream edge of Scott property by metal wall (about 200 m downstream of discharge)	06/10/89	1.8	54.9	36.5	6.8
PBI–01	Paperboard Industries Corp. Downstream	Fraser River, 60 m downstream of discharge, right bank	05/10/89	1.2	56.0	36.4	6.4
PBI–02		Fraser River, 200 m downstream of discharge, right bank	05/10/89	0.0	32.7	53.0	14.3
PBI–03		Fraser River, 300 m downstream of discharge, right bank	05/10/89	0.0	34.1	55.9	10.0

* particle size categories are defined as follows: gravel = 2–64 mm, sand = 0.062–2 mm, silt = 0.004–0.062 mm, clay = <0.004 mm

Table 3. DIOXIN AND FURAN RESIDUES, ORGANIC CARBON CONTENT AND MOISTURE CONTENT OF BED SEDIMENTS COLLECTED UPSTREAM AND DOWNSTREAM OF THE PULP MILLS AND PETROLEUM REFINERY

SAMPLE NUMBER	SAMPLING LOCATION	MOISTURE CONTENT (%)	ORGANIC CARBON (%)	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8 T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8 T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
PRUS-01	Fibreco Pulp Inc.	31	1.34	L4	L4	L24	L68	L88	L21	L4	L4	L24	L68	L88	L21
PRUS-02	Upstream Peace River	34	1.35	L2	L2	L61	L79	L63	L73	L2	L2	L61	L79	L63	L73
PRUS-03		46	1.18	L15	L15	L8	L40	L48	L52	L15	L15	L8	L40	L48	L52
PINE-01	Fibreco Pulp Inc.	32	1.08	L2	L2	L3	L6	L23	L24	L2	L2	L3	L6	L23	L24
PINE-02	Upstream Pine River	37	1.15	L9	L9	L4	L30	L18	L26	L9	L9	L4	L30	L18	L26
PINE-03		34	0.88	L40	L40	L190	L331	L150	L225	L40	L40	L190	L331	L150	L225
PETR-01	Petro-Canada Products	34	1.67	L20	L20	L75	L92	L75	L140	L20	L20	L75	L92	L75	L140
PETR-02	Downstream	32	1.26	L19	L19	L78	L62	L50	L131	L19	L19	L78	L62	L50	L131
PETR-03		48	2.43	L14	L14	L25	L40	L42	L51	L14	L14	L25	L40	L42	L51
FIBR-01	Fibreco Pulp Inc.	34	0.64	L12	L12	L38	L38	L19	L72	L12	L12	L38	L38	L19	L72
FIBR-02	Downstream	38	1.94	L7	L7	L42	L42	L20	L38	L7	L7	L42	L42	L20	L38
FIBR-03		41	1.92	L6	L6	L61	L55	L44	L51	L6	L6	L61	L55	L44	L51
KITU-01	Eurocan Pulp & Paper Co.	42	0.39	L4	L4	L2	L47	L18	L22	L4	L4	L2	L47	L18	L22
KITU-02	Upstream	50	0.60	L4	L4	L11	L16	L15	L35	L4	L4	L11	L16	L15	L35
KITU-03		29	0.22	L2	L2	L6	L11	L9	L10	L2	L2	L6	L11	L9	L10
EUR-01	Eurocan Pulp & Paper Co.	35	0.20	L2	L2	L3	L42	L26	L23	L2	L2	L3	L42	L26	L23
EUR-02	Downstream	32	0.24	L2	L2	L2	L60	L21	L20	L2	L2	L2	L60	L21	L20
EUR-03		68	1.71	L1	L1	L42	578**	L15	L17	L1	L1	L42	L68	L15	L17
HOPE-01	Lower Fraser River Mills	30	0.24	L44	L44	L100	L80	L50	L71	L44	L44	L100	L80	L50	L71
HOPE-02	Upstream	30	0.30	L23	L23	L100	L100	L100	L100	L23	L23	L100	L100	L100	L100
HOPE-03		30	0.64	L23	L23	L87	L100	L100	L70	L23	L23	L87	L100	L100	L70

Table 3. (Cont'd) DIOXIN AND FURAN RESIDUES, ORGANIC CARBON CONTENT AND MOISTURE CONTENT OF BED SEDIMENTS COLLECTED UPSTREAM AND DOWNSTREAM OF THE PULP MILLS AND PETROLEUM REFINERY

SAMPLE NUMBER	SAMPLING LOCATION	MOISTURE CONTENT (%)	ORGANIC CARBON (%)	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8 T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8 T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
SCOT-01	Scott Paper Limited	30	1.88	L13	L13	L21	110	L22	446	24	24	L21	(36)	L18	L22
SCOT-02	Downstream	30	1.57	L15	L15	L46	L58	L141	160	19	19	L46	L58	L141	L38
SCOT-03		30	1.51	L10	L10	L31	200	118	267	L10	L10	L31	L51	L110	L60
PBI-01	Paperboard Industries	30	0.61	L6	L6	L12	L16	L32	255	22	22	L12	L16	L32	L33
PBI-02	Corp. Downstream	30	1.02	L7	L7	L21	L52	L75	546	L7	L7	L21	L52	L75	L46
PBI-03		30	1.91	L19	L19	L46	L47	L9	386	L19	L19	L46	L47	L9	L10

L denotes less than specified detection limit.
* denotes no value was obtained.
** denotes the H6CDD concentration is the mean of two analyses (687 ppt and 470 ppt).
( ) denotes value was below method detection limit; however a peak was detected.

Table 4. QUALITY CONTROL RESULTS OF BED SEDIMENT SPLITS

SAMPLE NUMBER	SAMPLING LOCATION	MOISTURE CONTENT (%)	ORGANIC CARBON (%)	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8 T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8 T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
FIBR-02*	Fibreco Pulp Inc.	38	1.94	L7	L7	L42	L42	L20	L38	L7	L7	L42	L42	L20	L38
Split A	Downstream	38	N/A	L11	L11	L39	L60	L50	L145	L11	L11	L39	L60	L50	L145
Split B		39	N/A	L26	L26	L40	L21	L50	L26	L26	L26	L40	L21	L50	L26
EUR-01*	Eurocan Pulp & Paper Co.	35	0.20	L2	L2	L3	L42	L26	L23	L2	L2	L3	L42	L26	L23
Split A	Downstream	35	N/A	L14	L14	L37	L62	L50	L83	L14	L14	L37	L62	L50	L83
Split B		35	N/A	L10	L10	L40	L62	L50	L70	L10	L10	L40	L62	L50	L70

L denotes less than specified detection limit.
* denotes samples reported in Table 3
N/A denotes analysis was not done.

Table 5. ANALYTICAL QUALITY CONTROL RESULTS FOR DIOXIN ANALYSES ON BED SEDIMENTS, EXPRESSED AS PERCENT RECOVERY

SAMPLE NUMBER	SITE LOCATION	SURROGATE SPIKE					PERFORMANCE STANDARD
		Total C13T4CDD	Total C13P5CDD	Total C13H6CDD	Total C13H7CDD	Total C13O8CDD	
PRUS–01	Fibreco Pulp Inc.	118	110	108	98	91	145
PRUS–02	Upstream Peace River	114	130	109	99	95	94
PRUS–03		108	132	133	89	87	115
PINE–01	Fibreco Pulp Inc.	48	96	86	49	49	93
PINE–02	Upstream Pine River	94	102	113	96	98	98
PINE–03		50	85	74	74	111	100
FIBR–01	Fibreco Pulp Inc.	72	112	119	105	98	120
FIBR–02	Downstream	213	153	124	100	95	171
Split A (FIBR–02)		75	64	46	115	112	100
Split B (FIBR–02)		79	82	62	161	79	100
FIBR–03		65	141	125	112	98	102
PETR–01	Petro–Canada Products	74	58	54	71	62	100
PETR–02	Downstream	106	82	83	101	106	100
PETR–03		58	68	69	65	58	100
KITU–01	Eurocan Pulp & Paper Co.	73	74	76	61	55	148
KITU–02	Upstream	100	91	77	92	100	133
KITU–03		74	118	53	111	110	92

Table 5. (Cont'd) ANALYTICAL QUALITY CONTROL RESULTS FOR DIOXIN ANALYSES ON BED SEDIMENTS, EXPRESSED AS PERCENT RECOVERY

SAMPLE NUMBER	SITE LOCATION	SURROGATE SPIKE Total C13T4CDD	Total C13P5CDD	Total C13H6CDD	Total C13H7CDD	Total C13O8CDD	PERFORMANCE STANDARD
EUR–01	Eurocan Pulp & Paper Co. Downstream	90	72	67	67	76	112
Split A (EUR–01)		84	77	67	99	113	100
Split B (EUR–01)		62	58	45	86	80	100
EUR–02		135	91	75	57	69	98
EUR–03		112	100	88	75	88	112
HOPE–01	Lower Fraser River Mills Upstream	62	59	73	140	118	100
HOPE–02		66	59	110	86	122	100
HOPE–03		75	74	37	66	33	100
SCOT–01	Scott Paper Limited Downstream	60	85	71	74	48	100
SCOT–02		59	56	47	50	41	100
SCOT–03		77	98	102	107	94	95
PBI–01	Paperboard Industries Corp. Downstream	66	100	99	96	60	100
PBI–02		95	88	60	62	35	100
PBI–03		88	87	81	62	86	100

second analysis of a field split showed no detectable residues of dioxins or furans; however the detection limits were high. These differing results may be due in part to difficulties in obtaining a completely homogeneous sample for analysis. Further sampling is required to fully characterize the Pine River sediment. Appendix A, Table A-1 presents the results of the original analysis on these samples.

Kitimat River Bed Sediment

The bed sediments collected from the Kitimat River upstream of Eurocan Pulp and Paper Company had no detectable residues of dioxins or furans. One sample (EUR-03) collected downstream of Eurocan Pulp and Paper Company had a H6CDD concentration of 687 pg/g (parts per trillion or ppt). To confirm this result the sample was re-analysed. The second analysis showed a concentration of 470 ppt H6CDD; the mean of these two results is 578 ppt. Similar concentrations of H6CDD were found in marine bed sediment samples collected from Kitimat Arm in 1990 (Goyette and Boyd 1991). Goyette and Boyd measured H6CDD concentrations in bed sediments ranging from below detection to 982 pg/g. These authors also detected concentrations of heptachlorodibenzodioxin (H7CDD) and octachlorodibenzodioxin (O8CDD) in these marine sediments.

The EUR-03 sample contained higher silt-clay content (30% higher) and organic carbon content (two times higher) than the other Kitimat River samples. Dioxins and furans have low solubility in water and high affinity to soil particles with high organic carbon content (Palausky et al. 1986; Arthur and Frea 1989). In the EUR-03 sample, the presence of H6CDD may have been detected because of the higher organic carbon content.

A potential source of H6CDD in non-chlorine bleaching pulp mills is the use of chlorophenol contaminated wood chips. The production of

chlorophenols is known to produce trace amounts of chlorinated dioxins including H6CDD (Hagenmaier and Brunner 1987). In British Columbia chlorophenols have been used for preserving wood and wood products for export. The Eurocan Pulp and Paper Company plant site includes a former woodmill. Until 1977, this woodmill operated a drive-through chlorophenol dip tank for anti-sapstain treatment (S. Liu, pers. comm.). As noted by Kitunen et al. (1987), the historical use of chlorophenols (and chlorophenol contaminated wood chips) may be one source of H6CDD.

Lower Fraser River Bed Sediment

Initial analyses of bed sediment samples collected upstream of the lower Fraser River mills showed no detectable residues of dioxins or furans (Appendix A, Table A). These samples were re-analysed since detection limits in the initial analyses were high. Re-analysis showed similar results - no dioxins or furans were detected but the detection limits were high (Table 3). The high detection limits may have been the result of sample matrix interference. Samples with excessive co-extractives require extensive clean-up prior to analysis. In some samples the clean-up procedure may not remove the interference thus resulting in higher detection limits. One possible source of interference may have been organic matter originating from decaying salmon that were present at the upstream site during sampling. As a result, the Hope bed sediment samples likely contained sufficient quantities of organic matter (decaying salmon) to produce the interference during analysis.

Bed sediment samples collected downstream of the lower Fraser River mills contained detectable residues of dioxins and furans. The levels of 2,3,7,8-T4CDF measured downstream of Scott Paper Limited, New Westminster (19 to 24 ppt) are similar to the level (22 ppt) measured in one sample downstream of Paperboard Industries

Corporation, Burnaby. Note that these 2,3,7,8-T4CDF levels are lower than the 2,3,7,8-T4CDF detection limits for the upstream (Hope) samples.

Similar levels of 2,3,7,8-T4CDF (5.8 to 26 ppt) were measured in lower Fraser River bed sediments collected in 1990 by Swain and Walton (1991). Their samples were collected in the vicinity of Paperboard Industries Corporation and at the mouth of the Main Arm of the Fraser River. Mah et al. (1989) measured 2,3,7,8-T4CDF in bed sediments sampled from the vicinity of six pulp mills located at least 240 km upstream of Hope in the Fraser River basin. Five of the upstream mills use the chlorine bleached kraft process. Amendola et al. (1987) state that the 2,3,7,8-T4CDD and 2,3,7,8-T4CDF isomers are the principal isomers found in chlorine-bleached pulp mill matrices.

Mah et al. (1989) measured 2,3,7,8-T4CDF in one "upstream" site. This site was located on the Fraser River upstream of pulp mills located in Quesnel but 135 km downstream of three chlorine bleaching kraft mills situated in Prince George. Their results indicate that pulp mills located upstream on the Fraser River may produce detectable residues of 2,3,7,8-T4CDF considerable distances downstream.

All six bed sediment samples collected in the vicinity of Scott Paper Limited and Paperboard Industries Corporation had measureable levels of O8CDD. Two of the six samples also had measureable residues of H6CDD and one sample contained a third isomer, H7CDD. Similar results were found by Swain and Walton (1991). They detected all five congeners of dioxin in bed sediments collected from the lower Fraser River; but the H6CDD, H7CDD and O8CDD congeners predominated.

Levels of O8CDD measured in **suspended** sediments collected from the lower Fraser River in March 1989 (Environment Canada, 1989

unpublished data) are similar to the levels measured in bed sediments in the present study. The results of the dioxin and furan analyses (Table B-1) and analytical quality control (Table B-2) on these suspended sediment samples are presented in Appendix B. Two 24 hour suspended sediment samples were collected using a Westfalia continuous flow centrifuge. Both samples were collected from the Main Arm of the lower Fraser River. The first sample (STEV-100), collected near the George Massey Tunnel (Appendix B, Figure B-1), had an O8CDD concentration of 370 ppt while the second sample (ANN-200), collected just downstream of Annacis Island (Appendix B, Figure B-1), had an O8CDD concentration of 329 ppt.

In our study, these highly chlorinated congeners of dioxin were not detected in Fraser River bed sediment samples collected upstream at Hope; nor were they detected by Mah et al. (1989) in their Fraser River Basin samples collected at least 240 km upstream of Hope. The lower Fraser River has various potential sources of the higher chlorinated dioxin congeners. Previous studies (Czuczwa and Hites 1984; Czuczwa and Hites 1986) have shown that the primary sources of O8CDD to the environment include: municipal incinerator emissions, industrial incinerator emissions and pentachlorophenol. Czuczwa and Hites (1986) found that O8CDD predominated in air-particulate and sediment samples. Based on their historical use, Elliot et al. (1989) attribute chlorophenols as the most important potential source of dioxins to the British Columbia environment. Tetra- and pentachlorophenols have been used by the British Columbia wood industry for the prevention of sapstain fungus. Hagenmaier and Brunner (1987) found commercial pentachlorophenol and pentachlorophenate to contain measureable levels of all dioxin and furan isomers, but the octa-, hepta- and hexa- isomers predominated. Considerable chlorophenol contamination of stormwater run-off to the lower Fraser River has occurred from the stacking of chlorophenol treated lumber in large outdoor storage sites (Krahn et al. 1987).

Fish Tissue Results

A detailed description of fish samples used for dioxin and furan analyses is presented in Table 6. The results of fish tissue analyses for dioxins and furans are presented in Table 7.

Quality Assurance (QA) and Quality Control (QC)

As part of the QA/QC procedures composite fish tissue samples from two different locations were split into three subsamples. Each subsample was assigned a unique label and submitted for analysis. The results of the fish tissue splits (Table 8) indicate a high level of reproducibility, with a coefficient of variation of 7.5% for the one furan isomer that was detected. Laboratory analytical QA/QC procedures are those of Mah et al. (1989). The laboratory QA/QC results for dioxin analysis on fish tissues are presented in Table 9.

Pine and Peace River Fish

Fish were collected from the Pine and Peace Rivers upstream and downstream of Fibreco Pulp Incorporated and the Petro-Canada Products refinery. These fish samples showed no detectable residues of dioxins or furans.

Kitimat River Fish

Fish collected from the Kitimat River upstream of Eurocan Pulp and Paper Company showed no detectable residues of dioxins or furans. One sample (Dolly Varden, *Salvelinus malma*), collected downstream of the mill, had a detectable concentration of 2,3,7,8-T4CDF and total T4CDF (24 ppt). Similar concentrations of 2,3,7,8-T4CDF (14

Table 6. DESCRIPTIONS OF FISH SAMPLES USED FOR DIOXINS AND FURANS ANALYSES

SITE LOCATION	SAMPLING DATE	FISH SPECIES	NO. OF FISH IN COMPOSITE	MEDIAN FORK LENGTH (Range) mm	MEDIAN WEIGHT (Range) g	MEDIAN AGE (Range) years
Fibreco Pulp Inc. Upstream Peace River	21/08/89	*Prosopium williamsoni* (mountain whitefish)	12	172.0 (167–183)	60.2 (52.2–73.9)	1 (1)
	23/08/89 27/08/89	*Catostomus catostomus* (longnose sucker)	7	444.0 (406–473)	1220.6 (767.1–1388.9)	20 (12–24)
	23/08/89 27/08/89	*Esox lucius* (northern pike)	6	608.5 (486–754)	1992.3 (884.0–3198.0)	5.5 (2–9)
Fibreco Pulp Inc. Upstream Pine River	18/08/89 19/08/89	*Catostomus catostomus* (longnose sucker)	7	272.0 (255–385)	238.1 (171.4–609.4)	7 (6–15)
	04/10/89 05/10/89 07/10/89	*Prosopium williamsoni* (mountain whitefish)	7	372.0 (354–428)	666.9 (563.8–979.2)	11 (5–16)
	18/08/89 20/08/89 04/10/89	*Stizostedion vitreum* (walleye)	5	465.0 (399–494)	1169.7 (887.5–1565.2)	11 (7–28)
Petro–Canada Products Downstream	25/08/89 26/08/89	*Stizostedion vitreum* (walleye)	7	435.0 (315–504)	860.4 (358.8–1553.2)	9 (3–21)
Fibreco Pulp Inc. Downstream	25/08/89 to 27/08/89	*Catostomus catostomus* (longnose sucker)	7	412.0 (374–462)	839.6 (668.3–1310.3)	16 (8–21)
	24/08/89 to 27/08/89	*Catostomus macrocheilus* (largescale sucker)	6	473.5 (400–556)	1326.3 (1111.9–2226.0)	16 (10–28)
	25/08/89 26/08/89	*Exos lucius* (northern pike)	8	471.5 (440–498)	771.5 (723.8–960.0)	3.5 (2–8)
Eurocan Pulp & Paper Co. Upstream	07/09/89 to 14/09/89	*Oncorhynchus mykiss* (rainbow trout)	9	200.0 (175–205)	91.1 (65.1–102.0)	2 (2)
		Cottus aleuticus (coast range sculpin)	60	103.5 * (100–125)	15.1 (10.1–25.4)	9.5 ^ (5–23)
		Salvelinus malma (dolly varden)	10	187.0 (157–250)	79.0 (45.8–193.4)	2 (2–4)
Eurocan Pulp & Paper Co. Downstream	14/09/89	*Oncorhynchus mykiss* (rainbow trout)	10	178.0 (140–300)	70.5 (36.1–280.0)	2 (1–4)
	11/09/89 to 14/09/89	*Cottus asper* (prickly sculpin)	26	160.5 * (150–187)	54.9 (43.0–92.0)	5.5 ^ (4–13)
	13/09/89 14/09/89	*Salvelinus malma* (dolly varden)	5	229.0 (184–260)	169.0 (89.3–231.1)	3 (3–4)

Table 6. (Cont'd) DESCRIPTIONS OF FISH SAMPLES USED FOR DIOXINS AND FURANS ANALYSES

SITE LOCATION	SAMPLING DATE	FISH SPECIES	NO. OF FISH IN COMPOSITE	MEDIAN FORK LENGTH (Range) mm	MEDIAN WEIGHT (Range) g	MEDIAN AGE (Range) years
Lower Fraser River Mills Upstream	12/08/89	*Mylocheilus caurinus* (peamouth chub)	7	264.0 (252–280)	256.7 (224.6–294.4)	11 (7–17)
		Catostomus macrocheilus (largescale sucker)	7	301.0 (287–335)	291.9 (253.5–426.8)	4 (4–5)
		Ptychocheilus oregonensis (northern squawfish)	7	270.0 (260–310)	228.9 (202.1–334.9)	9 (8–12)
Scott Paper Limited Downstream	05/10/89 06/10/89	*Ptychocheilus oregonensis* (northern squawfish)	7	307.0 (299–329)	357.9 (304.1–481.9)	9 (7–19)
	06/10/89	*Mylocheilus caurinus* (peamouth chub)	9	189.0 (154–209)	69.6 (42.5–93.6)	3 (2–8)
	05/10/89	*Catostomus macrocheilus* (largescale sucker)	7	291.0 (273–326)	281.0 (236.2–395.7)	3 (3–4)
Paperboard Industries Corp. Downstream	06/10/89 10/10/89	*Ptychocheilus oregonensis* (northern squawfish)	7	309.0 (268–319)	346.9 (243.0–428.4)	9 (8–11)
	05/10/89 06/10/89 10/10/89	*Mylocheilus caurinus* (peamouth chub)	16	193.0 (180–208)	82.2 (64.6–106.0)	4 (2–6)
	06/10/89 10/10/89	*Catostomus macrocheilus* (largescale sucker)	7	294.0 (276–307)	308.8 (245.5–338.7)	4 (3–7)
	06/10/89	*Acipenser transmontanus* (white sturgeon)	6	341.5 (296–498)	270.1 (166.0–850.0)	3 (3–4)

* refers to total length rather than fork length.
^ denotes only 12 fish were used for aging purposes.

Table 7. DIOXIN AND FURAN RESIDUES, LIPID CONTENT AND MOISTURE CONTENT OF MUSCLE TISSUE FROM FISH COLLECTED UPSTREAM AND DOWNSTREAM OF THE PULP MILLS AND PETROLEUM REFINERY

SITE LOCATION	FISH SPECIES	LIPID CONTENT (%_wet_wt.)_)	MOISTURE CONTENT (%)	DIOXIN CONCENTRATION (pg/g wet wt.) 2,3,7,8 T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g wet wt.) 2,3,7,8 T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
Fibreco Pulp Inc. Upstream Peace River	*Catostomus catostomus* (longnose sucker)	4.4	79	L3	L3	L10	L16	L19	L15	L3	L3	L10	L16	L19	L15
	Esox lucius (northern pike)	2.1	78	L3	L3	L21	L30	L30	L19	L3	L3	L21	L30	L30	L19
	Prosopium williamsoni (mountain whitefish)	8.4	73	L6	L6	L33	L49	L30	L55	L6	L6	L33	L49	L30	L55
Fibreco Pulp Inc. Upstream Pine River	*Catostomus catostomus* (longnose sucker)	2.5	81	L3	L3	L9	L16	L10	L12	L3	L3	L9	L16	L10	L12
	Prosopium williamsoni (mountain whitefish)	7.3	76	L4	L4	L15	L7	L30	L11	L4	L4	L15	L7	L30	L11
	Stizostedion vitreum (walleye)	3.1	79	L2	L2	L10	L11	L10	L15	L2	L2	L10	L11	L10	L15
Fibreco Pulp Inc. Downstream	*Catostomus catostomus* (longnose sucker)	6.4	78	L10	L10	L25	L8	L10	L23	L10	L10	L25	L8	L10	L23
	Catostomus macrocheilus (largescale sucker)	5.1	78	L10	L10	L10	L15	L10	L14	L10	L10	L10	L15	L10	L14
	Esox lucius (northern pike)	2.1	75	L4	L4	L12	L16	L10	L15	L4	L4	L12	L16	L10	L15
Petro-Canada Products Downstream	*Stizostedion vitreum* (walleye)	3.4	80	L3	L3	L12	L5	L10	L15	L3	L3	L12	L5	L10	L15
Eurocan Pulp and Paper Co. Upstream	*Oncorhynchus mykiss* (rainbow trout)	5.3	75	L2	L2	L10	L5	L10	L15	L2	L2	L10	L5	L10	L15
	Salvelinus malma (dolly varden)	7.6	74	L4	L4	L12	L6	L10	L15	L4	L4	L12	L6	L10	L15
	Cottus aleuticus (coast range sculpin)	4.2	N/A	L6	L6	L18	L22	L30	L22	L6	L6	L18	L22	L30	L22
Eurocan Pulp and Paper Co. Downstream	*Oncorhynchus mykiss* (rainbow trout)	6.8	75	L4	L4	L22	L11	L10	L15	L4	L4	L22	L11	L10	L15
	Salvelinus malma (dolly varden)	7.6	73	L4	L4	L11	L33	L33	L34	24	24	L11	L33	L33	L34
	Cottus asper (prickly sculpin)	3.0	78	L8	L8	L31	L47	L30	L28	L8	L8	L31	L47	L30	L28

Table 7. (Cont'd)

DIOXIN AND FURAN RESIDUES, LIPID CONTENT AND MOISTURE CONTENT OF MUSCLE TISSUE FROM FISH COLLECTED UPSTREAM AND DOWNSTREAM OF THE PULP MILLS AND PETROLEUM REFINERY

SITE LOCATION	FISH SPECIES	LIPID CONTENT (%_wet_wt.)_)	MOISTURE CONTENT (%)	DIOXIN CONCENTRATION (pg/g wet wt.) 2,3,7,8 T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g wet wt.) 2,3,7,8 T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
Lower Fraser River Mills Upstream	*Mylocheilus caurinus* (peamouth chub)	6.0	73	0.83	0.83	L3	L4	L5	L10	15.4	15.4	L3	L4	L5	L10
	Catostomus macrocheilus (largescale sucker)	4.0	80	L2	L2	L3	L4	L5	L10	3.8	3.8	L3	L4	L5	L10
	Ptychocheilus oregonensis (northern squawfish)	4.0	79	L1	L1	L3	L4	L7	L6	15	15	L3	L4	L7	L6
Scott Paper Limited Downstream	*Mylocheilus caurinus* (peamouth chub)	3.6	78	L2	L2	L3	L4	L5	L10	10.3	10.3	L3	L4	L5	L10
	Catostomus macrocheilus (largescale sucker)	3.8	79	L1	L1	L2	L3	L4	L5	L1	L1	L2	L3	L4	L5
	Ptychocheilus oregonensis (northern squawfish)	4.1	78	L2	L2	L4	L5	L10	L10	44	44	L4	L5	L10	L10
Paperboard Industries Corp. Downstream	*Mylocheilus caurinus* (peamouth chub)	3.4	79	L2	L2	L3	L4	L10	L10	19	24	L3	L4	L10	L10
	Catostomus macrocheilus (largescale sucker)	3.2	80	L2	L2	L3	L4	L5	L15	L2	L2	L3	L4	L5	L15
	Ptychocheilus oregonensis (northern squawfish)	4.2	78	L1	L1	L2	L3	L5	L10	12	12	L2	L3	L5	L10
	Acipenser transmontanus (white sturgeon)	1.8	83	L2	L2	L11	L5	L5	L16	L2	L2	L11	L5	L5	L16

L denotes less than specified limit
* denotes no value obtained
N/A denotes results were not available.

Table 8. QUALITY CONTROL RESULTS OF FISH TISSUE SPLITS

SITE LOCATION	FISH SPECIES	LIPID CONTENT (%_wet_wt.)	MOISTURE CONTENT (%)	DIOXIN CONCENTRATION (pg/g wet wt.) 2,3,7,8 T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g wet wt.) 2,3,7,8 T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
Fibreco Pulp Inc. Downstream	*Esox lucius** (northern pike)	2.1	75	L4	L4	L12	L16	L10	L15	L4	L4	L12	L16	L10	L15
	Split A	1.3	78	L7	L7	L20	L20	L25	L33	L7	L7	L20	L20	L25	L33
	Split B	1.4	78	L5	L5	L27	L27	L30	L32	L5	L5	L27	L27	L30	L32
Scott Paper Limited Downstream	*Ptychocheilus oregonensis** (northern squawfish)	4.1	78	L2	L2	L4	L5	L10	L10	44	44	L4	L5	L10	L10
	Split A	3.4	77	L10	L10	L53	L49	L30	L46	40	40	L53	L49	L30	L46
	Split B	3.6	78	L6	L6	L25	L22	L30	L18	38	38	L25	L22	L30	L18

L denotes less than specified detection limit.
* denotes samples reported in Table 7.

Table 9. ANALYTICAL QUALITY CONTROL RESULTS FOR DIOXIN ANALYSES ON FISH MUSCLE TISSUE, EXPRESSED AS PERCENT RECOVERY

SITE LOCATION	FISH SPECIES	SURROGATE SPIKE					PERFOMANCE STANDARD
		Total C13T4CDD	Total C13P5CDD	Total C13H6CDD	Total C13H7CDD	Total C13O8CDD	
Fibreco Pulp Inc. Upstream Peace River	*Catostomus catostomus* (longnose sucker)	93	86	60	68	58	100
	Esox lucius (northern pike)	62	70	30	100	85	100
	Prosopium williamsoni (mountain whitefish)	93	118	93	124	110	100
Fibreco Pulp Inc. Upstream Pine River	*Catostomus catostomus* (longnose sucker)	94	92	91	67	73	100
	Prosopium williamsoni (mountain whitefish)	76	71	31	61	62	100
	Stizostedion vitreum (walleye)	62	71	67	75	72	100
Fibreco Pulp Inc. Downstream	*Catostomus catostomus* (longnose sucker)	55	81	43	62	62	100
	Catostomus macrocheilus (largescale sucker)	65	135	169	118	142	100
	Esox lucius (northern pike)	64	71	65	49	67	100
	Split A	84	72	75	95	67	100
	Split B	62	72	75	104	98	100
Petro-Canada Products Downstream	*Stizostedion vitreum* (walleye)	104	104	79	79	70	100
Eurocan Pulp and Paper Co. Upstream	*Oncorhynchus mykiss* (rainbow trout)	42	52	51	53	55	100
	Salvelinus malma (dolly varden)	66	88	90	109	117	100
	Cottus aleuticus (coast range sculpin)	95	107	63	81	70	100

Table 9. ANALYTICAL QUALITY CONTROL RESULTS FOR DIOXIN ANALYSES ON FISH MUSCLE TISSUE, EXPRESSED AS PERCENT RECOVERY (Cont'd)

SITE LOCATION	FISH SPECIES	SURROGATE SPIKE Total C13T4CDD	Total C13P5CDD	Total C13H6CDD	Total C13H7CDD	Total C13O8CDD	PERFOMANCE STANDARD
Eurocan Pulp and Paper Co. Downstream	*Oncorhychus mykiss* (rainbow trout)	83	134	103	140	131	100
	Salvelinus malma (dolly varden)	92	109	67	94	92	100
	Cottus asper (prickly sculpin)	93	117	83	80	57	100
Lower Fraser River Mills Upstream	*Mylocheilus caurinus* (peamouth chub)	104	128	126	112	104	100
	Catostomus macrocheilus (largescale sucker)	127	141	137	116	124	100
	Ptychocheilus oregonensis (northern squawfish)	106	113	112	102	100	68
Scott Paper Limited Downstream	*Mylocheilus caurinus* (peamouth chub)	100	117	112	97	78	50
	Catostomus macrocheilus (largescale sucker)	109	117	109	110	98	100
	Ptychocheilus oregonensis (northern squawfish)	74	93	83	79	71	100
	Split A	93	94	99	96	73	100
	Split B	80	72	64	107	72	100
Paperboard Industries Corp. Downstream	*Mylocheilus caurinus* (peamouth chub)	91	116	109	91	96	100
	Catostomus macrocheilus (largescale sucker)	105	126	135	127	120	100
	Ptychocheilus oregonensis (northern squawfish)	102	122	117	104	88	100
	Acipenser transmontanus (white sturgeon)	85	66	55	61	57	100

ppt to 19 ppt) were found in the hepatopancreas of dungeness crab (*Cancer magister*) collected from Kitimat Arm by the Department of Fisheries and Oceans (Government of Canada, 1990; Harding and Pomeroy 1990). These hepatopancreas samples also had measureable concentrations of other dioxin and furan congeners. Migration studies on Dolly Varden have shown that the habitat of three to four year old fish (the age of fish used in this study) is the stream in which they were spawned (Scott and Crossman 1973). The adults (three to six years old) of anadromous populations move seaward in late May and early June, remaining short distances from the stream mouth, then move back into the streams usually in mid-July to September (Smith and Slaney 1980). The Dolly Varden collected for this study may have spent time in Kitimat Arm.

Lower Fraser River Fish

The levels of 2,3,7,8-T4CDF and total T4CDF measured in fish collected upstream and downstream of the lower Fraser River mills were similar. The dioxin, 2,3,7,8-T4CDD, was detected in only one sample, a peamouth chub (*Mylocheilus caurinus*) sample collected at the upstream site. These two isomers were the principal forms of dioxins and furans measured in fish collected by Mah et al. (1989) from the upper and mid-Fraser River in 1988. It should be noted that fish collected upstream of a given location may have previously resided downstream of that location, and vice versa.

In the lower Fraser River fish, the peamouth chub and northern squawfish (*Ptychocheilus oregonensis*) samples had higher levels of T4CDF, (24 ppt and 44 ppt, respectively) than the largescale sucker (*Catostomus macrocheilus*) samples (below the detection limit to 3.8 ppt). With the small sample sizes, it is difficult to comment on species-concentrations relationships. The results of this study are consistent with those observed in Mah et al. (1989). Higher levels of furans were measured in fish, like northern squawfish and

peamouth chub, that generally occupy the higher trophic levels.

Health and Welfare Evaluation of the Fish Data

Health and Welfare Canada assessed the data on dioxins and furans in fish collected in 1989 from the Peace, Pine, Kitimat, and Fraser Rivers. The assessments, as reported in Government of Canada press releases, concluded that the levels did not pose a health risk and consumption restrictions were not necessary (Government of Canada, 1990 and 1991).

CONCLUSIONS

1) No dioxins or furans were measured in bed sediments or fish collected from the Pine and Peace Rivers, or upstream of Eurocan Pulp and Paper Company in the Kitimat River. No dioxins or furans were detected in bed sediments collected near Hope, the upstream site for the lower Fraser River mills.

2) H6CDD was detected in one bed sediment sample collected from the Kitimat River downstream of Eurocan Pulp and Paper Company. Bed sediments collected from the lower Fraser River had measureable levels of dioxins and furans. The source of these dioxins and furans is unknown. The samples collected from the vicinity of Scott Paper Limited had detectable concentrations of H6CDD, H7CDD, O8CDD and 2,3,7,8-T4CDF; whereas the samples collected from the vicinity of Paperboard Industries Corporation had detectable levels of 2,3,7,8-T4CDF and O8CDD.

3) One Dolly Varden (*Salvelinus malma*) sample collected from the Kitimat River downstream of Eurocan Pulp and Paper had a measureable concentration of 2,3,7,8-T4CDF. Northern squawfish and peamouth chub samples (*Ptychocheilus oregonensis* and *Mylocheilus caurinus*, respectively) collected from the lower Fraser River at the upstream Hope site and in the vicinity of Scott Paper Limited and Paperboard Industries Corporation also had measureable levels of 2,3,7,8-T4CDF. One peamouth chub sample collected near Hope, upstream of the lower Fraser River mills, had a detectable concentration of 2,3,7,8-T4CDD.

4) The Health and Welfare Canada assessment of the data on dioxins and furans in fish concluded that the levels did not pose a health risk and consumption restrictions were not necessary.

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APPENDIX A

Initial Dioxin and Furan Results for Re-analysed Bed Sediment Samples

Appendix A Table A–1. INITIAL DIOXIN AND FURAN RESULTS FOR BED SEDIMENTS THAT WERE RE–ANALYSED

SAMPLE NUMBER	MOISTURE CONTENT (%)	ORGANIC CARBON (%)	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8 T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8 T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
PINE–03	34	0.88	L5	L5	L6	158	L130	L77	L5	L5	L6	342	696	L77
HOPE–01	30	0.24	L20	L20	L137	L233	L80	L60	L20	L20	L137	L233	L80	L60
HOPE–02	30	0.30	L15	L15	L100	L143	L41	L75	L15	L15	L100	L143	L41	L75
HOPE–03	30	0.64	L15	L15	L160	L500	L100	L75	L15	L15	L160	L500	L100	L75

L denotes less than specified detection limit.

APPENDIX B

Suspended Sediment Sampling in the lower Fraser River, March 1989

Appendix B Table B–1. DIOXIN AND FURAN RESIDUES AND ORGANIC CARBON CONTENT OF SUSPENDED SEDIMENTS COLLECTED FROM THE LOWER FRASER RIVER

SAMPLE NUMBER	SAMPLING LOCATION	SAMPLING DATE	ORGANIC CARBON (%)	DIOXIN CONCENTRATION (pg/g dry wt.) 2,3,7,8 T4CDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	FURAN CONCENTRATION (pg/g dry wt.) 2,3,7,8 T4CDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF
STEV–100	Richmond	20/03/89	2.91	L23	L23	L10	L30	L36	370	L23	L23	L10	(28)	L36	L22
ANN–200	Delta	21/03/89	2.51	L7	L7	L8	L12	L24	329	L7	L7	L8	14	L24	L84

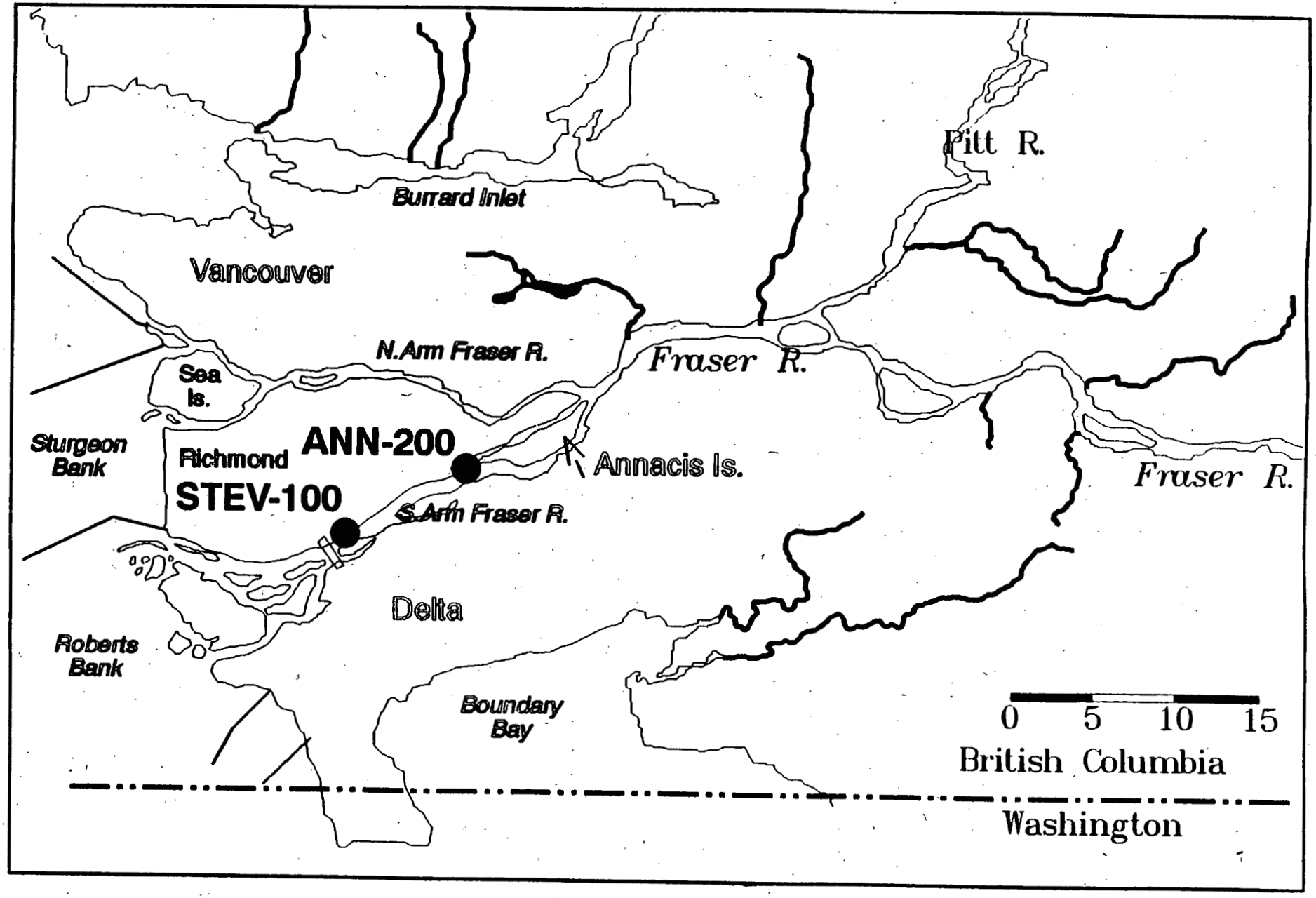
Note: Approximate volume of water centrifuged per sample was 8300 litres.
L denotes less than specified detection limit.
( ) denotes value was below method detection limit; however a peak was detected.

Appendix B Table B–2. ANALYTICAL QUALITY CONTROL RESULTS FOR DIOXIN ANALYSES ON SUSPENDED SEDIMENTS, EXPRESSED AS PERCENT RECOVERY

SAMPLE NUMBER	SITE LOCATION	SURROGATE SPIKE					PERFORMANCE STANDARD
		Total C13T4CDD	Total C13P5CDD	Total C13H6CDD	Total C13H7CDD	Total C13O8CDD	
STEV–100	Richmond	63	86	98	60	57	126
ANN–200	Delta	96	136	148	110	76	100

Appendix B

Figure B-1. Locations of Suspended Sediment Sampling Sites in the lower Fraser River.


Pitt R.
Burrard Inlet
Vancouver
N.Arm Fraser R.
Fraser R.
Sea Is.
Sturgeon Bank
Richmond
ANN-200
STEV-100
Annacis Is.
S.Arm Fraser R.
Fraser R.
Delta
Roberts Bank
Boundary Bay
0 5 10 15
British Columbia
Washington