

**AN INITIAL DILUTION ZONE (IDZ)
IMPACT ASSESSMENT
OF SELECTED INDUSTRIES
IN THE FRASER RIVER ESTUARY**

**TECHNICAL REPORT SERIES
FREMP WQWM-93-06
DOE FRAP 1993-14**

**Fraser River Estuary Management Program
Suite 301 - 960 Quayside Drive
New Westminster, B.C.
V3M 6G2**

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**Prepared for FREMP
Water Quality/Waste Management Committee**

by

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INITIAL DILUTION ZONE IMPACT ASSESSMENT

PREFACE

The Fraser River Estuary Management Program (FREMP) is a cooperative program linking federal and provincial government agencies, port authorities, regional districts, municipalities and First Nations. The program provides a vehicle for coordinating decision-making on environmental conservation, and development in the estuary. The six funding partners to FREMP are: Environment Canada, Fisheries and Oceans Canada, the Greater Vancouver Regional District, the BC Ministry of Environment, Lands, and Parks, the Fraser River Harbour Commission, and the North Fraser River Harbour Commission.

The present study was coordinated through the Water Quality/Waste Management Committee of FREMP, and represents one in the series of reports published as part of the WQWM Technical Report Series by this Committee.

Funding for this project was provided by Environment Canada through the Fraser River Action Plan. One component of the Fraser River Action Plan is pollution abatement. This project contributed to an understanding of how current discharges affect the environment of the Fraser River estuary, and provided information to assist in setting priorities for abatement actions. The views expressed herein are those of the authors, and do not necessarily state or reflect the policies of Environment Canada.

EXECUTIVE SUMMARY

The initial dilution zone (IDZ) monitoring program is a study to document impacts of wastewater discharges on the receiving environment of the Lower Fraser River in the immediate vicinity of selected effluent discharges. An IDZ, as defined by the British Columbia Ministry of Environment, Lands, and Parks Water Quality Objectives for the lower Fraser River (Swain and Holms 1985), is the area between 100 m upstream and 100 m downstream of an outfall. The IDZ study formed part of the first year of the Fraser River Estuary Monitoring Program (FREMP) Environmental Monitoring Program.

The study consisted of sampling receiving water and sediments within the IDZs of ten industries which were also sampled as part of FREMP's effluent characterization study (FREMP 1993). The industries involved were LaFarge Canada, Tilbury Cement, International Forest Products (IFP) Port Hammond, IFP Fraser Mills, Scott Paper, MacMillan Bloedel (New Westminster), Tree Island Industries, Domtar, Fraser Wharves, and Westshore Terminals. Hilinex Packaging was not included in the IDZ study because it does not discharge directly to the Fraser River. A reference site was established near the FREMP water quality monitoring station at Mission.

Receiving water samples were collected at a distance of <25 m from the most significant outfall discharging directly to the Fraser River at each site. Field measurements included general physico-chemical parameters (pH, temperature, dissolved oxygen, salinity). Approximate dilutions were determined using clusters of drogues released at each outfall. Water samples were returned to the laboratory and tested for chronic toxicity using *Ceriodaphnia dubia*.

Sediment samples were collected at three locations for each discharge at approximately 100 m upstream, and 25 m and 100 m downstream of each outfall. The sediment samples were analyzed for physico-chemical parameters and toxicity. All samples were analyzed for particle size, total organic carbon, and total metals. Sediments from sites related to the forest industry (the two IFP sites, Scott Paper, MacMillan Bloedel, and Domtar) were analyzed for chlorophenols. In addition, polycyclic aromatic hydrocarbons (PAHs) were measured in samples from Domtar and Westshore Terminals. All sediments were tested for acute toxicity using the solid phase Microtox test, and for sublethal effects using *Macoma balthica*.

Effluent dilutions at the edge of the IDZ were calculated based on the drogue data. In addition to the dilution indicated by the movement of drogue clusters, some dilution is achieved at the outfall due to the jetting and buoyancy rise of the effluent. This "outfall dilution" was assumed to equal 3:1 (an average dilution for a submerged outfall) for all the industries except Scott Paper. Because of the high discharge rate of Scott Paper, the

outfall dilution was assumed to be 2:1. The total dilution at 100 m from the point of discharge for each industry (taking into account both outfall dilution and drogue movement) ranged from 4.3:1 for Scott Paper to 588:1 for Domtar.

The sediment chemistry analyses showed that concentrations of metals at the test sites were generally similar to, or lower than, levels measured at other sites within the Fraser Estuary during the past four years. Overall, sediments near the industrial sites did not contain higher levels of metals than the reference sediments from Mission or the Fraser Port/BC Environment routine monitoring site at Barnston Island. However, when the ten industrial sites plus the reference site were compared, some effects of specific industries were apparent. The highest concentrations of lead, zinc, and manganese occurred in the sediments near Tree Island Industries. Studies conducted between the late 1970s and the mid-1980s indicated that historically this metal finishing plant discharged elevated levels of lead and zinc. The highest concentrations of aluminum, iron, copper, and nickel were found in sediment samples from the LaFarge IDZ. A 1987 effluent characterization study noted elevated levels of aluminum in the effluent from this cement plant, and historically the plant contributed loadings of iron and copper.

Pentachlorophenol was detectable in each of the three sediment samples from IFP Port Hammond, IFP Fraser Mills, and Domtar. It was not detectable in the reference sediments or in any of the samples from Scott Paper and MacMillan Bloedel. The concentration of pentachlorophenol in two of the three samples from Port Hammond and Fraser Mills exceeded the 0.010 µg/g Water Quality Objective for total chlorophenols in Fraser River sediments. However, in general the pentachlorophenol levels were lower than concentrations measured at many sites in the Fraser Estuary over the past decade.

Some PAHs were detectable at each of the three sites where these compounds were measured, but the levels at Mission were substantially lower than levels at the two industrial sites (Domtar and Westshore Terminals). The distribution of individual PAHs differed between the Domtar and Westshore Terminals sites. The concentrations of acenaphthene, benzo(a)anthracene, benzo(a)pyrene, fluoranthene and pyrene were higher near Domtar, while concentrations of anthracene, fluorene, naphthalene, and phenanthrene were higher at Westshore Terminals. Overall, the concentrations of low molecular weight PAHs were higher at Westshore Terminals, while the concentrations of high molecular weight PAHs and total PAHs were higher at Domtar. The concentrations of all PAHs except acenaphthene, anthracene, benzo(a)anthracene and chrysene at Domtar and Roberts Bank were similar to or lower than levels reported at other sites in the Fraser Estuary in recent studies. The concentrations of all PAHs except acenaphthene in a single sample from Domtar met the Water Quality Objectives set for sediments in Burrard Inlet (but not officially applicable to the Fraser Estuary).

The only receiving water sample that showed toxicity to *Ceriodaphnia dubia* was the sample from the Scott Paper IDZ. In this sample, a reduced number of young were produced, with the lowest observable effect occurring at a concentration of 25% (that is,

the initial receiving water diluted to 25%). A factor contributing to the toxicity was likely that the available dilution at the Scott Paper outfall was the lowest of all the sites tested, based on the estimated volume of the discharge.

Sediments from three of the sites sampled were acutely toxic to luminescent bacteria. The solid phase Microtox test indicated that, on average, sediments from the Scott Paper, LaFarge Canada, and Fraser Wharves sites significantly depressed bacterial light output as compared with the reference sediments. Fraser Wharves had the most toxic sediments of the three sites. The reason for the sediment toxicity at these sites was not apparent from the sediment chemistry results.

Only one of the sediment samples tested demonstrated sublethal toxicity to *Macoma balthica*. This single sample was of sediment collected 100 m upstream of the Scott Paper discharge in the North Arm. This area of the river is also subject to input from two combined sewer overflows (2505) in addition to receiving effluent from Scott Paper. Therefore, a more intensive sampling program than the one conducted here is required to confirm the significance of this result, and to determine the exact causes of the sediment toxicity observed.

The study concluded that there were some site specific industrial impacts including elevated levels of metals, pentachlorophenol (PCP), and polycyclic aromatic hydrocarbons (PAH) in sediments. Chronic toxicity of the receiving water was measured at one site, and sediment toxicity was detected at three sites. Additional studies are required to confirm the significance of these results with respect to the overall health of the Fraser Estuary and to identify the causes of the toxicity observed.

On the basis of the results of this study, the following recommendations are made:

that information from wastewater/effluent characterization programs being conducted in the estuary be used to design future IDZ studies for specific industries;

that a suite of standard bioassay tests be developed for use in the estuary that can routinely be used to monitor toxicity of effluents, receiving water, and sediments;

that future receiving water toxicity tests be based on 100% concentration only to demonstrate the presence or absence of toxicity in the receiving water;

that appropriate reference sites for river water and sediment be assigned to act as "control" sites for the different toxicity bioassays to be performed; and

that a separate research program be conducted that involves comparative testing with *Macoma balthica*, *Chironomus tentans*, a marine amphipod, or other appropriate test organisms to determine the most appropriate invertebrate species

for monitoring toxicity of Fraser Estuary sediments.

TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	2
TABLE OF CONTENTS	5
LIST OF TABLES	6
LIST OF FIGURES	7
LIST OF APPENDICES	8
ACKNOWLEDGEMENTS	8
INTRODUCTION	1
1.1 Background	1
1.2 Study Objectives	2
METHODS	4
2.1 Sample Sites	4
2.2 Field Methods	13
2.2.1 Effluent Location and Dilution	13
2.2.2 Water Sampling	17
2.2.3 Sediment Sampling	17
2.3 Toxicity Testing Methods	20
2.3.1 Water Test - <i>Ceriodaphnia dubia</i>	20
2.3.2 Toxicity Testing of Sediments	21
2.4 Sediment Chemistry Analyses	22
RESULTS AND DISCUSSION	23
3.1 Effluent Dilutions	23
3.2 Water Chemistry and Toxicity	25
3.3 Sediment Chemistry	29
3.3.1 Quality Assurance/Quality Control	29

3.3.2	Metals	34
3.3.3	Chlorophenols	38
3.3.4	Polycyclic Aromatic Hydrocarbons	42
3.4	Sediment Toxicity	46
3.4.1	Solid Phase Microtox?	46
3.4.2	<i>Macoma balthica</i>	48
CONCLUSIONS AND RECOMMENDATIONS		51
4.1	IDZ Impacts	51
4.2	Recommendations for Future Studies	51
REFERENCES		R-1

LIST OF TABLES

Table		Page
2.1-1	Industries Monitored for the Fraser River Estuary Initial Dilution Zone Impact Assessment	8
2.2-1	Drogue Data Used to Determine Effluent Dilutions	15
2.2-2	Sediment Sampling Locations and Field Measurements	18
3.1-1	Fraser River Effluent Dilutions Calculated from Drogue Data	24
3.2-1	Water Sampling Results	26
3.2-2	<i>Ceriodaphnia</i> Results for Fraser River Bioassays	28
3.3-1	QA/QC Results for Duplicate Metals Analyses	31
3.3-2	QA/QC Results for Duplicate Organic Analyses	33
3.3-3	Mean Concentrations of Metals at Ten Industrial Sites in the Fraser River Estuary, 1993	35

3.3-4	Metals Measured in Sediments of the Fraser River Estuary During Recent Studies	37
3.3-5	Mean Concentrations of Chlorophenols at Industrial Sites in the Fraser River Estuary, 1993	39
3.3-6	Chlorophenols Measured in Sediments of the Fraser River Estuary During Recent Studies	41
3.3-7	Mean Concentrations of Polycyclic Aromatic Hydrocarbons at Industrial Sites in the Fraser River Estuary, 1993	43
3.3-8	Polycyclic Aromatic Hydrocarbons Measured in Sediments of the Fraser River Estuary During Recent Studies	45
3.4-1	Results of Fraser River Sediment Microtox Tests	47
3.4-2	Results of Fraser River Sediment <i>Macoma balthica</i> Bioassays	49

LIST OF FIGURES

Figure		Page
2-1	Sampling Sites.....	7

LIST OF APPENDICES

Appendix

1	QA/QC for Toxicity Tests
2	Zenon Environmental Laboratories Analytical and QA/QC Methods
3	Detailed Sediment Chemistry Data

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The study team thanks the Scientific Authorities, Eric McGreer and Doug Walton, for their support throughout the study and for constructive comments on the previous draft of this report.

Toxicity testing was conducted by Beak Consultants Limited (now IRC Integrated Resource Consultants Inc.), who also provided a vessel, assisted with the sampling, and determined the effluent dilutions.

This project was funded by Environment Canada through the Fraser River Action Plan. The views expressed herein are those of the authors and do not necessarily state or reflect those of Environment Canada.

INTRODUCTION

1.1 Background

The environmental quality of the Fraser River Estuary has been a concern for the past two decades. To assess the quality of and develop management goals for the estuary, the federal and provincial environmental agencies conducted the Fraser River Estuary Study from 1977 through 1982. The first phase of this study (1977-78) found no estuary-wide environmental contamination but did identify local problems and data gaps. The second phase of the study (1979-82) developed a proposed management plan.

Subsequently, the Fraser River Estuary Management Program (FREMP) was established to coordinate activities among the various agencies interested in the estuary. A major goal of FREMP is to "maintain ambient water quality levels in the Fraser River, outer estuary, and Boundary and Semiahmoo Bays that will ensure the preservation of fisheries and wildlife and, where suitable, provide for water contact recreation" (Standing Committee 1991). To meet this objective, FREMP routinely reports on the current environmental status of the estuary and coordinates an on-going environmental monitoring program.

The recent reports on environmental quality (Standing Committee 1987, 1990) indicate that specific areas of degradation exist for water, sediments and biota. Some toxic contaminants are also of concern and may require specific monitoring and control. Of particular interest are anti-sapstain chemicals, polycyclic aromatic hydrocarbons, and dioxins/furans (Standing Committee 1991).

To address these concerns, FREMP developed a Water Quality Plan that includes a multi-agency coordinated environmental monitoring program designed to:

- determine the status of ambient environmental quality, assess trends and gauge compliance with Water Quality Objectives;

- obtain data in sloughs, where environmental extremes may occur;

- identify areas where enforcement and/or abatement action may be required; and

- provide information for the development and revision of water Quality Objectives.

The Environmental Quality Monitoring Program coordinated by FREMP operates on a three-year cycle and is designed to provide environmental trend data on the fate and effects of industrial contaminants in the Fraser Estuary. The program includes monitoring of

water quality, effluent, sediment, and biota.

In the Water Quality Plan (Standing Committee 1991), FREMP identified three categories of effluents to be monitored during the three-year cycle. These categories are municipal sewage treatment plants, heavy industries, and other industries. The heavy industries include 13 sites of particular concern due to their high discharge volumes and potential to carry contaminants. Half of these industries are to be monitored in the first year and half in the second year of the three-year cycle. In addition, FREMP identified five other industries perceived to have comparatively minor environmental impacts. Two to three of these industries are to be included in the first year of the monitoring program to provide assurance that unforeseen contaminants are not being discharged.

In 1992, FREMP initiated an effluent monitoring program at seven of the targeted "heavy industrial" sites and five additional industries. The FREMP Water Quality/Waste Committee contracted Norecol Environmental Consultants Ltd. to undertake a receiving environment program concurrently with the effluent monitoring program.

The receiving environment study focused on the initial dilution zones (IDZ) or areas within 100 m upstream and downstream of the outfall from each industry. It included:

- in situ* receiving water measurements;
- a receiving water chronic toxicity test;
- sediment contaminant analyses;
- sediment acute and chronic toxicity tests; and
- collection of benthic invertebrate samples for future analysis of species composition.

This document reports the results of the IDZ monitoring program.

1.2 Study Objectives

The IDZ monitoring program is part of the first year of the FREMP monitoring cycle. The first year of the cycle is primarily a pilot program to establish the number and locations of sample sites, identify the parameters to be tested, and establish the sampling and testing protocols including requirements for replicate sampling and quality assurance/quality control (QA/QC) requirements.

The specific objective of the IDZ Impact Assessment is that it assess impacts of wastewater discharges on the receiving environment of the Lower Fraser River in the immediate vicinity of selected effluent discharges. The study's additional objectives are to:

- identify the most appropriate sampling locations, contaminant and baseline water/sediment quality parameters;

identify appropriate species for toxicity testing (bioassays); and
establish data compilation and reporting techniques.

METHODS

2.1 Sample Sites

The sample sites included 10 industries which encompassed the lower Fraser River between the International Forest Products (Fletcher Challenge) Sawmill at Port Hammond (Figure 2-1) and the Westshore Terminals Coal Port at Roberts Bank. A reference site was established near Mission at the FREMP water quality monitoring station.

The industries selected for monitoring included the following companies identified as "heavy industries":

International Forest Products, Port Hammond
International Forest Products, Fraser Mills
Scott Paper Ltd.
MacMillan Bloedel, New Westminster
Tree Island Industries;

the following identified as "other" industries:

Domtar, Coquitlam
Tilbury Cement Ltd. (formerly Genstar)
Westshore Terminals, Roberts Bank; and

the following industries not classified in the FREMP Water Quality Plan (Standing Committee 1991):

LaFarge Canada Inc.
Fraser Wharves.

Table 2.1-1 indicates the industrial sectors to which each of these industries belong. The following brief descriptions of these industries are based on information contained in the individual Waste Management Permits. Additional information is provided from the summary report of the 1986 effluent monitoring program conducted by the British Columbia Environment Ministry and the Fraser River Harbour Commission (Supervisory Coordinating Committee 1987) and other monitoring reports, where available.

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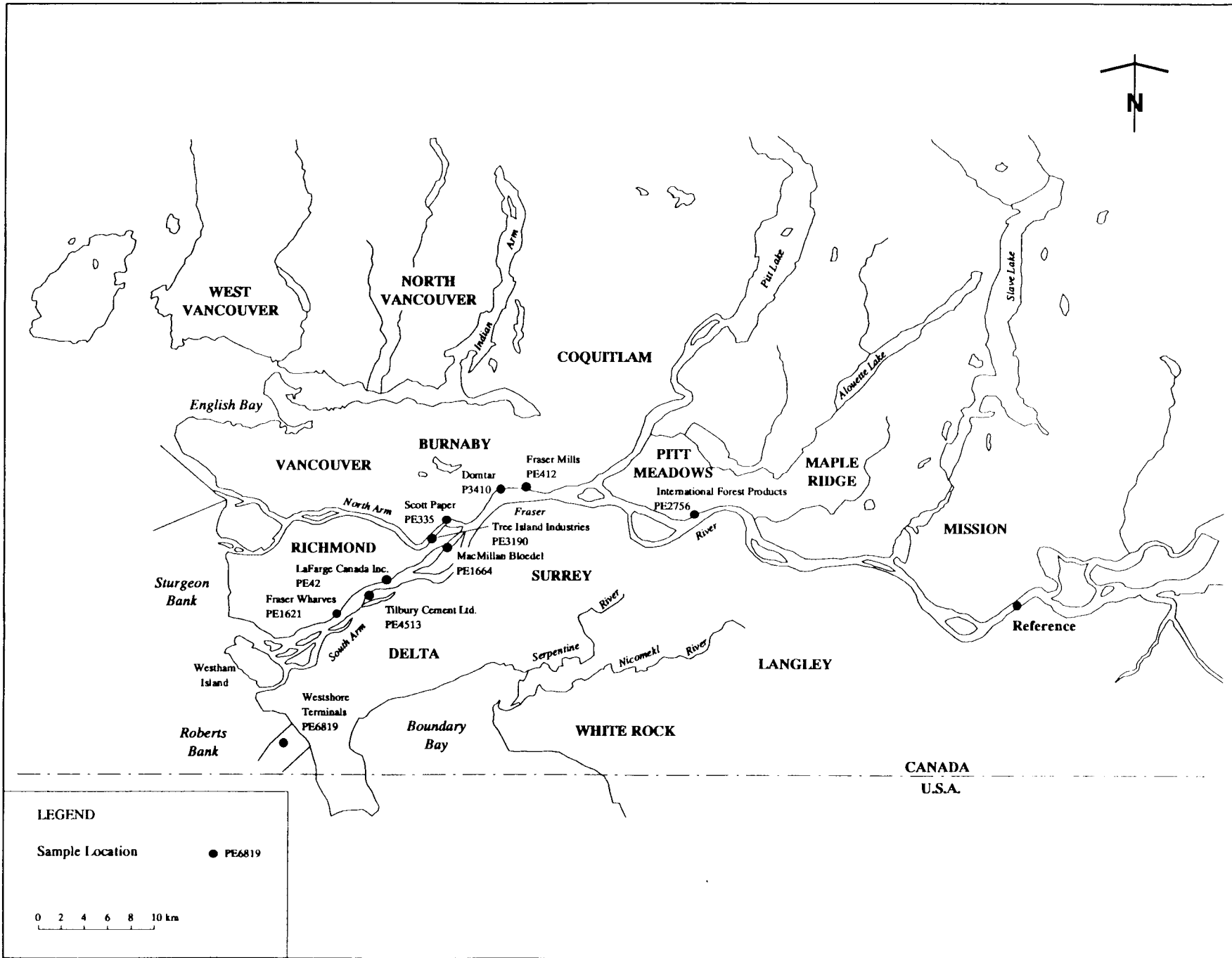


TABLE 2.1-1**INDUSTRIES MONITORED FOR THE FRASER RIVER ESTUARY INITIAL
DILUTION ZONE IMPACT ASSESSMENT, 1993**

INDUSTRY NAME	PERMIT NUMBER	SECTOR	CLASSIFICATION (Standing Committee 1991)
LaFarge Canada Inc.	PE-42	Cement	Not classified
Tilbury Cement Ltd.	PE-4513		Other industry
Scott Paper Ltd.	PE-335	Forestry (paper products)	Heavy industry
International Forest Products, Fraser Mills	PE-412	Forestry (wood products)	Heavy industry
MacMillan Bloedel, New Westminster	PE-1664		Heavy industry
International Forest Products, Hammond	PE-2756		Heavy industry
Tree Island Industries	PE-3190	Metal Finishing	Heavy industry
Domtar (Coquitlam)	PE-3410	Wood Preservation	Other industry
Westshore Terminals	PE-6819	Coal terminal	Other industry
Fraser Wharves	PE-1621	Auto Wash (Dewaxing Facility)	Not classified

LaFarge Canada Inc. (PE-42)

LaFarge Canada operates a cement manufacturing plant in Richmond on the north shore of the Main Arm just downstream from Annacis Island. The plant produces portland cement from lime, silica, alumina, and iron. Raw materials are ground with water to form a slurry and fed into a kiln fuelled by coal, coke, natural gas or landfill gas (Supervisory Coordinating Committee 1987).

The facility has three permitted effluent streams. The first effluent has a maximum permitted discharge rate of 2,950 m³/d and includes cooling water from kiln bearings and process cooling. The second effluent is cooling water combined with site runoff. The final and smallest effluent stream comes from a cement truck wash station and has a maximum permitted flow of 11 m³/d. The second effluent was selected for monitoring because site runoff from a cement operation is usually of concern due to its high pH.

The quality of the LaFarge effluent was reviewed as part of the Fraser River Estuary Study (Swain 1980). The study noted that the effluent sometimes had elevated suspended solids and pH. In addition, the plant discharged measurable loadings of mercury, iron, lead, zinc, and copper.

The LaFarge site was included in the 1986 effluent monitoring program. The results showed that the LaFarge effluents were not toxic and were similar to river water with the exception of elevated turbidity and oil and grease content. The surface runoff was highly alkaline (pH 11). Most metals in surface runoff were associated with particulates, but the concentration dissolved aluminum was higher in surface runoff than in river water. The only measurable impact of the LaFarge effluents on the receiving water was elevated oil and grease (5 mg/L outside the initial dilution zone).

Tilbury Cement Limited (PE-4513)

Tilbury Cement Ltd., located in Delta, is a cement manufacturing plant. It has one permitted cooling water effluent with a maximum allowable discharge rate of 18,200 m³/d. The effluent discharges via a submerged diffuser.

The plant began producing in 1978, operating under the name of Genstar. The Fraser River Estuary Study report on industrial effluents (Swain 1980) noted that Water Management Branch had conducted two surveys of the Fraser River near Genstar, finding no measurable temperature effect at distances greater than 50 m downstream from the discharge. Swain (1980) did not report any concerns about the discharge other than temperature.

International Forest Products, Port Hammond (PE-2756)

International Forest Products (Interfor) operates a sawmill at Port Hammond. The facility has four permitted effluents. Two effluents are the condensates from six lumber dry kilns, which may discharge at a combined maximum rate of 50 m³/d. The third and largest effluent stream is compressor cooling water which is allowed to discharge at a maximum rate of 2,500 m³/d. The final effluent is boiler blowdown which discharges at a maximum 40 m³/d.

The 1978 monitoring study (Cain et al. 1980 cited in Swain 1980) indicated quantities of 2,3,4,6-TCP and PCP in the wastewater. Swain (1980) suggested that the presence of these compounds could be related to the use of wood preservatives (anti-sapstains). Currently, this mill has replaced chlorophenol-based anti-sapstains with a didecyl dimethyl ammonium chloride (DDAC)-based product (Envirochem Special Projects Inc. 1992a).

International Forest Products, Fraser Mills (PE-412)

International Forest Products (Interfor) operates a sawmill at Fraser Mills in Coquitlam. The mill was originally constructed in 1890 and has operated under various ownership since then.

Historically the discharge included fly ash effluent (Swain 1980). However, currently the operation discharges only non-contact cooling water from compressors. The maximum permitted discharge rate is 60 m³/d. The effluent passes through an oil separator sump and screen before discharging via a submerged outfall.

A study conducted in 1978 revealed measurable quantities of 2,3,4,6-tetrachlorophenol (TCP) and pentachlorophenol (PCP) in the wastewater. Swain (1980) suggested that the presence of these compounds could be related to the use of wood preservatives (anti-sapstains). Currently, this mill is using an anti-sapstain product that is based on DDAC (Envirochem Special Projects Inc. 1992a) and is not expected to be discharging chlorinated phenolics.

Scott Paper Ltd. (PE-335)

Scott Paper Ltd. operates a groundwood pulp and paper mill in New Westminster. The mill was originally built in 1926 (Swain 1980). Currently, its major products are bathroom and commercial tissue and towels. The process includes pulping, paper making and converting. The groundwood process supplies only about 30% of the required pulp; the remaining requirement is made up of purchased Kraft and other pulp (Supervisory Coordinating Committee 1987). Scott's process does not involve chlorine bleaching.

The plant has two permitted effluents. Cooling water and fibre-free effluent from the

groundwood pulping area may discharge at a weekly average rate of 910 m³/d and a maximum of 1150 m³/d. Effluent from the paper mill may discharge at a weekly average rate of 18,200 m³/d and a maximum rate of 23,000 m³/d. The latter effluent passes through a fibre recovery system, clarifier, and lagoon before discharging via a submerged outfall.

Historical data from the Fraser River Estuary Study indicate that the mill discharged measurable quantities of tri-, tetra-, and pentachlorophenols. Swain (1980) suggested that the source of these phenolic compounds may have been a slimicide. Currently available slimicides do not contain phenolics.

The Scott Paper mill was included in the 1986 effluent monitoring program (Supervisory Coordinating Committee 1987). The study identified high loadings of aluminum, iron, and chemical oxygen demand (COD) from the plant to the river. Chlorophenols were found in the effluent at parts per trillion levels. Individual components of the paper mill effluent occasionally showed toxicity, but the plant's final effluent was never toxic.

MacMillan Bloedel, New Westminster (PE-1664)

MacMillan Bloedel Industries Limited operates a sawmill in New Westminster. The facility includes two permitted discharges. The first effluent includes cooling water from a planer mill, lumber dry kiln, standby compressor, equipment washdown water and boiler blowdown. It is permitted to discharge at a maximum rate of 91 m³/d. The second effluent is steam condensate from steam actuated equipment. It discharges at a maximum rate of 146 m³/d. Only the latter effluent discharges directly to the river via a submerged outfall.

Monitoring during the Fraser River Estuary Study indicated that washdown water (not currently discharged) and cooling water contained 2,3,4,6-TCP, PCP, and traces of 2,4,6-trichlorophenol (Cain et al. 1980 cited in Swain 1980). The source of these compounds likely was the anti-sapstains used at the site. However, chlorophenols should no longer be present in the discharge as Agriculture Canada terminated the registration of chlorophenol-based anti-sapstains on December 30, 1990 (Envirochem Special Projects Inc. 1992a).

Tree Island Industries (PE-3190)

Tree Island Industries operates a metal finishing plant on Lulu Island. The company's major product is nails. They also produce mesh, rebar, coathangers and wire (Supervisory Coordinating Committee 1987). The process includes pickling steel rod in hydrochloric acid (HCl) to remove rust, drawing the rod into wire, and fabricating the wire into nails and other products. The finishes are applied to the products by galvanizing, phosphating, or vinyling (Supervisory Coordinating Committee 1987).

The plant has two permitted discharges. One is a combined stream which includes wastewater treatment plant and septic tank effluent. This effluent discharges to infiltration lagoons at a permitted rate of 2,000 m³/d including a maximum of 50 m³/d domestic

sewage. The second effluent is cooling water which discharges via a submerged outfall at a maximum permitted rate of 2,500 m³/d. Storm water from the site also discharges through this outfall (Supervisory Coordinating Committee 1987).

Historically, levels of zinc, lead, and iron in the Tree Island effluent have been a concern (Swain 1980). The facility was included in the 1986 effluent monitoring program. This study showed low pH (5.6) and high dissolved zinc levels (0.8 to 5.2 mg/L) in groundwater near the infiltration lagoon. However, the adjacent water which presumably receives this groundwater proved non-toxic in fish bioassays. The direct discharge (cooling and storm water) also contained dissolved zinc and other metals and exhibited slightly toxic effects to rainbow trout (Supervisory Coordinating Committee 1987). At the time of the monitoring, the company was involved in a program to improve its effluent quality; that program has continued.

Domtar Inc. (PE-3410)

Domtar operates a wood preserving plant in Coquitlam. The facility uses pressure treatment to impregnate chemicals into wood. The chemicals used on site are chromated copper arsenate (CCA), ammoniacal copper arsenate (ACA), creosote (which is sometimes applied as a 50% mixture with petroleum oil), and PCP (which is still registered to preserve wood for long-term use out-of-doors.)

The facility has one permitted discharge which consists of cooling water and steam condensate. The permitted discharge rate is a monthly average of 415 m³/d and a daily maximum of 465 m³.

The British Columbia Environment Ministry monitored the Domtar site for pentachlorophenol, tetrachlorophenol (TTCP) and creosote (Russo 1988). The study included chemical analyses of water and sediments and *in situ* rainbow trout bioassays to measure toxicity and bioaccumulation. The results showed acceptable water quality in all areas except the north ditch where the PCP and TTCP concentrations exceeded Canadian water quality guidelines for the protection of aquatic life. However, test fish at all sites accumulated PCP and TTCP.

On behalf of the B.C Environment Ministry and Environment Canada, Envirochem Special Projects Inc. (1992b) surveyed six Lower Mainland wood preserving facilities including Domtar. The study included monitoring surface runoff for total copper, chromium, and arsenic, total organic carbon (TOC) and toxicity (rainbow trout and Microtox? bioassays). The results identified individual plants only as sites A through F but showed the presence of metals, PCP, and/or polycyclic aromatic hydrocarbons (constituents of creosote) in runoff. In addition, most runoff samples were toxic to rainbow trout during the 96 hour test.

Fraser Wharves (PE-1621)

Fraser Wharves Ltd., located in Richmond, holds a permit to discharge effluent from a car dewaxing and washing operation to the South Arm of the Fraser River. The maximum permitted discharge rate is $160 \text{ m}^3/\text{d}$, but no discharge is currently occurring.

In the past, Fraser Wharves has received automobiles shipped from Japan which were heavily waxed to protect them during ocean transport. The dewaxing facility removed this protective coating by washing with kerosene and hot water (Swain 1980). The cars currently being off-loaded at the site are not waxed; hence, the dewaxing and washing facility is not operating. However, Fraser Wharves Ltd. continues to maintain an active discharge permit in the event that the dewaxing operation will be required in the future.

Westshore Terminals (PE-6819)

Westshore Terminals Ltd. operates a coal loading terminal at Roberts Bank. The site includes two permitted discharges. The smaller discharge ($30 \text{ m}^3/\text{d}$) comes from a package sewage treatment plant and septic tank. The major discharge (maximum $10,000 \text{ m}^3/\text{d}$) is primarily from a water treatment plant providing water for use in the coal pile dust suppression system. This effluent passes through a sedimentation basin and flocculation facility before discharging through an outfall that is not submerged at low water. The outfall does not operate continuously but rather discharges approximately every five days (C. McDevitt, TRI, personal communication).

2.2 Field Methods

The sampling program included identification of the effluent plume location, estimation of effluent dilutions, field measurements of physical water quality parameters, collection of water samples for toxicity tests, and collection of sediment samples for chemical analyses, toxicity tests, and benthic invertebrate identifications.

2.2.1 Effluent Location and Dilution

At each outfall a quantity of dye was released in the effluent to mark the path of the effluent and to identify the locations for the sediment collections. To determine the concentration of the effluent at the sediment sampling locations drogues were released near the water surface above the outfall and tracked for at least 100 m from the outfall. The drogues were released in a cluster of 10 and the time of release of the cluster was recorded.

At various distances downstream from the outfall the time of travel of each individual drogue was recorded. Normally the times were recorded for a distance of about 50 m and 100 m downstream.

The mean travel time for the drogue cluster at each downstream distance is a measure of the velocity. The velocity is the distance divided by the time of travel. The variance or spread of the drogue clusters at each location is a measure of the dispersion or dilution.

Variance is the spread of the individual drogues about the mean. The variances of the times of travel were computed from the recorded travel times for each of the individual drogues using standard statistical methods. Using the measured velocities, the time variances were converted to spatial variances by multiplying the time variances by the velocity. Table 2.2-1 summarizes these data.

TABLE 2.2-1
DROGUE DATA USED TO DETERMINE EFFLUENT DILUTIONS

LOCATION	DISTANCE FROM OUTFALL m	VELOCITY m/s	VARIANCE m
Westshore Terminals	Drogue study ineffective under site conditions		
LaFarge Cement	100	0.41	26.0
Tilbury Cement	40.3	0.21	3.49
	83.	0.21	6.76
	171.	0.15	39.5
Scott Paper	36.6	0.37	3.25
	91.5	0.41	3.25
Fraser Wharves	79.	1.05	0
	159.	1.0	3.85
IFP Port Hammond	50.8	0.19	6.06
	100.1	0.19	21.4
IFP Fraser Mills (East)	50.8	0.12	8.15
	100.	0.12	13.
(West)	47.	0.17	1.71
	100.	0.18	5.02
Domtar	50.	0.12	2.89
	100.	0.12	27.6
MacMillan Bloedel	50.	0.43	5.03
	100.	0.41	6.98
Tree Island	50.	0.079	3.73

The dilution of the discharged effluent in the receiving water is a function of the volume of effluent discharged and the variance and velocities in the receiving water. The growth rate of the spatial variance with distance from the outfall is a logarithmic function (Okubo 1971). By fitting a logarithmic relationship to the measured data the variance at the outfall and at a distance of 100 m away was determined. The dilution is inversely related to the variance X velocity.

2.2.2 Water Sampling

Water samples for toxicity bioassays (*Ceriodaphnia dubia*) were collected as close as possible to each outfall (always <25 m away and in the direction of the river flow, which varied depending upon the tide). A reference sample was collected from the water column at the FREMP water quality monitoring site at Mission. In each case the sample collection consisted of filling two 5-L plastic containers by immersing them in the water.

Field water quality measurements included temperature, dissolved oxygen, pH, conductivity and salinity. All measurements were taken at the water collection sites using Yellow Springs Instruments meters.

If conductivity/salinity measurements indicated the presence of a salt wedge (salinity >3.0 ppt), the samples were not kept for toxicity testing. Rather, the site was resampled on another day when no salt wedge was present.

2.2.3 Sediment Sampling

Sediments were collected for toxicity testing, chemical analyses, and benthic invertebrate identifications. The sampling was conducted using a 32-foot vessel equipped with radar, GPS, and depth sounding equipment. Sediment samples downstream of the outfall were collected in the path of the effluent (as indicated by the drogues) to ensure that they were in an area affected by the discharge.

For the toxicity tests and chemical analyses, three samples were collected at each industry. These sites were located approximately 25 m from the outfall (or as close to 25 m as it was possible to bring the boat) and approximately 100 m upstream and 100 m downstream from the outfall. If the sediment at the preferred site was too coarse or contained too much debris to provide valid data the nearest available site having appropriate sediment characteristics was sampled. Table 2.2-2 describes the actual sediment sampling sites.

TABLE 2.2-2

**FRASER RIVER INITIAL DILUTION ZONE IMPACT ASSESSMENT
SEDIMENT SAMPLING LOCATIONS AND FIELD MEASUREMENTS**

INDUSTRY	DATE	SAMPLE ID	LATITUDE	LONGITUDE	DEPTH (m)	REDOX
Westshore Terminals	15 Feb 93	Outfall	49°01.01'N	123°10.18'W	4.0	49
	15 Feb 93	100 m West	49°01.03'N	123°10.23'W	5.0	127
	15 Feb 93	100 m East	49°00.95'N	123°10.00'W	4.8	19
LaFarge Cement	16 Feb 93	Outfall	49°09.37'N	123°00.17'W	9.7	-215
	16 Feb 93	100 m U/S	49°09.40'N	123°00.08'W	11.3	-151
	17 Feb 93	100 m D/S	49°09.35'N	123°00.25'W	14.3	-140
Tilbury Cement	17 Feb 93	#1 100 m D/S	49°08.74'N	123°01.75'W	3.5	-118
	17 Feb 93	#2 100 m D/S	49°08.72'N	123°01.75'W	2.6	-91
	17 Feb 93	#3 25 m N	49°08.78'N	123°01.65'W	8.2	-105
Scott Paper	19 Feb 93	Outfall	49°12.02'N	122°56.20'W	5.6	-95
	19 Feb 93	100 m U/S	49°12.03'N	122°56.12'W	4.9	-150
	19 Feb 93	50 m D/S	49°12.01'N	122°56.26'W	5.9	-125
Fraser Wharves	20 Feb 93	Outfall	49°07.77'N	123°04.04'W	14.0	-195
	20 Feb 93	100 m U/S	49°07.85'N	123°03.95'W	16.6	-130
	20 Feb 93	100 m D/S	49°07.69'N	123°04.14'W	9.5	-140
Mission (Reference Site)	22 Feb 93	Control	49°08.24'N	122°16.00'W	6.0	-172
Interfor - Port Hammond	27 Feb 93	Outfall	49°12.22'N	122°38.93'W	6.1	-44
	27 Feb 93	100 m U/S	49°12.27'N	122°38.78'W	4.0	-11
	27 Feb 93	200 m D/S	49°12.14'N	122°39.13'W	5.0	-75
Interfor - Fraser Mills	27 Feb 93	Outfall (80 m SW)	49°13.48'N	122°51.60'W	4.0	-87
	27 Feb 93	150 m U/S	49°13.48'N	122°51.45'W	2.0	-117
	27 Feb 93	175 m D/S	49°13.49'N	122°51.70'W	4.3	-39
Domtar	2 Mar 93	Outfall (50 m S)	49°13.52'N	122°51.98'W	3.3	-212
	2 Mar 93	150 m D/S	49°13.52'N	122°52.15'W	4.0	-106
	2 Mar 93	400 m D/S	49°13.48'N	122°52.43'W	4.5	-135
MacMillan Bloedel	6 Mar 93	Outfall	49°11.54'N	122°57.13'W	5.3	145
	6 Mar 93	100 m D/S	49°11.48'N	122°57.20'W	4.5	121
	6 Mar 93	200 m D/S	49°11.45'N	122°57.27'W	3.6	86
Tree Island	6 Mar 93	Outfall	49°11.35'N	122°57.43'W	4.2	112
	6 Mar 93	50 m D/S	49°11.34'N	122°57.46'W	2.0	-94
	6 Mar 93	150 m D/S	49°11.29'N	122°57.53'W	1.5	-198

For benthic invertebrates a single sample was collected approximately 25 m from the outfall, usually downstream, depending upon the availability of suitable substrate. At the reference site, where no outfall was present, single samples were collected for toxicity, chemistry, and invertebrates.

The samples were collected with a stainless steel VanVeen sampler (0.1 m²) equipped with removable screens to allow access to the surface of the sediment. A grab was considered successful and sediments were collected from it when the surface of the sediment appeared virtually undisturbed. The surface of each grab sample to a depth of approximately 2.5 cm was removed with a stainless steel spoon avoiding collection of sediment that had contacted the sampler. The selected sediment was placed in a glass pan and completely mixed with the sediment from subsequent grabs. The collection and mixing continued until sufficient sample had been collected for the required toxicity and chemical tests.

The sediment samples were then transferred to appropriate containers for transportation to the laboratories. Samples for toxicity testing were placed in 5-L plastic jars. Samples for chemical analyses were placed in pre-cleaned glass jars supplied by Zenon Environmental Laboratories. For particle size analysis an additional sediment aliquot for particle size analysis was placed in a separate glass jar. The samples were stored in coolers in the field. Upon return to the laboratory the samples for chemical analyses were frozen and the samples for particle size analyses refrigerated until they were shipped to the analytical laboratory.

Prior to and during sampling several precautions were taken to minimize the potential for contamination. Each day prior to collection of the first sample, the VanVeen grab, spoon, and mixing pan were washed in river water and rinsed with acetone and hexane. All equipment was similarly washed between samples. Field personnel preparing the composite samples wore disposable gloves, which were changed between sites. In addition, between sediment grabs the glass mixing bowl was covered with aluminum foil and placed in a cooler to protect the sample from engine exhaust and other possible sources of contamination.

Sediment oxidation-reduction (redox) potential was measured in the field using a redox pen (Hanna Instruments, Woonsocket, Rhode Island). To avoid contamination of the chemistry-toxicity composite samples, a separate sediment grab was collected for the redox measurement. The measurement was taken by pushing the pen into the undisturbed sediment to a depth of approximately 2 cm and recording the digital output once the reading had stabilized (generally after two to three minutes).

At each site one additional sediment grab was collected for benthic invertebrate identifications. This sample was taken approximately 25 m from the outfall. The entire content of the grab was set aside and washed through a 212 or 300 µm sieve. The 212 µm sieve was used wherever possible, but at some sites the substrate was so coarse that

virtually none would pass through the finer sieve. In this case, the 300 µm sieve was used. At the Westshore Terminals site (Roberts Bank, a marine habitat) a 500 µm sieve was used.

The material retained on the screen was transferred to a jar and preserved with 10% buffered formalin. After two to three days the formalin was poured off and replaced with 70% ethanol. The samples were then shipped to Environment Canada (G. Derksen) for future sorting and enumeration.

2.3 Toxicity Testing Methods

Beak Consultants undertook the toxicity testing. The tests consisted of a chronic toxicity test on the receiving water, and one acute and one chronic test on the sediments. The following sections describe the toxicity test procedures.

2.3.1 Water Test - *Ceriodaphnia dubia*

Chronic toxicity of all freshwater receiving waters was tested with *Ceriodaphnia dubia*. An oyster larval test was intended for the marine waters at Westshore Terminals, but problems were encountered with the test methodology. The seawater was not repeated because Westshore Terminals discharges intermittently, and generally does not discharge during dry weather.

The reproductive and survival test for *Ceriodaphnia dubia* was conducted according to the method described in Environment Canada's EPS 1/RMS/21 (1992). The brood stock used for these tests were maintained in cultures at 25°C with a photoperiod of 16 hours light and 8 hours dark. Prior to use test organisms were acclimated to the control/dilution water obtained from the reference site in Mission. This culture maintained a less than 10% mortality rate and an average of greater than 15 young produced during the week prior to test commencement, with greater than 6 young produced per brood organism in previous brood. There were no ephippa produced in brood or test stock cultures.

Testing of each receiving water sample was conducted with five dilutions of each sample, 100%, 50%, 25%, 12.5% and 6.25% with ten replicates of each dilution. A control with ten replicates was also conducted with each test series. Neonate daphnids less than 24 hours old were transferred to the test vessel to initiate the test.

Each test solution was renewed daily with the test receiving/dilution water which had been collected before the start of the test and remained stored at 4°C. Replacement solutions were brought to temperature (25°C) in a water bath prior to the transferring of the individual organisms. Daily measurements of dissolved oxygen, temperature, pH and conductivity were made and recorded. The number of adults surviving and young produced per individual adult in each series was recorded and young removed daily. In

most cases daphnids did not start producing young until the fourth day.

Sodium chloride was used as the reference toxicant which was conducted weekly within the testing period. A control chart for the reference toxicant is presented in Appendix 1. A minimum of 10% of test waters were duplicated.

Test endpoints were measured based on daphnid survival and reproduction. The LC50 (the lethal concentration at which 50% of the test population dies) of the test solutions was calculated as a measure of survival and the NOEC (no-observed-effect-concentration) and LOEC (lowest-observed-effect-concentration) were calculated as a measure of reproductive decline.

2.3.2 Toxicity Testing of Sediments

Solid Phase Microtox

The Microtox bioluminescence procedure was used to determine the acute toxicity of test sediments. The test procedures are detailed in the Microtox manuals and in the Environment Canada (1992) report "Toxicity Test Using Luminescent Bacteria (*Photobacterium phosphoreum*)". The solid phase Microtox test allows the test organisms to directly contact the solid particle-bound toxicants in an aqueous suspension of the test sample. Thus, organisms are exposed to soluble and insoluble organic and inorganic toxic materials.

Sediment samples to be tested were thoroughly mixed, and pore water was separated by centrifuge. A saline diluent was then added to the solid material and mixed. Test organisms were exposed to serial dilutions of the suspended solids solution. The test solution/organism mixture was incubated for 20 minutes, the solid material filtered and the elutriate/organism solution measured for bioluminescence (light) emitted by the test organisms.

As part of the quality control program, at least 10% of the tests were done in duplicate. The reference toxicant employed was phenol. The control chart for the reference toxicant is presented in Appendix 1.

Macoma balthica

The bivalve *Macoma balthica* was used to test sediments for chronic toxicity in an avoidance type test. The field and laboratory procedures for this test followed the method of McGreer (1982) with modifications by Van Aggelen (1988). A glass aquarium was filled to a depth of 5 cm with test sediment on one side and control sediment obtained from the organism collection site on the other side. The test and control sediments were separated by a glass plate and the aquarium filled with clean marine water with a salinity of 25 ppt to a depth of 5 cm. Test vessels were allowed to settle for 24 hours to reduce turbidity in the water column before commencement of the test.

Ten organisms were placed on each side of the test vessel and the burial times for each organism was recorded. After a 24 hour period the glass plate separating the test and control sediments was removed. The number of organisms resurfacing was recorded daily. At the end of the ten day test period the glass plate was carefully replaced between the test and control sediments. The sediments were removed and sieved with numbers of organisms on each side recorded and placed in separate beakers containing clean marine water. The organism mortalities as observed by lack of movement or siphon extension was also recorded.

Dissolved oxygen, pH and salinity were recorded in each test vessel at the initiation and end of the test period.

The duplication of at least 10% of the tests was conducted as part of the quality control procedures. The results from the test and control aquaria were compared statistically with a Chi-square test.

2.4 Sediment Chemistry Analyses

Zenon Environmental Laboratories performed the chemical analyses. All samples were analyzed for sediment grain size, total organic carbon (TOC), and metals (by ICP scan). Additional analyses were done depending upon the nature of the industry. Polycyclic aromatic hydrocarbons (PAH) were analyzed in samples from the Domtar and Westshore Terminals sites. Chlorophenols were analyzed in samples from the forest industry sites (the two Interfor sites, MacMillan Bloedel, and Scott Paper) and the Domtar site. The control sample from Mission was analyzed for PAH and chlorophenols. In addition, a low level arsenic determination (hydride generation) was done on the Domtar sediments.

Laboratory quality assurance/quality control methods included the use of method blanks, duplicate data, surrogate standards, and standard reference material. Appendix 2 includes summaries of analytical methods, a complete description of QA/QC methods, data quality objectives, and QA/QC results.

RESULTS AND DISCUSSION

3.1 Effluent Dilutions

Column B of Table 3.1-1 summarizes the dilutions at 100 m from each outfall. These dilutions are based on single trackings of clusters of drogues and do not consider the impact of the tidal and river flow variations. They are "snap shot" measurements that provide an estimate of the dilution achieved within 100 m of the discharge at a single time.

TABLE 3.1-1 FRASER RIVER EFFLUENT DILUTIONS CALCULATED FROM DROGUE DATA				
LOCATION	OUTFALL DILUTION ESTIMATED¹ (A)	RIVER VELOCITY MEASURED m/s	DILUTION AT 100 m MEASURED (B)	TOTAL DILUTION AT 100 m (AXB)
Westshore Terminals	Drogue studies ineffective under site conditions			
Tilbury Cement	0.33 (3:1)	0.21	0.038	0.0125 (80:1)
LaFarge Cement	0.33 (3:1)	0.41	0.012	0.004 (250:1)
Scott Paper	0.50 (2:1)	0.41	0.46	0.23 (4.3:1)
Fraser Wharves	0.33 (3:1)	1.00	0.90	0.30 (3.3:1)*
IFP Port Hammond	0.33 (3:1)	0.19	0.011	0.004 (250:1)
IFP Fraser Mills	0.33 (3:1)	0.18	0.074	0.024 (42:1)
Domtar	0.33 (3:1)	0.12	0.005	0.0017 (588:1)
MacMillan Bloedel	0.33 (3:1)	0.43	0.082	0.027 (37:1)
Tree Island	0.33 (3:1)	0.079	0.083	0.027 (37:1)

- Details on the outfall design, depth, effluent characteristics and discharge rate were not known consequently a mean submerged outfall dilution was assumed.

* Probably underestimated; however, site not discharging during study

In addition to the dilutions achieved by mixing with the receiving water there is the dilution achieved at the outfall due to the jetting and buoyancy rise of the effluent. This dilution is not included in the drogue cluster measurements and must be added to the dilution predicted by the drogue cluster measurements. While the outfall dilution can be predicted using outfall prediction models like the USEPA CORMIX2, data are required on the effluent discharge rate and buoyancy, configuration of the outfall, water depths over the outfall and velocities in the receiving water near the outfall. To determine the outfall dilution achieved, it would be necessary to consider the variations of the tidal stages and generated velocities which are a combination of the tidal stage and river flow. These analyses are beyond the scope of this study which requires an estimate of the effluent dilution at 100 m. A conservative estimate has been used for the outfall dilution, namely that most submerged outfalls can achieve a dilution of at least 3:1. Measurements at a multiport submerged outfall in the lower Fraser showed the outfall dilution to be 0.13; consequently the estimate of 0.33 is a good conservative estimate for the outfall dilution. The most effective method for determining the outfall dilution for a particular outfall is to measure the dilution. This is the approach used and the data are presented in Table 3.1-1 column A. The total estimated dilution for 100 m from the outfall is also presented in Table 3.1-1.

With the exception of Scott Paper and Fraser Wharves the percentage effluent at 100 m is less than 2%. Sediments located 100 m from the outfall are impacted by less than 2% effluent. At Fraser Wharves the percentage effluent (if discharged) would be 30%; and at Scott Paper it is 23%. Thus, the dilution at these locations is significantly less than that found at the other locations.

When the receiving water has higher velocities the drogues do not have sufficient time to separate in 100 m and the estimates of the variance (hence of dispersion and dilution) for these cases are likely underestimated. Some indication of the degree of underestimation is provided by measurements of the dilution downstream of Scott Paper using dye injection techniques. Such tests indicated a dilution of about 17:1 (6% effluent) in the receiving water at 100 m during low tide. Based on site observations, the underestimate of the dilution at Fraser Wharves may be more severe than the underestimate for Scott Paper.

3.2 Water Chemistry and Toxicity

Table 3.2-1 presents the results of the water chemistry measurements. The data do not appear to show any particular impacts in the various IDZ. However, the dissolved oxygen levels were higher at Mission and Port Hammond than at most other sites.

TABLE 3.2-1**FRASER RIVER INITIAL DILUTION ZONE IMPACT ASSESSMENT
WATER SAMPLING RESULTS**

INDUSTRY	DATE	LATITUDE	LONGITUDE	TEMP. C	pH	DISSOLVED OXYGEN mg/L	SALINITY ppt	CONDUCT. umhos/cm
Westshore Terminals	12-May-93	49 01.01' N	123 10.18' W	--	7.7	8.0	28.0	--
LaFarge Cement	16-Feb-93	49 09.37' N	123 00.17' W	6.5	7.4	11.0	2.0	1500
Tilbury Cement	17-Feb-93	49 08.78' N	123 01.65' W	1.6	7.4	11.2	5.2	4000
Scott Paper	19-Feb-93	49 12.02' N	122 56.20' W	3.0	7.6	12.1	4.0	3330
Fraser Wharves	20-Feb-93	49 07.77' N	123 04.04' W	3.0	7.6	10.8	8.0	9000
Mission (Reference Site)	22-Feb-93	49 07.98' N	122 16.74' W	1.0	7.7	13.4	0.0	110
Interfor - Port Hammond	27-Feb-93	49 12.22' N	122 38.93' W	1.0	7.6	13.6	0.0	180
Interfor - Fraser Mills	27-Feb-93	49 13.48' N	122 51.60' W	2.0	7.4	11.0	0.0	120
Domtar	2-Mar-93	49 13.52' N	122 51.98' W	5.5	7.6	10.4	1.0	180
MacMillan Bloedel	6-Mar-93	49 11.50' N	122 57.18' W	4.8	7.6	9.9	1.1	600
Tree Island Industries	6-Mar-93	49 11.35' N	122 57.43' W	5.0	7.4	9.8	1.4	320

Results of the *Ceriodaphnia dubia* tests are shown in Table 3.2-2. The only sample that proved toxic in this test was the receiving water collected at the Scott Paper outfall. The receiving water was not lethal to the *Ceriodaphnia*, but exposure to it did result in a measurable decrease in the number of young produced. The lowest observable effect occurred at a concentration of 25% (that is, the initial receiving water diluted to 25%).

TABLE 3.2-2
CERIODAPHNIA RESULTS OF FRASER RIVER BIOASSAYS

LOCATION	LC50 VALUE ¹	LOEC ²	NOEC ³
Mission	> 100%	> 100%	100%
Port Hammond	> 100%	> 100%	100%
Fraser Mills	> 100%	> 100%	100%
Scott Paper	> 100%	25%	12.5%
Macmillan Bloedel	> 100%	> 100%	100%
Tree Island	> 100%	> 100%	100%
Lafarge	> 100%	> 100%	100%
Tilbury	> 100%	> 100%	100%
Domtar	> 100%	> 100%	100%

1. The LC50 value is the concentration at which 50% of the population tested would survive.
2. The LOEC (Lowest Observable Effect Concentration) is the lowest concentration at which an effect was measured by a significant ($P < 0.05$) decrease in young produced.
3. The NOEC (No Observable Effect Concentration) is the highest concentration at which no effects were measured by a significant ($P < 0.05$) decrease in young produced.
4. The tests are based on a single grab sample of water collected <25 m from the most significant outfall at each site.

This sublethal toxicity likely was related to the limited dilution available for the Scott Paper effluent. The undiluted effluent from all ten industries was toxic to *Ceriodaphnia* (TRI, in preparation). However, the available dilution was less at Scott Paper than at any site except Fraser Wharves, which is not currently discharging and therefore was not tested for receiving water toxicity. In addition, although the Scott effluent was not as toxic as effluents from some of the other industries, the high discharge rate caused this effluent to have the highest daily Chronic Toxicity Emission Rate of any of the industries studied (TRI, in preparation).

An alternate explanation is that because of different test conditions, the receiving water tests were not fully comparable to TRI's effluent tests. During the seven-day *Ceriodaphnia* bioassays, the test solutions were renewed with receiving water collected prior to the start of the tests. In the wastewater tests, fresh effluent was used for the renewals on days three and five. The Environment Canada (1992a) protocols indicate that storage of a single sample for use throughout the static renewal test is undesirable due to concerns with respect to sample stability. Thus, it is possible that toxic components of the receiving water were lost over the course of the test.

Nevertheless, the results of these tests should not be discounted, nor is renewal with receiving water samples freshly-collected every two days necessarily desirable. Variability in either effluent quality or receiving water quality over the course of the test could cause the toxicity of the renewed solution to differ from that of the starting solution. In a river such as the Fraser that receives many effluents, there is a real potential for day to day variations in water quality that are unrelated to the effects of a particular effluent being tested.

The sublethal toxicity to the *Ceriodaphnia* of the receiving water from the immediate vicinity of the Scott Paper outfall is not expected to have a widespread impact on the river, but under tide and flow conditions similar to those observed during the present study, some toxicity might remain beyond the IDZ. The "no observable effect" concentration (NOEC) in the receiving water test was 12.5%. Assuming that the 100% receiving water tested already represented a 2:1 dilution (50%) of the effluent (Table 3.1-1), then the lowest observable effect occurred at a total effluent dilution of 8:1, and no effect occurred at a dilution of 16:1. The dilution at 100 m (by definition, the limit of the IDZ) estimated from the drogue study was 4.3:1 (Table 3.1-1), but dye studies have shown it to be >16:1.

3.3 Sediment Chemistry

3.3.1 Quality Assurance/Quality Control

Method blanks were used to identify potential contamination during sample preparation and analysis. Data for method blanks is presented and discussed in Zenon's report (Appendix 3). Traces of aluminum, chromium, copper, iron, and zinc were present in one or both blanks, but concentrations were generally near the detection limit and are not

believed to have significantly biased the results. Therefore, the results were not corrected for detectable concentrations in the blanks.

Precision of all analyses was determined using duplicate samples. The acceptable precision for duplicate metals analyses is $\pm 25\%$ for concentrations less than 20 times the method detection limit or $\pm 10\%$ for samples greater than 20 times the detection limit (APHA 1992). Table 3.3-1 indicates that precision was generally good for metals of environmental concern, although copper and zinc the LaFarge duplicates and copper in the Domtar duplicates were slightly outside the acceptance limits. Precision was poor for the arsenic samples analyzed by ICP but good for the samples analyzed by hydride generation.

TABLE 3.3-1

QA/AC RESULTS FOR DUPLICATE METALS ANALYSES

PARAMETER	MDC	DOMTAR			SCOTT			MACMILLAN-BLOEDEL			LAFARGE		
		#1	#2	% DIFF.	#1	#2	% DIFF.	#1	#2	% DIFF.	#1	#2	% DIFF.
Silver	1	< 1	< 1	0.0%	< 1	< 1	0.0%	< 1	< 1	0.0%	< 1	< 1	0.0%
Aluminum	2	26700	26200	1.9%	28600	28400	0.7%	29200	29800	-2.0%	33100	32700	1.2%
Arsenic	0.2	5.2	5.2	0.0%	---	---	---	---	---	---	---	---	---
Arsenic	10	---	---	---	22	16	31.6%	< 10	< 10	0.0%	15	24	-46.2%
Barium	0.1	179	172	4.0%	193	193	0.0%	199	201	-1.0%	209	204	2.4%
Beryllium	0.1	0.5	0.5	0.0%	0.6	0.7	-15.4%	0.5	0.5	0.0%	0.7	0.7	0.0%
Bismuth	2	< 2	< 2	0.0%	< 2	< 2	0.0%	< 2	< 2	0.0%	< 2	< 2	0.0%
Calcium	1	10900	10900	0.0%	11800	11800	0.0%	12000	11900	0.8%	32000	33800	-5.5%
Cadmium	0.1	0.6	0.5	18.2%	0.7	0.6	15.4%	0.7	0.6	15.4%	0.8	1	-22.2%
Cobalt	0.3	11.9	12.1	-1.7%	11.9	12.2	-2.5%	13	13.5	-3.8%	13.2	12.9	2.3%
Chromium	0.2	36.8	36.7	0.3%	51.1	48.4	5.4%	48.2	41	16.1%	44.9	35.8	22.6%
Copper	0.1	27.5	34.8	-23.4%	28.3	27	4.7%	32.1	32.3	-0.6%	39.3	39.2	0.3%
Iron	0.3	36100	36100	0.0%	34700	35000	-0.9%	37700	37900	-0.5%	37400	37000	1.1%
Potassium	40	3990	3830	4.1%	4690	4740	-1.1%	4590	4800	-4.5%	5880	5820	1.0%
Magnesium	2	11100	11000	0.9%	11300	11200	0.9%	12500	12500	0.0%	12600	12500	0.8%
Manganese	0.2	467	464	0.6%	465	466	-0.2%	496	498	-0.4%	519	513	1.2%
Molybdenum	0.4	< 0.4	< 0.4	0.0%	< 0.4	< 0.4	0.0%	< 0.4	< 0.4	0.0%	< 0.4	< 0.4	0.0%
Sodium	1	784	733	6.7%	1040	1010	2.9%	1100	1120	-1.8%	1720	1730	-0.6%
Nickel	0.8	38.1	37.5	1.6%	41	41.1	-0.2%	42.2	42.6	-0.9%	43.6	42.9	1.6%
Phosphorus	4	774	774	0.0%	744	752	-1.1%	766	768	-0.3%	805	802	0.4%
Lead	2	8	8	0.0%	10	11	-9.5%	8	9	-11.8%	13	12	8.0%
Sulphur	3	466	472	-1.3%	485	480	1.0%	548	557	-1.6%	788	774	1.8%
Antimony	1.5	< 1.5	< 1.5	0.0%	< 1.5	2	0.0%	< 1.5	< 1.5	0.0%	2.1	2.4	-13.3%
Selenium	10	< 10	< 10	0.0%	< 10	< 10	0.0%	< 10	< 10	0.0%	< 10	< 10	0.0%
Tin	2	< 2	< 2	0.0%	2	< 2	0.0%	< 2	< 2	0.0%	7	11	-44.4%
Strontium	0.1	66.5	64.7	2.7%	73.2	72.2	1.4%	71.6	71.3	0.4%	115	119	-3.4%
Tellurium	2	< 2	< 2	0.0%	< 2	< 2	0.0%	< 2	< 2	0.0%	< 2	< 2	0.0%
Titanium	0.3	1470	1410	4.2%	1470	1630	-10.3%	1310	1400	-6.6%	1510	1600	-5.8%
Thallium	2	< 2.0	< 2.0	0.0%	2.9	2.3	23.1%	< 2.0	< 2.0	0.0%	5.1	1.99	87.7%
Vanadium	0.3	62.1	61.1	1.6%	63.6	64.4	-1.3%	63.1	63.5	-0.6%	64.9	64.4	0.8%
Zinc	0.2	72.5	75.7	-4.3%	80.8	75.8	6.4%	83.3	83.8	-0.6%	111	82.7	29.2%
Zirconium	0.3	6.7	7.4	-9.9%	10.5	8.9	16.5%	10.4	10.2	1.9%	11.8	8.6	31.4%

Acceptable precisions for duplicate analyses base neutral organics (including PAHs) are $\pm 40\%$ for concentrations less than 20 times the method detection limit and $\pm 20\%$ for samples greater than 20 times the detection limit (APHA 1992). Table 3.3-2 shows that precision for high molecular weight PAHs was acceptable, while precision for several low molecular PAHs (naphthalene, acenaphthene, phenanthrene, and anthracene) was outside the recommended limits. The laboratory attributes the reduced precision to difficulty in preparing identical subsamples of sediments.

TABLE 3.3-2

QA/QC RESULTS FOR DUPLICATE ORGANICS ANALYSES

PARAMETER	MDC	DOMTAR			SCOTT			MACMILLAN BLOEDDELL		
		#1	#2	% DIFF.	#1	#2	% DIFF.	#1	#2	% DIFF.
Pentachlorophenol	0.005	0.009	< 0.050	**	< 0.005	< 0.005	0.0%	< 0.005	< 0.005	0.0%
Tetrachlorophenols	0.005	< 0.050	< 0.050	0.0%	< 0.005	< 0.005	0.0%	< 0.005	< 0.005	0.0%
Trichlorophenols	0.005	< 0.050	< 0.050	0.0%	< 0.005	< 0.010	0.0%	< 0.005	< 0.005	0.0%
Naphthalene	0.001	0.011	0.007	44.4%	---	---	---	---	---	---
Acenaphthylene	0.001	< 0.001	< 0.001	0.0%	---	---	---	---	---	---
Acenaphthene	0.001	0.005	0.003	50.0%	---	---	---	---	---	---
Fluorene	0.001	0.006	0.004	40.0%	---	---	---	---	---	---
Phenanthrene	0.001	0.027	0.020	29.8%	---	---	---	---	---	---
Anthracene	0.001	0.005	0.003	50.0%	---	---	---	---	---	---
Total low MW PAH's	0.001	0.054	0.037	37.4%	---	---	---	---	---	---
Fluoranthene	0.001	0.027	0.026	3.8%	---	---	---	---	---	---
Pyrene	0.001	0.023	0.023	0.0%	---	---	---	---	---	---
Benzo(c)phenanthrene	0.001	0.002	0.002	0.0%	---	---	---	---	---	---
Benz(a)anthracene	0.001	0.009	0.006	40.0%	---	---	---	---	---	---
Chrysene	0.001	0.012	0.014	-15.4%	---	---	---	---	---	---
Benzo(b+k)fluoranthene	0.001	0.016	0.013	20.7%	---	---	---	---	---	---
Benzo(j)fluoranthene	0.001	0.001	0.003	-100.0%	---	---	---	---	---	---
7 12-Dimethylb(a)a	0.005	< 0.005	< 0.005	0.0%	---	---	---	---	---	---
Benzo(a)pyrene	0.001	0.006	0.004	40.0%	---	---	---	---	---	---
3-Methylcholanthrene	0.002	< 0.002	< 0.002	0.0%	---	---	---	---	---	---
Indeno(1 2 3-c d)pyr	0.002	0.003	0.002	40.0%	---	---	---	---	---	---
Dibenz(a h)anthracen	0.002	< 0.002	< 0.002	0.0%	---	---	---	---	---	---
Benzo(g h i)perylene	0.002	< 0.002	< 0.002	0.0%	---	---	---	---	---	---
Dibenzo(a l)pyrene	0.005	< 0.005	< 0.005	0.0%	---	---	---	---	---	---
Dibenzo(a i)pyrene	0.005	< 0.005	< 0.005	0.0%	---	---	---	---	---	---
Dibenzo(a h)pyrene	0.005	< 0.005	< 0.005	0.0%	---	---	---	---	---	---
Total high MW PAH's	0.005	0.099	0.093	6.3%	---	---	---	---	---	---
Total PAH's	0.005	0.15	0.13	14.3%	---	---	---	---	---	---

The accuracy of metals analyses was determined by analyzing certified reference samples. Data for these analyses with the applicable acceptance limits ($\pm 25\%$) are presented in Appendix 2. Recoveries of most metals were acceptable. However, chromium recoveries were low (42.7% and 27.7%), and aluminum recoveries were slightly low (72.8% and 73.3%). In addition, the recovery of arsenic in one sample was high (136%).

3.3.2 Metals

Concentrations of metals in the sediment samples from all sites were similar to or lower than metals levels measured at other sites in the Fraser Estuary (Swain and Walton 1990, 1992) but higher than levels reported by Swain and Walton (1988). There was some variability among sites, with comparatively elevated metals levels occurring at Tree Island Industries and LaFarge Cement. In general metals levels in the reference sample from Mission were not lower than levels at most downstream sites.

Concentrations of metals in the samples showed a limited relationship with sediment particle size. The Roberts Bank (Westshore Terminals) samples had the highest proportions of sand (hence the lowest proportions of silts and clays) and the lowest concentrations of all metals except chromium (Table 3.3-3). However, the highest concentrations of metals did not occur at sites with the lowest proportions of sand or the highest proportions of clay. Rather, the highest metals levels occurred in the samples collected near Tree Island Industries and LaFarge Cement, which had sand-silt-clay distributions that were in the mid-range of all sites sampled.

TABLE 3.3-3

MEAN CONCENTRATIONS OF METALS AT TEN INDUSTRIAL SITES IN THE FRASER RIVER ESTUARY, 1993
(Values in ug/g)

PARAMETER	MDC	REFERENCE (MISSION)	LAFARGE	TILBURY	PORT HAMMOND	FRASER MILLS	SCOTT PAPER	MACMILLAN BLOEDEL	TREE ISLAND	DOMTAR	FRASER WHARVES	ROBERTS BANK
%Sand	0.1	25.2	39.9	43.6	45.0	18.9	49.9	30.4	26.9	21.5	30.2	73.6
%Silt	0.1	35.9	20.8	24.3	26.0	26.7	22.9	29.1	25.2	31.2	25.8	17.4
%Clay	0.1	38.9	39.3	32.1	29.0	54.5	27.2	40.5	47.9	47.3	44.1	9.1
Total Organic Carbon	n/a	7100	11967	7333	6900	7867	8383	6850	8800	7400	9833	7667
Silver	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Aluminum	2	30300	33567	30000	28300	31267	28433	30000	30833	29283	33133	25567
Arsenic	0.2	---	---	---	---	---	---	---	---	6	---	---
Arsenic	10	23	18	10	< 10	< 10	11	< 10	< 10	< 10	18	11
Barium	0.1	209	209	205	192	212	194	203	216	196	209	146
Beryllium	0.1	0.7	0.8	0.7	0.6	0.6	0.7	0.6	0.6	0.6	0.7	0.6
Bismuth	2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Calcium	1	14900	19167	12567	12633	11633	11667	12083	14500	11533	12000	11933
Cadmium	0.1	0.8	0.9	0.9	0.5	0.8	0.7	0.7	0.9	0.6	0.7	0.5
Cobalt	0.3	12.9	13.7	12.8	12.6	13.4	12.0	13.2	13.5	12.8	13.2	10.0
Chromium	0.2	48.2	43.8	49.0	37.7	35.5	47.6	43.8	40.8	36.5	46.0	52.5
Copper	0.1	27.9	40.0	31.5	29.3	32.1	27.8	31.9	34.9	32.2	37.0	17.7
Iron	0.3	36400	39233	37133	36500	38767	34617	37933	38300	38033	37933	30933
Potassium	40	5300	5867	5173	4750	5070	4762	4972	4850	4637	6030	4620
Magnesium	2	13000	12983	12000	11967	12133	11217	12500	12133	11783	13033	11333
Manganese	0.2	513	542	513	464	511	449	505	582	510	509	352
Molybdenum	0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	1.1	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
Sodium	1	973	2012	1610	864	871	1022	1107	1066	872	3273	4690
Nickel	0.8	43.8	44.9	44.1	40.1	41.0	41.0	41.8	43.2	39.8	44.7	36.0
Phosphorus	4	730	844	750	733	794	731	764	798	791	818	766
Lead	2	8	12	7	8	9	10	9	15	9	10	5
Sulphur	3	524	829	582	491	524	528	547	530	492	853	963
Antimony	1.5	1.7	1.8	1.9	< 1.5	< 1.5	2.3	1.5	< 1.5	< 1.5	2.2	2.5
Selenium	10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Tin	2	< 2	4	4	< 2	< 2	5	< 2	< 2	< 2	5	4
Strontium	0.1	72.9	91.3	77.1	69.0	71.6	70.8	71.4	76.3	70.0	78.1	72.1
Tellurium	2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Titanium	0.3	1350	1588	1763	1553	1587	1503	1428	1443	1507	1610	1617
Thallium	2	< 2.0	2.5	2.4	2.1	< 2.0	2.2	< 2.0	< 2.0	2.1	3.5	3.6
Vanadium	0.3	58.4	67.7	70.0	62.2	65.6	62.2	63.8	64.8	63.0	67.1	61.2
Zinc	0.2	69.0	89.9	71.5	74.7	81.5	78.9	80.6	147.5	79.4	80.8	58.3
Zirconium	0.3	10.9	10.8	8.1	6.9	8.9	9.9	9.1	10.4	7.5	10.6	7.6

MDC = Minimum Detectable Concentration

n/a = not applicable (calculated value)

--- = Test not done (arsenic measured by hydride generation only at Domtar sites)

In addition, metals concentrations showed at most a weak relationship to sediment organic carbon content. On average, the LaFarge IDZ had the highest organic carbon concentration. However, among the three individual samples from that site, the sample with the highest organic carbon content had the lowest concentrations of most metals.

The distribution of metals in sediments did not show any trend from upstream to downstream similar to that reported by Swain and Walton (1988, 1991). Metals levels in the control sample from Mission generally fell within the mid-range for all sites. The highest concentrations of metals were associated with two industries, Tree Island Industries and LaFarge Cement. Metal levels at these two sites were higher than concentrations at Swain and Walton's (1988, 1990) Barnston Island reference site, while metal levels at the remaining industries were similar to the 1990 concentrations at Barnston Island.

The highest average and highest single sample concentrations of lead, zinc, and manganese and the highest single sample cadmium concentration occurred at Tree Island Industries IDZ (Table 3.3-3 and Appendix 3). These results likely reflect the historically elevated levels of metals (particularly zinc and lead) in the discharge from the metal finishing plant. The zinc concentrations at Tree Island were significantly higher than concentrations at the other sites. However, they were not as high as the maximum sediment zinc concentration measured in 1991 near Chatterton Petrochemical, and they were much lower than the zinc concentrations in Gunderson Slough near Titan Steel and Wire and B.C. Cleanwood Preservers (Table 3.3-4; Swain and Walton 1992).

TABLE 3.3-4

METALS MEASURED IN SEDIMENTS OF THE FRASER RIVER ESTUARY DURING RECENT STUDIES
(Values in ug/g)

PARAMETER	LOCATION	N	MINIMUM	MAXIMUM	MEAN	REFERENCE
Aluminum	Lower Fraser (11 sites)	31	24600	34200	--	Present Study
Aluminum	Near Paperboard Industries	4	16900	23700	20325	Swain and Walton 1992
Aluminum	Near Chatterton Petrochemical	5	12900	18000	15407	Swain and Walton 1992
Aluminum	Gunderson Slough*	5	13000	33500	22514	Swain and Walton 1992
Aluminum	Main Stem near Barnston Island	10	6370	8720	7964	Swain and Walton 1988
Aluminum	Upper North Arm	10	9940	12100	10834	Swain and Walton 1988
Aluminum	Main Arm - Annacis Island	10	10800	14400	12060	Swain and Walton 1988
Arsenic	Lower Fraser (11 sites)	31	5.2	23	--	Present Study
Arsenic	Near Paperboard Industries	4	5.82	8.74	7.04	Swain and Walton 1992
Arsenic	Near Chatterton Petrochemical*	5	5.28	40.8	11.2	Swain and Walton 1992
Arsenic	Gunderson Slough*	5	7.63	1540	56.6	Swain and Walton 1992
Arsenic	Main Stem near Barnston Island	5	4.18	5.15	4.74	Swain and Walton 1990
Arsenic	North Arm (2 sites)	10	4.23	10.9	--	Swain and Walton 1990
Arsenic	Main Arm (2 sites)	9	3.39	8.21	--	Swain and Walton 1990
Cadmium	Lower Fraser (11 sites)	31	0.5	1.1	--	Present Study
Cadmium	Near Paperboard Industries	4	0.14	0.21	0.17	Swain and Walton 1992
Cadmium	Near Chatterton Petrochemical	5	0.01	0.23	0.12	Swain and Walton 1992
Cadmium	Gunderson Slough*	5	0.20	1.33	0.46	Swain and Walton 1992
Cadmium	Main Stem near Barnston Island	5	0.20	0.24	0.22	Swain and Walton 1990
Cadmium	North Arm (2 sites)	10	0.26	0.38	--	Swain and Walton 1990
Cadmium	Main Arm (2 sites)	9	0.20	0.37	--	Swain and Walton 1990
Cadmium	Near battery recycling plant	1	--	11	--	MOE 1990
Chromium	Lower Fraser (11 sites)	31	28.9	60.6	--	Present Study
Chromium	Near Paperboard Industries	4	48.3	55.9	52.3	Swain and Walton 1992
Chromium	Near Chatterton Petrochemical*	5	41.9	206	54.9	Swain and Walton 1992
Chromium	Gunderson Slough*	5	65.3	2280	175	Swain and Walton 1992
Chromium	Main Stem near Barnston Island	5	45.6	49.6	47.6	Swain and Walton 1990
Chromium	North Arm (2 sites)	10	52.3	60.6	--	Swain and Walton 1990
Chromium	Main Arm (2 sites)	9	46.3	55.0	--	Swain and Walton 1990
Chromium	Main Stem near Barnston Island	10	17	23	20.7	Swain and Walton 1988
Chromium	Upper North Arm	10	24	28	26.9	Swain and Walton 1988
Chromium	Main Arm - Annacis Island	10	24	32	29.6	Swain and Walton 1988
Copper	Lower Fraser (11 sites)	31	16.2	40.5	--	Present Study
Copper	Near Paperboard Industries	4	35.2	48	41.1	Swain and Walton 1992
Copper	Near Chatterton Petrochemical*	5	30.2	142	44.0	Swain and Walton 1992
Copper	Gunderson Slough*	5	52.2	3590	181	Swain and Walton 1992
Copper	Main Stem near Barnston Island	5	36.2	39.2	37.8	Swain and Walton 1990
Copper	North Arm (2 sites)	10	38.7	58.0	--	Swain and Walton 1990
Copper	Main Arm (2 sites)	9	39.2	42.9	--	Swain and Walton 1990
Copper	Main Stem near Barnston Island	10	14	20	17.0	Swain and Walton 1988
Copper	Upper North Arm	10	23	32	27.5	Swain and Walton 1988
Copper	Main Arm - Annacis Island	10	26	33	30.1	Swain and Walton 1988
Iron	Lower Fraser (11 sites)	31	29500	40400	--	Present Study
Iron	Near Paperboard Industries	4	27800	36400	31375	Swain and Walton 1992
Iron	Near Chatterton Petrochemical	5	14500	35850	26621	Swain and Walton 1992
Iron	Gunderson Slough	5	28400	44100	36519	Swain and Walton 1992
Iron	Main Stem near Barnston Island	5	30400	34600	33160	Swain and Walton 1990
Iron	North Arm (2 sites)	10	34400	42400	--	Swain and Walton 1990
Iron	Main Arm (2 sites)	9	33800	39100	--	Swain and Walton 1990

TABLE 3.3-4

METALS MEASURED IN SEDIMENTS OF THE FRASER RIVER ESTUARY DURING RECENT STUDIES
(Values in ug/g)

PARAMETER	LOCATION	N	MINIMUM	MAXIMUM	MEAN	REFERENCE
Iron	Main Stem near Barnston Island	10	15200	18400	17050	Swain and Walton 1988
Iron	Upper North Arm	10	20000	25300	22340	Swain and Walton 1988
Iron	Main Arm - Annacis Island	10	22300	28600	24830	Swain and Walton 1988
Lead	Lower Fraser (11 sites)	31	5	19	--	Present Study
Lead	Near Paperboard Industries	4	<10	12	<10.5	Swain and Walton 1992
Lead	Near Chatterton Petrochemical	5	<10	27	12	Swain and Walton 1992
Lead	Gunderson Slough*	5	<10	378	62	Swain and Walton 1992
Lead	Main Stem near Barnston Island	5	6.55	9.17	8.02	Swain and Walton 1990
Lead	North Arm (2 sites)	10	13.8	24.0	--	Swain and Walton 1990
Lead	Main Arm (2 sites)	9	9.56	12.6	--	Swain and Walton 1990
Lead	Main Stem near Barnston Island	4	<10	20	12.5	Swain and Walton 1988
Lead	Upper North Arm	5	<10	30	18.0	Swain and Walton 1988
Lead	Main Arm - Annacis Island	3	<10	20	16.7	Swain and Walton 1988
Nickel	Lower Fraser (11 sites)	31	34.9	46.2	--	Present Study
Nickel	Near Paperboard Industries	4	45.6	64.7	54.5	Swain and Walton 1992
Nickel	Near Chatterton Petrochemical*	5	37.5	52.9	47.8	Swain and Walton 1992
Nickel	Gunderson Slough*	5	28.4	67.3	49.3	Swain and Walton 1992
Nickel	Main Stem near Barnston Island	5	50.9	55.1	53.5	Swain and Walton 1990
Nickel	North Arm (2 sites)	10	48.8	55.2	--	Swain and Walton 1990
Nickel	Main Arm (2 sites)	9	46.9	54.6	--	Swain and Walton 1990
Nickel	Main Stem near Barnston Island	10	28	32	30.9	Swain and Walton 1988
Nickel	Upper North Arm	10	34	38	35.9	Swain and Walton 1988
Nickel	Main Arm - Annacis Island	10	33	40	37.8	Swain and Walton 1988
Zinc	Lower Fraser (11 sites)	31	55.7	207	--	Present Study
Zinc	Near Paperboard Industries	4	88.4	116	100	Swain and Walton 1992
Zinc	Near Chatterton Petrochemical*	5	64.2	278	86.8	Swain and Walton 1992
Zinc	Gunderson Slough*	5	110	4440	413	Swain and Walton 1992
Zinc	Main Stem near Barnston Island	5	83.1	93.6	89.1	Swain and Walton 1990
Zinc	North Arm (2 sites)	10	133	220	--	Swain and Walton 1990
Zinc	Main Arm (2 sites)	9	97.9	111	--	Swain and Walton 1990
Zinc	Main Stem near Barnston Island	10	34	43	38.8	Swain and Walton 1988
Zinc	Upper North Arm	10	61	81	69.7	Swain and Walton 1988
Zinc	Main Arm - Annacis Island	10	58	69	63.4	Swain and Walton 1988

* Geometric mean given

N - total number of samples (replicates X sites)

ND - Not detectable

The highest average and highest single sample concentrations of aluminum, iron, copper, and nickel occurred in the samples from the LaFarge Cement IDZ. In addition, the second highest concentrations of lead occurred at this site (Table 3.3-3). Previous studies (Swain 1980, Supervisory Coordinating Committee 1987) have noted elevated levels of aluminum in effluents from LaFarge Cement. In addition, the plant historically contributed loadings of iron, copper and lead (Swain 1980). The copper and lead levels at the LaFarge site are not particularly elevated by comparison with levels measured in the 1991 effluent monitoring study (Swain and Walton 1992). The iron concentrations are slightly elevated by comparison with levels measured in 1991 at sites other than Gunderson Slough. The aluminum concentrations are higher than those measured at any site including Gunderson Slough (Table 3.3-4). However, aluminum levels measured in the present study were generally higher than those encountered in the 1991 study and could reflect either analytical or temporal differences.

3.3.3 Chlorophenols

Pentachlorophenol was detectable in each of the three samples from IFP Port Hammond, IFP Fraser Mills, and Domtar. It was not detected ($<0.005 \mu\text{g/g}$) in any of the samples from Scott Paper or MacMillan Bloedel or in the reference sample from Mission. Tetra- and trichlorophenols were not detectable in any sample, but for a number of samples, interferences caused the detection limits to be elevated (0.010 or $0.050 \mu\text{g/g}$).

The concentrations of pentachlorophenol in two of the three samples from Port Hammond and Fraser Mills exceeded the $0.010 \mu\text{g/g}$ Water Quality Objective for total chlorophenols in Fraser River sediments (Swain and Holms 1985) (Table 3.3-5). Pentachlorophenol concentrations in sediment samples from the Domtar site were less than or equal to the Objective.

TABLE 3.3-5

MEAN CONCENTRATIONS OF CHLOROPHENOLS AT INDUSTRIAL SITES IN THE FRASER RIVER ESTUARY, 1993

(Values in ug/g)

PARAMETER	MDC	REFERENCE (MISSION)	PORT HAMMOND	FRASER MILLS	SCOTT PAPER	MACMILLAN BLOEDELL	DOMTAR
PARAMETER	MDC	REFERENCE (MISSION)	PORT HAMMOND	FRASER MILLS	SCOTT PAPER	MACMILLAN BLOEDELL	DOMTAR
%Sand	0.1	25.2	45.0	18.9	49.9	30.4	21.5
%Silt	0.1	35.9	26.0	26.7	22.9	29.1	31.2
%Clay	0.1	38.9	29.0	54.5	27.2	40.5	47.3
Total Organic Carbon	n/a	7100	6900	7867	8383	6850	7400
Pentachlorophenol	0.005	< 0.005	0.013	0.014	<	< 0.005	0.008
Tetrachlorophenols	0.005	< 0.005	<	<	<	< 0.005	<
Trichlorophenols	0.005	< 0.005	<	<	<	< 0.005	<

MDC = Minimum Detectable Concentration

n/a = not applicable (calculated value)

< = not detected

The chlorophenol levels encountered in the present study were generally similar to levels measured in sediments from the Fraser Estuary during other recent studies (Table 3.3-6).

TABLE 3.3-6

CHLOROPHENOLS MEASURED IN SEDIMENTS OF THE FRASER RIVER ESTUARY DURING RECENT STUDIES
(Values in ug/g)

PARAMETER	LOCATION	N	MINIMUM	MAXIMUM	MEAN	REFERENCE
Pentachlorophenol	Lower Fraser (6 sites)	16	<0.005	0.020	--	Present Study
Pentachlorophenol	Near Paperboard Industries	4	<0.005	0.009	0.006	Swain and Walton 1992
Pentachlorophenol	Near Chatterton Petrochemical	5	<0.005	0.014	0.006	Swain and Walton 1992
Pentachlorophenol	Gunderson Slough*	5	<0.005	0.338	0.015	Swain and Walton 1992
Pentachlorophenol	Lower Fraser (6 sites)	25	<0.005	<0.005	<0.005	Swain and Walton 1990
Pentachlorophenol	Near Wood Preserving Plant	1	--	0.107	--	Garrett and Shrimpton 1988
Pentachlorophenol	Iona Island	1	--	0.010	--	Rogers & Hall 1987
Tetrachlorophenol	Lower Fraser (6 sites)	16	<0.005	<0.050	--	Present Study
Tetrachlorophenol	Lower Fraser (6 sites)	25	<0.005	<0.005	<0.005	Swain and Walton 1990
Tetrachlorophenol	Near Wood Preserving Plant	1	--	0.063	--	Garrett and Shrimpton 1988
Tetrachlorophenol	Iona Island	1	--	0.013	--	Rogers & Hall 1987

* Geometric mean given

N - total number of samples (replicates X sites)

3.3.4 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) were analyzed only in the samples from Domtar, Westshore Terminals (Roberts Bank), and the reference site at Mission. Some of these compounds were present in all samples, but levels were considerably lower in the reference sample than in the samples from the downstream sites (Table 3.3-7). Concentrations of all PAHs except benzo(a)pyrene and indeno(1,2,3-c,d)pyrene were also higher at the Domtar and Westshore Terminals sites than at the Fraser Port/BC Environment reference site at Barnston Island (Swain and Walton 1990).

TABLE 3.3-7

**MEAN
CONCENTRATIONS OF POLYCYCLIC
AROMATIC
HYDROCARBONS
AT INDUSTRIAL
SITES IN THE
FRASER RIVER
ESTUARY, 1993
(Values in ug/g)**

PARAMETER	MDC	REFERENCE (MISSION)	ARITHMETIC MEAN	ROBERTS BANK	GEOMETRIC MEAN	ROBERTS BANK
			DOMTAR		DOMTAR	
%Sand	0.1	25.2	21.5	73.6	---	---
%Silt	0.1	35.9	31.2	17.4	---	---
%Clay	0.1	38.9	47.3	9.1	---	---
Total Organic Carbon	n/a	7100	7400	7667	---	---
Naphthalene	0.001	0.004	0.013	0.042	0.012	0.034
Acenaphthylene	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001
Acenaphthene	0.001	< 0.001	0.026	< 0.001	0.015	< 0.001
Fluorene	0.001	< 0.001	0.011	0.026	0.010	0.020
Phenanthrene	0.001	0.009	0.047	0.082	0.043	0.068
Anthracene	0.001	0.007	0.007	0.062	0.007	0.016
Total low MW PAH's	0.001	0.020	0.102	0.212	0.091	0.159
Fluoranthene	0.001	0.008	0.079	0.010	0.065	0.009
Pyrene	0.001	0.010	0.070	0.013	0.058	0.012
Benzo(c)phenanthrene	0.001	< 0.001	0.006	< 0.001	0.005	< 0.001
Benz(a)anthracene	0.001	0.002	0.025	0.009	0.021	0.008
Chrysene	0.001	0.004	0.028	0.020	0.025	0.017
Benzo(b+k)fluoranthene	0.001	0.005	0.038	0.010	0.033	0.009
Benzo(j)fluoranthene	0.001	< 0.001	0.003	< 0.001	0.003	< 0.001
7 12-Dimethylb(a)a	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Benzo(a)pyrene	0.001	0.003	0.013	0.006	0.012	0.006
3-Methylcholanthrene	0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Indeno(1 2 3-c d)pyr	0.002	< 0.002	0.006	0.003	0.005	0.003
Dibenz(a h)anthracen	0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Benzo(g h i)perylene	0.002	< 0.002	0.007	0.006	0.006	0.005
Dibenzo(a l)pyrene	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Dibenzo(a i)pyrene	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Dibenzo(a h)pyrene	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Total high MW PAH's	0.005	0.032	0.275	0.079	0.233	0.068
Total PAH's	0.005	0.052	0.377	0.288	0.325	0.227

MDC = Minimum
Detectable Concentration
n/a = not applicable
(calculated value)
< = not detected

The distribution of individual PAHs differed between the Domtar and Roberts Bank sites. The concentrations of acenaphthene, benzo(a)anthracene, benzo(a)pyrene, fluoranthene and pyrene were higher near Domtar. Concentrations of anthracene, fluorene, naphthalene, and phenanthrene were higher at Roberts Bank. Overall, the concentrations of low molecular weight PAHs were higher at Roberts Bank, while the concentrations of high molecular weight PAHs and total PAHs were higher at Domtar.

The concentrations of all PAHs except acenaphthene, anthracene, benzo(a)anthracene and chrysene at Domtar and Roberts Bank were similar to or lower than levels reported at some other sites in the Fraser Estuary in recent studies (Table 3.3-8). Swain (1993) noted that at one or more sites in the estuary, concentrations of PAHs including benzo(g,h,i)perylene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, and phenanthrene exceeded Water Quality Objectives set for sediments in Burrard Inlet (but not officially applicable to the Fraser Estuary). In the present study, these Objectives were met at all sites except a single sample from Domtar in which acenaphthene (0.059 µg/g) slightly exceeded the 0.05 µg/g objective.

TABLE 3.3-8

POLYCYCLIC AROMATIC HYDROCARBONS MEASURED IN SEDIMENTS OF THE FRASER RIVER ESTUARY DURING RECENT STUDIES

(Values in ug/g)

PARAMETER	LOCATION	N	MIN.	MAX.	MEAN	REFERENCE
Acenaphthene	Roberts Bank	3	<0.001	<0.001	<0.001	Present Study
Acenaphthene	Near Domtar	3	0.004	0.059	0.026	Present Study
Acenaphthene	Eburne Slough	1	--	0.030	--	Swain 1993
Acenaphthene	Lower Fraser (6 sites)	25	<0.005	<0.005	--	Swain and Walton 1990
Acenaphthylene	Roberts Bank	3	<0.001	<0.001	<0.001	Present Study
Acenaphthylene	Near Domtar	3	0.001	0.002	0.001	Present Study
Acenaphthylene	Eburne Slough	N.G	--	0.011	--	Swain 1993
Acenaphthylene	Lower Fraser (6 sites)	25	<0.005	0.053	--	Swain and Walton 1990
Acenaphthylene	Lower Fraser, Near STP	1	--	--	<0.015	Rogers & Hall 1987
Anthracene	Roberts Bank	3	<0.001	0.093	0.062	Present Study
Anthracene	Near Domtar	3	0.004	0.011	0.007	Present Study
Anthracene	Eburne Slough	N.G	--	0.046	--	Swain 1993
Anthracene	Lower Fraser (6 sites)	25	<0.005	0.070	--	Swain and Walton 1990
Anthracene	Fraser Estuary (10 sites)	10	ND	0.003	--	Hall et al. 1986
Benzo(a)anthracene	Roberts Bank	3	0.003	0.012	0.009	Present Study
Benzo(a)anthracene	Near Domtar	3	0.008	0.036	0.025	Present Study
Benzo(a)anthracene	Lower Fraser (6 sites)	25	<0.010	0.012	--	Swain and Walton 1990
Benzo(a)anthracene	Fraser Estuary (10 sites)	10	ND	0.018	--	Hall et al. 1986
Benzo(a)pyrene	Roberts Bank	3	0.004	0.008	0.006	Present Study
Benzo(a)pyrene	Near Domtar	3	0.005	0.017	0.013	Present Study
Benzo(a)pyrene	Lower Fraser (6 sites)	25	<0.02	0.10	--	Swain and Walton 1990
Benzo(g,h,i)perylene	Roberts Bank	3	0.002	0.009	0.006	Present Study
Benzo(g,h,i)perylene	Near Domtar	3	0.002	0.010	0.007	Present Study
Benzo(g,h,i)perylene	Lower Fraser (6 sites)	25	<0.02	0.091	--	Swain and Walton 1990
Chrysene	Roberts Bank	3	0.007	0.027	0.020	Present Study
Chrysene	Near Domtar	3	0.013	0.036	0.028	Present Study
Chrysene	Lower Fraser (6 sites)	25	<0.010	<0.010	--	Swain and Walton 1990
Chrysene	Fraser Estuary (10 sites)	10	ND	0.004	--	Hall et al. 1986
Fluoranthene	Roberts Bank	3	0.004	0.014	0.010	Present Study
Fluoranthene	Near Domtar	3	0.027	0.13	0.079	Present Study
Fluoranthene	Eburne Slough, North Arm	N.G	0.17	0.30	--	Swain 1993
Fluoranthene	Lower Fraser (6 sites)	25	<0.010	0.085	--	Swain and Walton 1990
Fluoranthene	Lower Fraser, Near STP	1	--	--	0.115	Rogers & Hall 1987
Fluoranthene	Fraser Estuary (10 sites)	10	trace	0.139	--	Hall et al. 1986
Fluorene	Roberts Bank	3	0.007	0.035	0.026	Present Study
Fluorene	Near Domtar	3	0.005	0.014	0.011	Present Study
Fluorene	Eburne Slough	N.G	--	0.052	--	Swain 1993
Fluorene	Lower Fraser (6 sites)	25	<0.005	0.005	--	Swain and Walton 1990
Fluorene	Fraser Estuary (10 sites)	10	ND	0.098	--	Hall et al. 1986
Indeno (1,2,3-c,d)pyrene	Roberts Bank	3	0.002	0.003	0.003	Present Study
Indeno (1,2,3-c,d)pyrene	Near Domtar	3	0.003	0.008	0.006	Present Study
Indeno (1,2,3-c,d)pyrene	Deas Slough	N.G	--	0.094	--	Swain 1993
Indeno (1,2,3-c,d)pyrene	Lower Fraser (6 sites)	25	<0.02	0.32	--	Swain and Walton 1990
Naphthalene	Roberts Bank	3	0.013	0.065	0.042	Present Study
Naphthalene	Near Domtar	3	0.009	0.015	0.013	Present Study
Naphthalene	Eburne Slough	N.G	--	0.035	--	Swain 1993
Naphthalene	Lower Fraser (6 sites)	25	<0.005	0.13	--	Swain and Walton 1990
Naphthalene	Lower Fraser, Near STP	1	--	--	<0.015	Rogers & Hall 1987
Naphthalene	Fraser Estuary (10 sites)	10	ND	trace	--	Hall et al. 1986

TABLE 3.3-8

**POLYCYCLIC AROMATIC HYDROCARBONS MEASURED IN SEDIMENTS OF THE FRASER RIVER ESTUARY
DURING RECENT STUDIES**

(Values in ug/g)

PARAMETER	LOCATION	N	MIN.	MAX.	MEAN	REFERENCE
Phenanthrene	Roberts Bank	3	0.026	0.11	0.082	Present Study
Phenanthrene	Near Domtar	3	0.024	0.058	0.047	Present Study
Phenanthrene	Deas Slough	N.G.	--	0.74	--	Swain 1993
Phenanthrene	North Arm, Eburne Slough	N.G.	0.18	0.26	--	Swain 1993
Phenanthrene	Lower Fraser (6 sites)	25	<0.005	0.40	--	Swain and Walton 1990
Phenanthrene	Lower Fraser, Near STP	1	--	--	0.044	Rogers & Hall 1987
Phenanthrene	Fraser Estuary (10 sites)	10	trace	0.075	--	Hall et al. 1986
Pyrene	Roberts Bank	3	0.005	0.018	0.013	Present Study
Pyrene	Near Domtar	3	0.023	0.11	0.070	Present Study
Pyrene	Lower Fraser	N.G.	--	0.230	--	Swain 1993
Pyrene	Lower Fraser (6 sites)	25	<0.010	0.040	--	Swain and Walton 1990
Pyrene	Lower Fraser, Near STP	1	--	--	0.045	Rogers & Hall 1987
Pyrene	Fraser Estuary (10 sites)	10	trace	0.335	--	Hall et al. 1986

N - total number of samples (replicates X sites)

N.G. - Not given

ND - Not detected

Note: No PAHs were detected at Paperboard Industries, Chatterton Petrochemical or Gunderson Slough
(Swain and Walton 1992)

3.4 Sediment Toxicity

3.4.1 Solid Phase Microtox

Table 3.4-1 gives the solid phase Microtox test results. The Microtox test indicated that, on average, sediments from the Scott Paper, LaFarge Canada, and Fraser Wharves sites were more toxic than the reference sediments, with Fraser Wharves having the most toxic sediments of the three sites.

**TABLE 3.4-1
RESULTS OF FRASER RIVER SEDIMENT MICROTOX TESTS**

LOCATION	EC50 VALUE	MEAN	t VALUE	TEST RESULT
Mission (Reference)	1.83 ¹	1.83		
Roberts Bank Outfall 100M East 100M West	9.27 4.95 7.35	7.19	-	-
Port Hammond Middle Upstream Downstream	9.87 2.11 3.08	5.02	-	-
Fraser Mills Outfall 100M Upstream 200M Downstream	0.62 1.87 1.26	1.25	1.13	NS
Scott Paper Outfall 100M Upstream 100M Downstream	0.73 1.04 0.35	0.71	4.33	S
MacMillan Bloedel Outfall 100M Downstream 200M Downstream	1.90 1.61 1.41	1.64	0.94	NS
Tree Island Indust. Outfall 50M Downstream 150M Downstream	3.04 1.49 4.27	2.93	-	-
Lafarge Outfall 100M Upstream 100M Downstream	0.75 0.52 0.95	0.74	421.1	S
Tilbury Middle South North	1.74 0.77 3.16	1.89	-	-
Domtar Outfall 100M Downstream 200M Downstream	1.49 1.80 2.52	1.94	-	-
Fraser Wharves Outfall 100M Upstream 100M Downstream	0.29 0.26 0.23	0.26	191.8	S

1. Composite of 3

NS = Not Significant

S = Significant (P<0.05)

The reason for the sediment toxicity at these sites was not apparent from the sediment chemistry results. The metal levels at the LaFarge site were elevated by comparison with most sites, but lower than the levels at Tree Island Industries, where the sediments were not toxic. The sediments from Scott Paper had no detectable chlorophenols; organic compounds were not measured at the other sites. However, the sediments from LaFarge Cement and Fraser Wharves had higher total organic carbon content than any other sites. In addition, an oily sheen was present in the LaFarge sediments. These observations imply that some unmeasured organic compound(s) were responsible for the toxicity.

Toxicity also appeared, in part, to be related to the available dilution. The theoretical dilution at 100 m from the effluent was lowest for the Fraser Wharves and Scott Paper sites. However, the dilution at LaFarge Cement was among the highest of the sites studied (Table 3.1-1).

In addition, the significance of the toxicity at Fraser Wharves is unclear. As the site does not currently have a discharge, the apparent toxicity must be related either to persistent toxicants previously discharged, toxicants released from another source, or response of the bacteria to some factor other than toxicity.

The sediments from Westshore Terminals and IFP Port Hammond and two of the three samples from Tree Island Industries were considerable less "toxic" to the bacteria than were the reference sediments from Mission. Although this result could imply the presence of toxic compounds at Mission, an alternate explanation is possible. The solid phase Microtox test is highly sensitive to sediment particle size and possibly organic carbon (Environment Canada 1992b). The sediments from Westshore Terminals had a substantially lower proportion of clay than the Mission sediments (mean 9.1% vs. 38.9%). The Port Hammond sediments also had a lower proportion of clay than the reference sediments (mean 29%).

3.4.2 *Macoma balthica*

The *Macoma balthica* test did not show particular toxicity in any of the sediments (Table 3.4-2). In one of the three tests of sediments from the Scott Paper IDZ, the bivalves appeared to favour the control sediments (15 animals in the control sediment, 5 in the test sediment). However, when viewed in the context of 31 separate tests (three samples from each industry and one reference sample), the uneven distribution in a single test cannot be considered statistically significant.

TABLE 3.4-2
RESULTS OF FRASER RIVER SEDIMENT *MACOMA*
***BALTHICA* BIOASSAYS**

LOCATION	Number of Animals after 10 Days		TEST RESULT
	Control Sediment	Test Sediment	
Control Sediment	8	12	
Mission (Reference)	12	8	NS
Roberts Bank			
Outfall	12	8	NS
100M East	10	10	NS
100M West	11	9	NS
Port Hammond			
Middle	12	8	NS
Upstream	9	11	NS
Downstream	10	9	NS
Fraser Mills			
Outfall	10	10	NS
100M Upstream	10	10	NS
200M Downstream	10	10	NS
Scott Paper			
Outfall	8	12	NS
100M Upstream	15	5	S
100M Downstream	12	8	NS
MacMillan Bloedel			
Outfall	10	10	NS
100M Downstream	11	9	NS
200M Downstream	10	10	NS
Tree Island Indust.			
Outfall	10	10	NS
50M Downstream	10	10	NS
150M Downstream	9	11	NS
Lafarge			
Outfall	11	9	NS
100M Upstream	12	8	NS
100M Downstream	11	9	NS
Tilbury			
Middle	11	9	NS
South	12	8	NS
North	10	10	NS
Domtar			
Outfall	10	10	NS
100M Downstream	11	9	NS
200M Downstream	10	10	NS
Fraser Wharves			
Outfall	10	10	NS
100M Upstream	13	7	NS
100M Downstream	10	10	NS

NS = Not Significant

S = Significant (P<0.05)

This result suggests that the *Macoma* test is less sensitive to the toxicants present in the sediments than the Microtox test, assuming that the Microtox results actually reflect toxicity and not responses to sediment particle size or organic content.

CONCLUSIONS AND RECOMMENDATIONS

4.1 IDZ Impacts

Overall, the IDZ study indicated some localized effects of the industries but no apparent widespread impacts. Concentrations of metals and organic compounds in the sediments were generally higher at the industrial sites than at the upstream reference site. However, they were within the same range or lower than levels measured at other sites in the Fraser Estuary over the past five years.

There were limited indications of sublethal toxic effects from some of the industries. The only receiving water toxicity noted (a reduction in the fecundity of *Ceriodaphnia*) occurred at Scott Paper. In addition, the sediments from the Scott Paper, LaFarge Cement, and Fraser Wharves were more toxic to luminescent bacteria (Microtox) than was the reference sediment from Mission.

It was not possible to identify the compound(s) responsible for sediment toxicity based on the chemical characterization data for the sediments. However, toxicity in both the sediments and the water column appeared largely related to available dilution. The Scott Paper and Fraser Wharves sites had the lowest dilutions of the sites studied, based on the field estimates. Dilution was high at the LaFarge Cement site, and toxicity may have been related to the oily sheen observed in the sediments.

4.2 Recommendations for Future Studies

One of the objectives of the IDZ study was to determine appropriate design for future studies, including sampling locations, chemical parameters to measure in water and sediment, and species for toxicity testing. Based on the successes and limitations of the present study, we offer the following recommendations:

- (1) Future IDZ impact assessments should be closely linked to the wastewater characterization program currently being conducted in the estuary. Ideally, the results of wastewater characterization should be used to determine the chemical parameters and types of toxicity tests to be used in follow-up IDZ assessments. As the current study was the first survey of this type, it included only a limited suite of chemical parameters. Future IDZ surveys should be part of an overall study design for a long-term monitoring strategy for the estuary.
- (2) Receiving water testing should continue to include field measurements for pH dissolved oxygen, temperature and conductivity, which may provide some evidence of the impact of an effluent plume. Additional upstream measurements (assuming

downstream flow) of these parameters are recommended to provide background data with which to compare conditions in the plume.

- (3) The *Ceriodaphnia* bioassay appears to be an appropriate test for receiving waters, but if Microtox or algal assays (which have recently been recommended for effluent characterization) prove more sensitive to a particular effluent, these tests should be considered for the receiving water.
- (4) Some modifications to the receiving water bioassay protocols are suggested. The presence or absence of toxicity in the receiving water may be more significant than the determination of a "no effect" dilution, especially when the initial dilution in the receiving water is not known precisely. Determining presence/absence of toxicity would require only a single test concentration (100%). In addition, another control sample should be added. The purpose of the additional control is to test for possible effects of other (unmonitored) discharges near the outfall being studied. The water for this sample should be collected immediately upstream of the IDZ for each industry included in the program.
- (5) If budget can be allocated, the list of parameters to be measured in all sediments should be expanded to include some parameters that may be widely distributed throughout the Fraser Estuary and thus may contribute to toxicity at sites other than their source(s). Specifically, PAHs should be considered a priority for addition to the standard parameter list because they are discharged in urban runoff as well as in various industrial effluents, and PAH levels above the Burrard Inlet objectives have been found at various locations in the estuary (Swain 1993). Chlorophenols (preferable measured by GC/MS, which reduces the problems with interferences) should be considered the next priority because of their persistence and history of widespread discharge in runoff from sawmills and discharge from contaminated areas. However, the priority for chlorophenol analyses at all sites is reduced because they are no longer used by sawmills, and their only local source is wood preservation plants.
- (6) The standard list of chemical parameters (to be measured in all sediment samples) should continue to include metals (because of their wide distribution and possible toxicity) and particle size and total organic carbon (because the latter parameters can affect toxicity tests). Arsenic analyses should be done by hydride generation.
- (7) Because different types of organisms may be sensitive to different types of toxicants, sediment bioassays should include at least two tests on organisms from different taxonomic groups. The Microtox test should be included in future studies because the bacteria represent a different taxonomic level than the organisms used in all of the other potential sediment tests.

However, the solid phase Microtox methodology needs to be refined. The response of the Microtox bacteria is affected by sediment particle size and possibly

organic carbon content. The Environment Canada (1992) protocols recommend matching the test sediments and reference sediments as closely as possible with respect to these parameters. The protocols also recommended the development of a set of standard reference sediments. Such standard reference sediments are not yet available. In their absence, the following recommendations apply:

Some preliminary sediment particle size and organic carbon analyses should be done to assure an appropriate match between reference and test sediments.

If future studies include several sites with different sediment characteristics, more than one reference sediment should be selected.

- (8) The choice of one or more additional sediment bioassays to be included in routine monitoring surveys merits further research. The other bioassays suggested for the Fraser Estuary program include amphipods, insects (*Chironomus tentans*), and *Macoma balthica*. If there is to be a standard test organism for the estuary, then *Macoma* may be the organism of choice. They survived well in sediments from the entire study area, including the marine sediments from Roberts Bank and the freshwater sediments from Mission. It is doubtful that either the freshwater *Chironomus* or the marine amphipods would have such a wide tolerance range.

However, the relative sensitivities of these different test organisms to toxicants is unknown. In the present study, the *Macoma* did not respond significantly to any of the test sediments. This could reflect either the relatively non-toxic nature of the sediments or the relative insensitivity of the clams. Therefore, if funding for research is available, some comparative testing (in a range of salinities) of *Macoma*, *Chironomus tentans*, and a marine amphipod is recommended.

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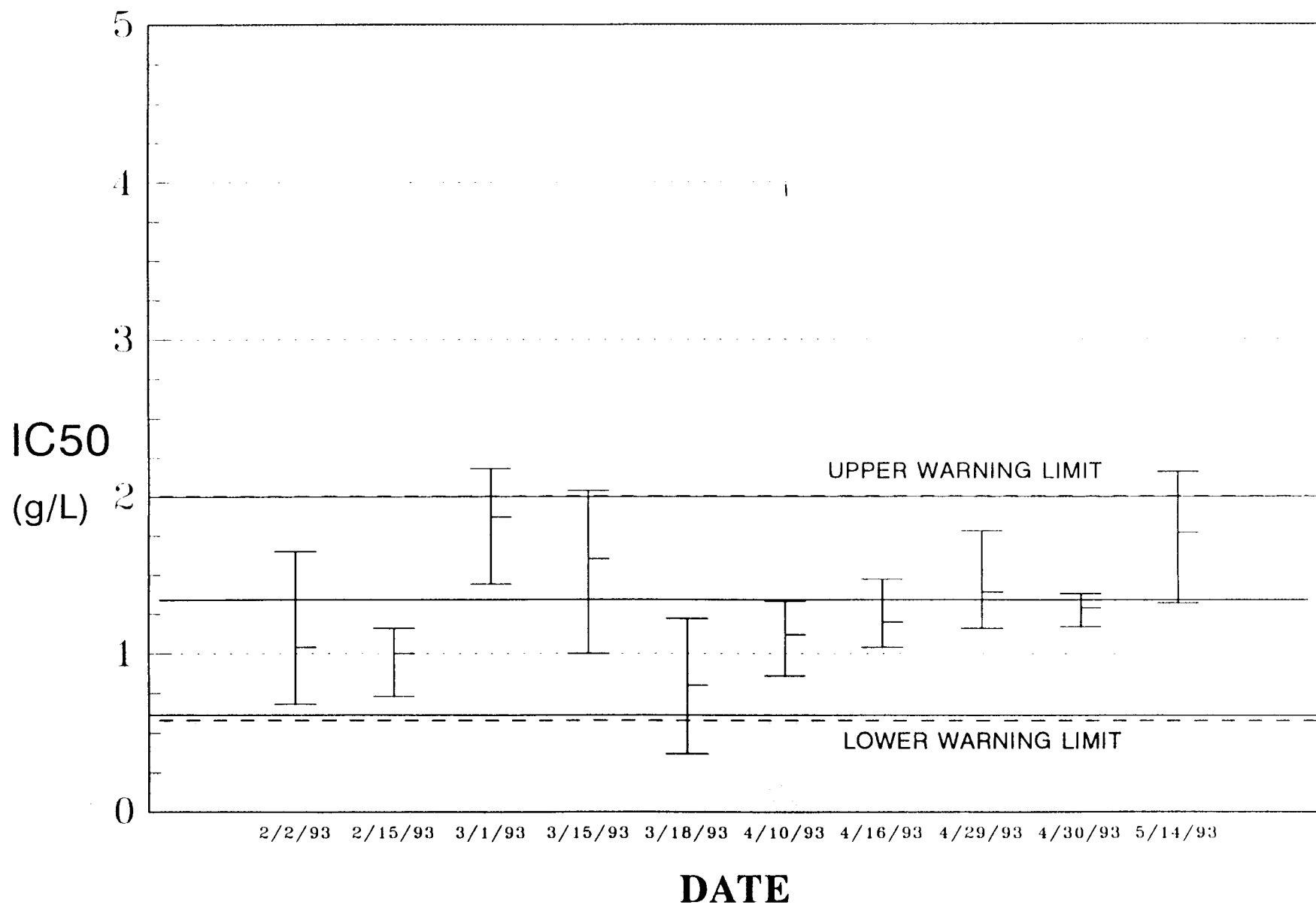
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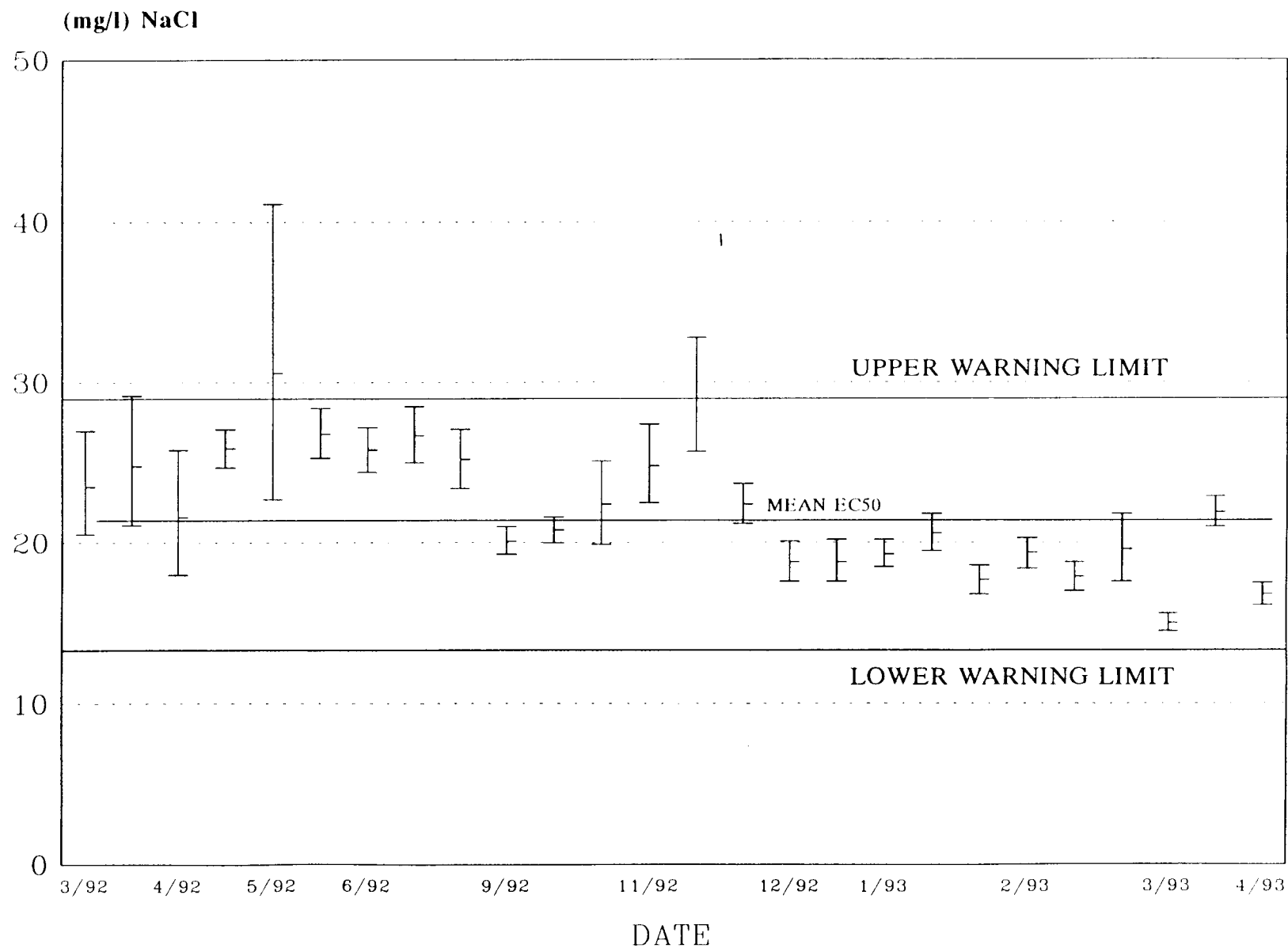
Appendix 1

QA/QC for Toxicity Tests

CONTROL CHART: CERIODAPHNIA SENSITIVITY TO REFERENCE TOXICANT (SODIUM CHLORIDE) IC50



CONTROL CHART: MICROTOX SENSITIVITY TO REFERENCE TOXICANT (SODIUM CHLORIDE) EC50



Appendix 2

Zenon Environmental Laboratories Analytical and QA/QC Methods



Ms. Annette Smith
Norecol Dames And Moore
250-13571 Commerce ParkWay
Richmond, B.C.
V6Y 2R2

June 8, 1993

Dear Ms. Smith:

Re: FREMP Sediment Assay

Regional
Laboratories:
British Columbia
Ontario
Quebec

Please find enclosed a brief explanation of analytical methods used to generate data for the FREMP Sediment Assay project. Methods used by Zenon are based upon those found in "Standard Methods for the Examination of Water and Wastewater", Sixteenth Edition, published by the American Public Health Association, 1015 Fifteenth Street, NW, Washington, DC 20005. Other methods are derived from the principles of the EPA or BC MOE methodologies quoted.

Polycyclic Aromatic Hydrocarbons (BC MOE): the sample is spiked with the appropriate, labelled, surrogate compounds. The sample is then Soxhlet extracted with dichloromethane. The extract is cleaned up on silica and concentrated to 1 ml. and analysed by GC/MS with a HP 5890 GC and a HP 5970 MSD. Selected ion monitoring is used to analyze all of the compounds to the required detection limit.

Chlorophenols (BC MOE): surrogates are added the sample is then extracted with a mixture of methylene chloride, methanol and sulphuric acid. The acidic components are then re-extracted into methylene chloride under acidic conditions. The extract is derivatized with diazomethane and cleaned up by Florisil column chromatography. The derivatives are analyzed by electron capture gas liquid chromatography.

MDC's were raised for chlorophenols due to sample dilutions. Dilutions were required for elevated levels and matrix interferences.

Metals (SM 302 F & SM 305): dried, ground and sieved soil samples are digested with nitric and perchloric acids (see attached SOP). The digestate is analyzed using simultaneous ICP. The sample is aspirated into the ICP for excitation of atoms and emission of electromagnetic radiation. The amount of radiation emitted is proportional to the analytes concentration.



Selenium (SM 302 F & 303E): air-dried, ground and sieved soil samples are digested with aqua regia. A diluted portion of this digestate is reduced with sodium borohydride forming the metal hydrides. These hydrides are then analyzed by sequential ICP or atomic absorption spectrophotometry and quantified using digested standards.

TOC (BC MOE): total organic carbon (TOC) is determined by calculating the difference of total carbon (TC) minus total inorganic carbon (TIC). To determine TC an induction furnace and an oxygen atmosphere are used to combust the sample to carbon monoxide (CO)/carbon dioxide (CO₂). A catalytic furnace converts the CO to CO₂. The resulting CO₂ together with the oxygen displaces fluid in a burette before and after absorption in a KOH solution. The difference in the burette readings is proportional to the CO₂ concentration in the sample. TIC is determined by first ashing the sample at 550°C to remove the organic carbon, and then following the above procedure.

Particle Sizing: a representative sub-sample is dried, preground and presieved through #10 mesh. The sample is then sieved, on a shaker, through #200 mesh (0.075-2.0 mm) sand, #400 mesh (0.038-0.075 mm) silt, and <#400 (0.0-0.038 mm) clay.

Your samples will be retained at Zenon for a period of 30 days from receipt of data. Thank you for the opportunity of working with you on this project. Please call me if you have any questions or need of further analytical services.

Yours truly,

Brent Kelly, BSc
Project Manager

Encl.
BPK/bk

Regional

Laboratories:

British Columbia

Ontario

Québec

Quality Control /Quality Assurance (QA/QC)

A complete QA/QC program is employed by ZENON. ZENON participates in many internal and external studies; the quality of results and methods are continuously being evaluated. Measures that were specifically used in this study are described below.

Method blanks

Laboratory method blank data are included in the results. A method blank is an analysis incorporating all aspects of the analysis, excluding the sample. Its value is to identify the presence of glassware, reagent or instrumentation induced contamination. In this study, two method blank were reported for this batch.

Some metals are present in the blanks. Calcium, Sodium and Zinc are all abundant in the environment, their presence in the blank is very difficult to eliminate. They are normally found in the blanks at levels near or at the detection limit. Aluminium, Copper, Iron, Sulphur and Lead are occasionally present in the blanks at or near the detection limit. The source is unknown. When blanks are contaminated, samples are checked for high values, if gross contamination is suspected the whole batch is redigested and analysed.

Duplicate Data

Samples are analysed in duplicate to ensure consistency of results. The original sample and the duplicate should have comparable values. Given an acceptable 25% deviation range. This acceptable 25% deviation range applies to actual results only, not to calculated results nor to results less than 5 times the method detection limit. As the result approaches the detection limit, the precision of the result decreases and therefore deviations in duplicates would increase.

Surrogate Standards

A surrogate standard is an organic compound similar in chemical composition to the analytes of interest, but which is not normally found in environmental samples. A known amount of surrogate standard is spiked into samples prior to sample preparation. Surrogate recovery provides information on precision and accuracy of measurements. Di/Tribromophenol Surrogates reported in Zenon sample ID # 3713, 3706, 3707, 3709, 4568 & 4774 were above acceptable range due to matrix interference where unidentified peaks coeluted with the surrogate. Di/Tribromophenol Surrogates reported in Zenon sample ID # 4565, 4566, 4556 & 4561 diluted out due to elevated levels.

Standard Reference Material

Standard reference materials (SRM's) are actual samples available in different matrices that have been extensively analysed by several laboratories and have certified concentration values for the compounds analysed. The analysis of SRM's gives a measure of the accuracy of the method when applied to that matrix. Poor recoveries are generally observed for some metals, such as sodium and titanium, in sediments since the acid digestion does not completely decompose the matrix.

For the metals, externally prepared NIST (National Institute of Standards & Technology) standards were used.

Zenon Environmental Laboratories - Certificate of Analysis

Reported to: Norecol Environmental
 Attention: Annett Smith
 Sample State: Solid

Date Reported: 23-Mar-89
 Quote #: AV93-038
 Project #: FREMP Sed. Assay

Zenon ID#

9304563

Client ID#

Reference Material

Element	MDC ug/g	Measured	Recovery %	
		Value ug/g		
Ag	1	<1.0	ND	
Al	2.0	44800	73.3	
As	10.0	19	81.2	
Ba	0.1	211	50.9	
Be	0.1	1.3	NCV	
Bi	2.0	<2.0	ND	
Ca	1.0	24600	94.6	
Cd	0.1	3.7	107.20	
Co	0.3	10.8	77.1	
Cr	0.2	37.4	27.7	
Cu	0.1	89.7	91.0	
Fe	0.3	39400	95.9	
K	40.0	13000	65.0	
Mg	2.0	11000	91.7	
Mn	0.2	470	84.7	
Mo	0.4	2.2	NCV	
Na	1.0	592	10.8	
Ni	0.8	35.8	81.2	
P	4.0	855	85.6	
Pb	2.0	145	90.0	
S	3.0	2750	69.2	
SB	1.5	<1.5	ND	
Se	10.0	<10	ND	
Sn	2.0	<2	ND	
Sr	0.1	69.4	NCV	
Te	2.0	<2	ND	
Ti	0.3	473	10.3	
Tl	2.0	<2	ND	
V	0.3	57.8	60.800	
Zn	0.2	401	91.600	
Zr	0.3	8.3	NCV	

NOTE:

ND (not detected) due to measured value below MDC

NCV (no certified value available)

Zenon Environmental Laboratories - Certificate of Analysis

Reported to: Norecol Environmental
 Attention: Annett Smith
 Sample State: Solid

Date Reported: 23-Feb-89
 Quote #: AV93-038
 Project #: FREMP Sed. Assay

Zenon ID#
 Client ID#

9303705
 Reference Material

Element	MDC	Measured	Recovery	
		Value		
	ug/g	ug/g	%	
Ag	1	<1.0	ND	
Al	2.0	44500	72.8	
As	10.0	32	136.0	
Ba	0.1	207	50.0	
Be	0.1	1.4	NCV	
Bi	2.0	<2.0	ND	
Ca	1.0	24800	95.4	
Cd	0.1	3.8	110.00	
Co	0.3	11.5	82.1	
Cr	0.2	57.7	42.7	
Cu	0.1	85.6	86.8	
Fe	0.3	39200	95.4	
K	40.0	12100	60.5	
Mg	2.0	10900	90.8	
Mn	0.2	469	84.5	
Mo	0.4	1.6	NCV	
Na	1.0	564	10.3	
Ni	0.8	37.3	84.6	
P	4.0	855	85.7	
Pb	2.0	146	90.7	
S	3.0	3290	82.9	
SB	1.5	<1.5	ND	
Se	10.0	<10	ND	
Sn	2.0	5	NCV	
Sr	0.1	67.3	NCV	
Te	2.0	<2	ND	
Ti	0.3	422	9.2	
Tl	2.0	5.4	NCV	
V	0.3	58.4	61.500	
Zn	0.2	401	91.550	
Zr	0.3	14.2	NCV	

NOTE:

ND (not detected) due to measured value below MDC

NCV (no certified value available)

Digestion of Soils, Sediments and Vegetaion for Metals Analysis

Final conditions: 1:100 dilution of sample.
5% HClO₄

Procedure:

A. Sample Preparation:

- (1) Dry at 105⁰C for 8 hours (Air dry for Hg)
- (2) Grind in mortar and pestle
- (3) Sieve through #10 and #100, regrind #10
- (4) Digest #100 residue

B. Digestion:

- (1) Weigh 0.75g sample into block digester tubes
Weigh 2 standards - Riversilt for soil & sediments
Orchard leaves for vegetation. Record all weights to
four decimal places. Run 2 blanks.
- (2) Add 3 ml conc. HNO₃
- (3) Heat in block digester at 130⁰C until brown
fumes are eliminated. Remove and cool. Solution
should be yellow.
- (4) Add 3.75 ml HClO₄
- (5) Heat in block digester at 220⁰C until dense white fumes
are present and solution is pale yellow or colorless.
Remove and cool.
- (6) Make up to volume in tubes 75 ml. Filter into 250 ml
poly bottles.

Zenon

8577 Commerce Court

Tel 604 444 4808

Environmental

Burnaby B.C.

Fax 604 444 4511

Laboratories

Canada V5A 4N5



TO

Norecol, Dames & Moore, Inc.
Crestwood Corporate Centre
13571 Commerce Parkway
Richmond, B.C., V6V 2R2

DATE

24-Jun-93

FAX NUMBER

TEL NUMBER

273-7791

273-7763

ATTENTION

Annette Smith

NUMBER OF PAGES INCLUDING COVER

3

COMMENTS

Annette:

Re: Question About QA/QC For FREMP Samples

1. The DQO for duplicates Zenon strives to achieve is $< \pm 25\%$ relative percent difference (RPD). When duplicate samples do not achieve DQO the analytical run is examined to ensure that the run QA/QC DQO's (calibration standard check, blanks etc.) were achieved. At this point the sample, both dried and original, is examined for homogeneity. If the difference cannot be attributed to heterogeneity the sample is repeated by digesting another aliquot from the dried, ground and sieved portion of the sample. Original digests are reanalysed if the DQO's for the in run QA/QC samples were not achieved.

In the case of metals, the DQO's are generally only applied to the regulated heavy metals outlined in CCME or CMCS in BC. Elements such as calcium, iron, or aluminium can vary significantly.

Unfortunately there are no published DQO's for solids from a Canadian regulating agency. These are generally established by the laboratory or the client on a project by project basis. USEPA does quote a RPD of $\pm 20\%$ at ten times the method detection limit in SW846 Method 6010 - ICAP Analysis. Attached is a copy of a table outlining precision and accuracy data from a study using this method.

2. Again we are only evaluating the regulated metals since it is not a complete digestion. Chromium, however is an exception where consistently low recoveries are observed. Generally we flag the result if it varies from the norm. Acceptable recoveries are based upon the 95% confidence interval given by the supplier. Methodologies or sample matrix are reviewed if we are unable to recover the heavy metals from the SRM.

Regional

Laboratories:

British Columbia

Ontario

Quebec

3 & 4. Storage will not affect the results for metals analysis. USEPA quotes a hold time of 6 months for solid samples. In regard to your comments on the day to day variability of the SRM's, what was the average recovery for the key elements on those given day?. Arsenic is a bad example since the certified value is only 2 times the method detection limit (MDL). Precision at or near the MDL is $\pm 50-100\%$ and hence a more sensitive technique will provide better precision at these levels. Thus, it is possible to observe positives one day non detects the next day.

4. Yes, should be very carefull when evaluating results that are 2-3 times the MDL. Variabilty is high and thus a more sensitive method should be used to confirm the results. When comparing MDL's to regulatory limits we should always try use methods that provide a comfort zone. We cannot always provide a better method and hence precision studies can be incorporated in the project. To better evaluate results we are compiling SRM data as part of a long term precision study.

Should you wish to dicuss this further please call at any time. Before you start a project let me know and we can discuss what methodologies should be used based on the application of the data.

Regards,

A handwritten signature in black ink, appearing to read 'S/Heier', with a long horizontal line extending to the right.

Shawn D. Heier, BSc
Manager, Client Liaison

TABLE 4.
ICP PRECISION AND ACCURACY DATA^a

Element	<u>Sample No. 1</u>			<u>Sample No. 2</u>			<u>Sample No. 3</u>		
	True Value (ug/L)	Mean Reported Value (ug/L)	Mean SD ^b (%)	True Value (ug/L)	Mean Reported Value (ug/L)	Mean SD ^b (%)	True Value (ug/L)	Mean Reported Value (ug/L)	Mean SD ^b (%)
Be	750	733	6.2	20	20	9.8	180	176	5.2
Mn	350	345	2.7	15	15	6.7	100	99	3.3
V	750	749	1.8	70	69	2.9	170	169	1.1
As	200	208	7.5	22	19	23	60	63	17
Cr	150	149	3.8	10	10	18	50	50	3.3
Cu	250	235	5.1	11	11	40	70	67	7.9
Fe	600	594	3.0	20	19	15	180	178	6.0
Al	700	696	5.6	60	62	33	160	161	13
Cd	50	48	12 2.5	2.9	16	14	13	16	
Co	700	512	10 20	20	4.1	120	108	21	
Ni	250	245	5.8	30	28	11	60	55	14
Pb	250	236	16 24	30	32	80	80	14	
Zn	200	201	5.6	16	19	45	80	82	9.4
Se ^c	40	32	21.9	6	8.5	42	10	8.5	8.3

^aNot all elements were analyzed by all laboratories.

^bSD = standard deviation.

^cResults for Se are from two laboratories.



National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material 2704

Buffalo River Sediment

exhib. 1087

This Standard Reference Material (SRM) is intended primarily for use in the analysis of sediments, soils, or materials of a similar matrix. SRM 2704 is a freeze-dried river sediment that was sieved and blended to achieve a high degree of homogeneity.

The certified elements for SRM 2704 are given in Table 1. The values are based on measurements using two or more independent and reliable analytical methods. Noncertified values for a number of elements are given in Table 2 as additional information on the composition. The noncertified values should not be used for calibration or quality control. Analytical methods used for the characterization of this SRM are given in Table 3 along with analysts and cooperating laboratories. All values (except for carbon) are based on measurements using a sample weight of at least 250 mg. Carbon measurements are based on 100 mg samples.

Notice and Warnings to Users: This certification is valid for 5 years from the shipping date. Should any of the certified values change before the expiration of the certification, purchasers will be notified by NIST.

Stability: This material was radiation sterilized (^{60}Co) at an estimated minimum dose of 2.8 megarads to reduce the rate of any biodegradation. However, its stability has not been rigorously assessed. NIST will monitor this material and will report any substantive changes in certification to the purchaser.

Use: A minimum sample weight of 250 mg (dry weight - see Instructions for Drying) should be used for analytical determinations relating to the certified values on this certificate.

Sample preparation procedures should be designed to effect complete dissolution. If volatile elements (i.e., Hg, As, Se) are to be determined, precautions should be taken in the dissolution of SRM 2704 to avoid volatilization losses.

Statistical consultation was provided by S.B. Schiller and K.R. Eberhardt of the Statistical Engineering Division.

The overall direction and coordination of the analyses were under the chairmanship of M.S. Epstein and B.I. Diamondstone of the Inorganic Analytical Research Division.

The technical and support aspects involved in the preparation, certification, and issuance of this Standard Reference Material were coordinated through the Standard Reference Materials Program by T.E. Gills.

Gaithersburg, MD 20899
July 9, 1990
(Revision of certificate dated 6-1-88)

William P. Reed, Acting Chief
Standard Reference Materials Program

(over)

Table 2. Noncertified Values

<u>Element</u>	<u>Content, Wt. %</u>	<u>Element</u>	<u>Content $\mu\text{g/g}$</u>
Chlorine	(< 0.01)	Bromine	(7)
		Cerium	(72)
		Cesium	(6)
		Dysprosium	(6)
		Europium	(1.3)
		Gallium	(15)
		Hafnium	(8)
		Iodine	(2)
		Lanthanum	(29)
		Lutetium	(0.6)
		Rubidium	(100)
		Scandium	(12)
		Samarium	(6.7)
		Strontium	(130)
		Tin	(9.5)
		Thorium	(9.2)
		Ytterbium	(2.8)
		Zirconium	(300)

Noncertified Values: Noncertified values are provided for information only. An element concentration value may not be certified, if a bias is suspected in one or more of the methods used for certification, or if two independent methods are not available. Certified values for some of these elements may eventually be provided in a revised certificate when more data is available.

	POLAR	Open beaker acid digestion with HF, HClO ₄ , and HNO ₃ with subsequent liquid-liquid extraction.	Cu, Pb, Zn
NRCC	CVAAS	Reflux acid digestion of sample in 250-mL quartz Erlenmeyer flasks with a mixture of HNO ₃ and HClO ₄ .	Hg
	ID-ICPMS	Microwave acid digestion	Ni, Cu, Zn, Pb, Cd, Sb, Sn, Tl, U
	GFAAS	Microwave acid digestion	Cd, Pb, Co, Cu, Ni, As, Sb
	XRF	Mixed tetraborate/carbonate fusion	S
ORAU	INAA	Direct-No preparation	Al, Ca, Fe, K, Na, Ti As, Ba, Ce, Co, Cr, Cs, Dy, Eu, Hf, Lu, Mn, Rb, Sb, Sc, Sm, Th, U, V, Yb, Zn
	CVAAS	Reflux acid digestion	Hg
PE	ICP-MS GFAAS	Microwave acid digestion	Hg, Se, Tl, Se, Tl

^aLaboratory abbreviations:

LANL = Los Alamos National Laboratory, Los Alamos, NM 87545

MCL/PSU = Mineral Composition Laboratory, The Pennsylvania State University, University Park, PA 16802

NIST = Center for Analytical Chemistry, National Institute of Standards & Technology, Gaithersburg, MD 20899

NRCC = Analytical Chemistry Division, National Research Council of Canada, Ottawa, Canada K1A0R6

ORAU = Oak Ridge-Associate Universities, Oak Ridge, TN 37831-0117

PE = Perkin-Elmer Corporation, Norwalk, CT 06859

^bMethod abbreviations:

COLOR = Colorimetry, Photometry, Spectrophotometry

COUL = Coulometry

CVAAS = Cold-Vapor Atomic Absorption Spectrometry

DCP = Direct-Current Plasma Emission Spectrometry

FAAS = Flame Atomic Absorption Spectrometry

FES = Flame Emission Spectrometry

GFAAS = Graphite Furnace Atomic Absorption Spectrometry

GRAV = Gravimetry

HGAAS = Hydride-Generation Atomic Absorption Spectrometry

IC = Ion Chromatography

ICP = Inductively-Coupled Plasma Emission Spectrometry

ID-ICPMS = Isotope-dilution Inductively-Coupled Plasma Mass Spectrometry

IGF = Inert Gas Fusion with Infrared Detection

INAA = Instrumental Neutron Activation Analysis

IENAA = Instrumental Epi-Thermal Neutron Activation Analysis

LEI = Laser-Enhanced Ionization Spectrometry (acid digestion/separation)

POLAR = Polarography

ID-TIMS = Isotope Dilution Thermal-Ionization Mass Spectrometry

XRF = X-Ray Fluorescence Spectrometry

ICP-MS = Inductively Coupled Plasma Mass Spectrometry

REGISTRATION OF YOUR SRM

Please complete and return this registration sheet to the address given on the reverse side. Frequently, we have difficulty contacting the actual users of SRM's because the addresses to which we ship are often those of procurement agents. The information on this registration sheet will enable us to inform you directly of any changes in the Certificate or other matters related to the use of this SRM and any update in it's certification.

Thank you

SRM Number: _____

Date Received: _____

Invoice Number: _____

Name: _____

Title: _____

Address: _____

Phone: _____

Fold Here

Additional Comments:

STANDARD METHODS

FOR THE EXAMINATION OF WATER AND WASTEWATER

1 8 T H E D I T I O N 1 9 9 2

Prepared and published jointly by:

**AMERICAN PUBLIC HEALTH ASSOCIATION
AMERICAN WATER WORKS ASSOCIATION
WATER ENVIRONMENT FEDERATION**

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**American Public Health Association
1015 Fifteenth Street, NW
Washington, DC 20005**

tion procedures, standard operating procedure for each analytical method (SOP), analyst training requirements, equipment preventive maintenance procedures, calibration procedures, corrective actions, internal quality control activities, performance audits, data assessment procedures for bias and precision, and data reduction, validation, and reporting.

The cover sheet with approval signatures indicates that the plan has been reviewed and judged suitable, and that the organization and responsibilities section outlines the chain-of-command and assigns specific functions to each person involved.

Sample control and documentation procedures permit tracing a sample and its derivatives through all steps from collection to analysis and display of results. Documentation always is important but is especially so when chain-of-custody requirements are imposed.

A standard operating procedure describes the method in such detail that an experienced analyst unfamiliar with the method can obtain acceptable results. Training requirements for analysts must be specified. The number of analyses required and the uncertainty of the results will vary with the type of analysis, sample characteristics, and the experience of the analyst.

Equipment preventive maintenance procedures are required.

A strict preventive maintenance program will reduce instrument malfunctions, maintain calibration, and reduce downtime.

Calibration procedures, corrective actions, internal quality control activities, performance audits, and data assessments for bias and precision are discussed in Section 1020B and C.

Data reduction, validation, and reporting are the final features of a QA program. The reading obtained from an analytical instrument must be adjusted for such factors as instrument efficiency, extraction efficiency, sample size, and background value, before it becomes a useful result. The QA plan specifies the correction factors to be applied as well as the steps to be followed in validating the result. Report results in standard units of mass, volume, or concentration. Use a prescribed method for reporting results below the method detection limit. Accompany each result or set of results by a statement of uncertainty.

2. Reference

1. STANLEY, T.W. & S.S. VERNER. 1983. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans. EPA-600/4-83-004. U.S. Environmental Protection Agency, Washington, D.C.

1020 B. Quality Control

Quality control (QC) may be either internal or external. Internal QC is the subject of this section; external QC, also known as "quality assessment," is discussed in 1020C. All analysts use some QC as an intuitive effort to produce credible results. However, a good quality control program consists of at least seven elements: certification of operator competence, recovery of known additions, analysis of externally supplied standards, analysis of reagent blanks, calibration with standards, analysis of duplicates, and maintenance of control charts. Sections 1010 and 1030 contain the necessary calculations.

1. Certification of Operator Competence

Before an analyst is permitted to do reportable work, competence in making the analysis is to be demonstrated. Requirements vary, but for most inorganic and organic chemical analyses, demonstration of acceptable single-operator precision and bias is sufficient. Make a minimum of four replicate analyses of an independently prepared check sample having a concentration between 5 and 50 times the method detection limit (MDL) for the analysis in that laboratory. General limits for acceptable work are shown in Table 1020:I; certain methods may specify more stringent limits.

2. Recovery of Known Additions

Use the recovery of known additions as part of a regular analytical protocol. Use known additions to verify the absence of matrix effects. When a new matrix type is to be analyzed, verify the amount of interference. Where duplicates are not applicable,

TABLE 1020:I. ACCEPTANCE LIMITS FOR DUPLICATE SAMPLES AND KNOWN ADDITIONS TO WATER AND WASTEWATER

Analysis	Recovery of Known Additions* %	Precision of Low-Level Duplicates*+ ± %	Precision of High-Level Duplicates*++ ± %
Metals	80-120	25	10
Volatile organics	70-130	40	20
Volatile gases	50-150	50	30
Base/neutrals	70-130	40	20
Acids	60-140	40	20
Anions	80-120	25	10
Nutrients	80-120	25	10
Other inorganics	80-120	25	10
Total organic carbon	80-120	25	10
Total organic halogens	80-120	25	15
Herbicides	40-160	40	20
Organochlorine pesticides	50-140	40	20
Captan	20-130	40	20
Endosulfans	25-140	40	20
Endrin aldehyde	25-140	40	20
Organophosphorus pesticides	50-200	40	20
Trichlorophon	20-200	40	20
Triazine pesticides	50-200	40	20
Carbamate pesticides	50-150	40	20

* Additions calculated as % of the known addition recovered, duplicates calculated as the difference as a percentage of the mean $[100(x_1 - x_2)/\bar{x}]$.

+ Low-level refers to concentrations less than 20 times the MDL. High-level refers to concentrations greater than 20 times the MDL.

‡ Also acceptance limits for independent laboratory control standards and certification of operator competence.

Zenon

13751 Commerce Court

Tel 604 444 4808

Environmental

Burnaby B.C.

Fax 604 444 4511

Laboratories

Canada V5A 4N5



November 16, 1993

Ms. Annette Smith
Norecol, Dames & Moore Inc.
Crestwood Corporate Centre
13751 Commerce Parkway
Richmond, B.C.
V6V 2R2

Dear Annette:

Regional

Laboratories:

British Columbia

Ontario

Quebec

The following is in response to your FAX of November 16, 1993 regarding Comments on Initial Dilution Zone Draft to Eric McGreer from Don Morse dated June 7, 1993.

The DQO for duplicates Zenon strives to achieve is less than $\pm 25\%$ relative percent difference (RPD). When duplicate samples do not achieve DQO the analytical run is examined to ensure that the run QA/QC DQO's (calibration standard check, blanks etc.) were achieved. At this point the sample, both dried and original, is examined for homogeneity. If the difference cannot be attributed to heterogeneity the sample is repeated by digesting another aliquot from the dried, ground and sieved portion of the sample. In the case of metals, the DQO's are generally only applied to the regulated heavy metals outlined by CCME or CMCS since elements such as calcium, iron, or aluminium can vary significantly. Unfortunately there are no published DQO's for solids from a Canadian regulating agency. These are generally established by the laboratory or the client on a project by project basis. USEPA does quote a RPD of $\pm 20\%$ at ten times the method detection limit in SW846 Method 6010 - ICAP Analysis. Attached is a table from this method outlining precision and accuracy data on real samples. No DQO's for the metals was established prior to starting this project.

The QA/QC section states that the NIST 2704 is a marine sediment and was used in place of a spiked blank. Again we are only evaluating the regulated metals since it is not a complete digestion. Chromium, however is an exception where consistently low recoveries are observed. Generally we flag the result if it varies from the norm. Acceptable recoveries are based upon the 95% confidence interval given by the supplier. Methodologies or sample matrix are reviewed if we are unable to recover the heavy metals from the SRM. The certificate of analysis is attached for perusal.



The methods are aptly described regarding what solvent or acid mixtures are used. A nitric perchloric acid mixture was used for all metals followed by analysis by ICAP-AES. The digestion procedure described for the selenium is not correct since this is an alternate method for hydride generation. Yes the detection limits for arsenic, selenium and antimony could have been lower if hydride generation was used, however only the straight ICAP scan was requested.

The surrogate recovery limits for the PAH and CP analysis are typical for this type of matrix. Recoveries are generally much better than this, however these are the check limits used. The attached Table 1020:I. from the 18th Edition of Standard Methods summarizes acceptable recoveries for known additions and also precision of duplicates. Almost all recoveries fall within the acceptable ranges for water samples which is an easier matrix to extract. Runs are reviewed if surrogates fall outside the 75-125 % range for any abnormalities prior to accepting results.

The samples were dry sieved and 75-100 g was used to determine the particle size distribution. The "Part. Size >400" should read "<400 mesh" and silt was incorrectly spelt. The attached data and methodology summaries have been corrected.

The number of significant figures for the TC/TIC/TOC results have been corrected in the final report.

The MDL's for several of the CP's were raised due to interference problems as indicated by the elevated surrogate recoveries. This was due to co-elution of non targeted parameters.

I trust that the enclosed is in accordance with your requirements. However, if you require any additional information or have any questions, please do not hesitate to call.

Sincerely yours,

A handwritten signature in black ink, appearing to read "SDH", written over a horizontal line.

Shawn D. Heier, BSc
Manager, Analytical Development

Encl.
SDH:sdh

Appendix 3

Detailed Sediment Chemistry Data

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:
Attention:
Sample State:

Norecol Dames & Moore
Annette Smith
Soils

Quote #: AV93-038
Project #: FREMP Sediment Assay

Zenon ID: 93003694 93003695 93003696 93003697 93003698
Client ID: TILB.1 SO TILB.2 MID TILB.3 NO FRAS. U/S FRA. OF

Parameter	MDC	Unit					
Moisture	0.1	%(W/W)	33.6	30.7	28.7	36.1	34.6
Part. Size 200 Mesh	0.1	"	33.3	34.2	63.3	27.6	30.8
Part. Size 400 Mesh	0.1	"	28.2	27.4	17.3	25.3	25.3
Part. Size <400 Mesh	0.1	"	38.5	38.4	19.4	47.1	44
Carbon Tot Inorganic	500	ug/g	2000	2000	1900	1200	1300
Carbon Total	500	"	12000	8300	7900	11000	11000
Pentachlorophenol	0.005	ug/g	—	—	—	—	—
Tetrachlorophenols	0.005	"	—	—	—	—	—
Trichlorophenols	0.005	"	—	—	—	—	—
Surrogate Recovery							
Dibromophenol		%	—	—	—	—	—
Tribromophenol		"	—	—	—	—	—
Silver	1	ug/g	<	<	<	<	<
Aluminum	2	"	29800	33500	26700	33900	32600
Arsenic	0.2	"	—	—	—	—	—
Arsenic	10	"	<	15	14	17	17
Barium	0.1	"	195	249	172	215	203
Beryllium	0.1	"	0.7	0.8	0.6	0.8	0.7
Bismuth	2	"	<	<	<	<	<
Calcium	1	"	12200	13200	12300	12100	11900
Cadmium	0.1	"	0.9	0.9	0.8	0.8	0.7
Cobalt	0.3	"	13.2	13.9	11.2	13.6	12.9
Chromium	0.2	"	60.6	47	39.4	45.5	47.8
Copper	0.1	"	34.8	31.1	28.6	37.8	36.6
Iron	0.3	"	38800	39500	33100	38400	37400
Potassium	40	"	4900	6240	4380	6310	5830
Magnesium	2	"	12300	12200	11500	13300	12900
Manganese	0.2	"	535	543	460	515	500
Molybdenum	0.4	"	<	<	<	<	<
Sodium	1	"	1480	1660	1690	3880	2980
Nickel	0.8	"	45.4	45.9	40.9	45.3	44.3
Phosphorus	4	"	787	756	707	821	821
Lead	2	"	8	9	5	10	9
Sulphur	3	"	694	546	506	875	789
Antimony	1.5	"	<	2.3	1.9	3.6	<
Selenium	10	"	<	<	<	<	<
Tin	2	"	<	2	9	4	6
Strontium	0.1	"	77.1	80.9	73.2	79.8	77.2
Tellurium	2	"	<	<	<	<	<
Titanium	0.3	"	1640	2070	1580	1680	1550
Thallium	2	"	<	3.1	<	<	<
Vanadium	0.3	"	72.7	75.5	61.7	68.3	65.9
Zinc	0.2	"	76.1	73.9	64.5	82.6	79.9
Zirconium	0.3	"	10.8	5.9	7.5	9.7	11

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:	Norecol Dames & Moore	Quote #:	AV93-038
Attention:	Annette Smith	Project #:	FREMP Sediment Assay
Sample State:	Soils		

Zenon ID: 93003694	93003695	93003696	93003697	93003698
Client ID: TILB.1 SO	TILB.2 MID	TILB.3 NO	FRAS. U/S	FRA. OF

Parameter	MDC	Unit					
PAH							
Naphthalene	0.001	ug/g	---	---	---	---	---
Acenaphthylene	0.001	"	---	---	---	---	---
Acenaphthene	0.001	"	---	---	---	---	---
Fluorene	0.001	"	---	---	---	---	---
Phenanthrene	0.001	"	---	---	---	---	---
Anthracene	0.001	"	---	---	---	---	---
Total low MW PAH's	0.001	"	---	---	---	---	---
Fluoranthene	0.001	"	---	---	---	---	---
Pyrene	0.001	"	---	---	---	---	---
Benzo(c)phenanthrene	0.001	"	---	---	---	---	---
Benz(a)anthracene	0.001	"	---	---	---	---	---
Chrysene	0.001	"	---	---	---	---	---
Benzo(b+k)fluoranthene	0.001	"	---	---	---	---	---
Benzo(j)fluoranthrene	0.001	"	---	---	---	---	---
7,12-Dimethylb(a)anthrene	0.005	"	---	---	---	---	---
Benzo(a)pyrene	0.001	"	---	---	---	---	---
3-Methylcholanthrene	0.002	"	---	---	---	---	---
Indeno(1,2,3-c,d)pyrene	0.002	"	---	---	---	---	---
Dibenz(a,h)anthracene	0.002	"	---	---	---	---	---
Benzo(g,h,i)perylene	0.002	"	---	---	---	---	---
Dibenzo(a,l)pyrene	0.005	"	---	---	---	---	---
Dibenzo(a,i)pyrene	0.005	"	---	---	---	---	---
Dibenzo(a,h)pyrene	0.005	"	---	---	---	---	---
Total high MW PAH's	0.005	"	---	---	---	---	---
Total PAH's	0.005	"	---	---	---	---	---
Surrogate Recovery							
Acenaphthene d10		%	---	---	---	---	---
Phenanthrene d10		"	---	---	---	---	---
Chrysene d12		"	---	---	---	---	---
Perylene d12		"	---	---	---	---	---

Sampled on : 93/02/17 93/02/17 93/02/17 93/02/20 93/02/20

NOTES:

CP MDC's raised due to sample dilutions

** Surrogate diluted out

* Surrogate recovery high due to co-elution

MDC = Minimum Detectable Concentration

< = Less than MDC

Organic results are not corrected for surrogate recoveries

Results are blank corrected

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:
Attention:
Sample State:

Norecol Dames & Moore
Annette Smith
Soils

Quote #: AV93-038
Project #: FREMP Sediment Assay

Zenon ID: 93003699	93003713	93003714	93003700	93003701
Client ID: FRAS. D/S	MISSION	BLANK#2	LAF.SO D/S	LAF.OF

Parameter	MDC	Unit					
Moisture	0.1	%(W/W)	35.7	33.4	<	33.3	34.4
Part. Size 200 Mesh	0.1	"	32.1	25.2	—	43.5	28.7
Part. Size 400 Mesh	0.1	"	26.7	35.9	—	19.8	25
Part. Size <400 Mesh	0.1	"	41.2	38.9	—	36.6	46.3
Carbon Tot Inorganic	500	ug/g	1600	3100	580	1600	5600
Carbon Total	500	"	11000	10000	580	13000	16000
Pentachlorophenol	0.005	ug/g	—	<	<	—	—
Tetrachlorophenols	0.005	"	—	<	<	—	—
Trichlorophenols	0.005	"	—	<	<	—	—
Surrogate Recovery							
Dibromophenol		%	—	151*	100	—	—
Tribromophenol		"	—	119	114	—	—
Silver	1	ug/g	<	<	<	<	<
Aluminum	2	"	32900	30300	3	34200	33100
Arsenic	0.2	"	—	—	—	—	—
Arsenic	10	"	21	23	<	23	15
Barium	0.1	"	208	209	0.1	215	209
Beryllium	0.1	"	0.7	0.7	<	0.8	0.7
Bismuth	2	"	<	<	<	<	<
Calcium	1	"	12000	14900	23	13000	32000
Cadmium	0.1	"	0.7	0.8	<	0.9	0.8
Cobalt	0.3	"	13.1	12.9	<	13.7	13.2
Chromium	0.2	"	44.6	48.2	1.3	43.6	44.9
Copper	0.1	"	36.5	27.9	0.6	40.5	39.3
Iron	0.3	"	38000	36400	6.1	40100	37400
Potassium	40	"	5950	5300	<	5960	5880
Magnesium	2	"	12900	13000	6	13200	12600
Manganese	0.2	"	511	513	<	561	519
Molybdenum	0.4	"	<	<	<	<	<
Sodium	1	"	2960	973	39	2390	1720
Nickel	0.8	"	44.5	43.8	<	45.2	43.6
Phosphorus	4	"	813	730	<	867	805
Lead	2	"	11	8	<	11	13
Sulphur	3	"	895	524	<	819	788
Antimony	1.5	"	1.6	1.7	<	<	2.1
Selenium	10	"	<	<	<	<	<
Tin	2	"	5	<	<	<	7
Strontium	0.1	"	77.3	72.9	0.1	80.8	115
Tellurium	2	"	<	<	<	<	<
Titanium	0.3	"	1600	1350	<	1660	1510
Thallium	2	"	6.5	<	2.3	<	5.1
Vanadium	0.3	"	67	58.4	<	69	64.9
Zinc	0.2	"	79.9	69	0.5	86.8	111
Zirconium	0.3	"	11.2	10.9	<	10.4	11.8

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:
Attention:
Sample State:

Norecol Dames & Moore
Annette Smith
Soils

Quote #: AV93-038
Project #: FREMP Sediment Assay

Zenon ID: 93003699	93003713	93003714	93003700	93003701
Client ID: FRAS. D/S	MISSION	BLANK#2	LAF.SO D/S	LAF.OF

Parameter	MDC	Unit					
PAH							
Naphthalene	0.001	ug/g	---	0.004	<	---	---
Acenaphthylene	0.001	"	---	<	<	---	---
Acenaphthene	0.001	"	---	<	<	---	---
Fluorene	0.001	"	---	<	<	---	---
Phenanthrene	0.001	"	---	0.009	<	---	---
Anthracene	0.001	"	---	0.007	<	---	---
Total low MW PAH's	0.001	"	---	0.02	<	---	---
Fluoranthene	0.001	"	---	0.008	<	---	---
Pyrene	0.001	"	---	0.01	<	---	---
Benzo(c)phenanthrene	0.001	"	---	<	<	---	---
Benz(a)anthracene	0.001	"	---	0.002	<	---	---
Chrysene	0.001	"	---	0.004	<	---	---
Benzo(b+k)fluoranthene	0.001	"	---	0.005	<	---	---
Benzo(j)fluoranthene	0.001	"	---	<	<	---	---
7,12-Dimethylb(a)anthrene	0.005	"	---	<	<	---	---
Benzo(a)pyrene	0.001	"	---	0.003	<	---	---
3-Methylcholanthrene	0.002	"	---	<	<	---	---
Indeno(1,2,3-c,d)pyrene	0.002	"	---	<	<	---	---
Dibenz(a,h)anthracene	0.002	"	---	<	<	---	---
Benzo(g,h,i)perylene	0.002	"	---	<	<	---	---
Dibenzo(a,l)pyrene	0.005	"	---	<	<	---	---
Dibenzo(a,i)pyrene	0.005	"	---	<	<	---	---
Dibenzo(a,h)pyrene	0.005	"	---	<	<	---	---
Total high MW PAH's	0.005	"	---	0.032	<	---	---
Total PAH's	0.005	"	---	0.052	<	---	---
Surrogate Recovery							
Acenaphthene d10		%	---	64	69	---	---
Phenanthrene d10		"	---	71	75	---	---
Chrysene d12		"	---	74	86	---	---
Perylene d12		"	---	72	72	---	---

Sampled on : 93/02/20 93/02/22 93/02/22 93/02/17 93/02/16

NOTES:

CP MDC's raised due to sample dilutions
 ** Surrogate diluted out
 * Surrogate recovery high due to co-elution
 MDC = Minimum Detectable Concentration
 < = Less than MDC
 Organic results are not corrected for surrogate recoveries
 Results are blank corrected

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:
Attention:
Sample State:

Norecol Dames & Moore
Annette Smith
Soils

Quote #: AV93-038
Project #: FREMP Sediment Assay

Parameter	MDC	Unit	Zenon ID: 93003702	93003703	93003704	93003705	93003706
			Client ID: LAF.OF Duplicate	LAF. NO.	BLANK #1	REF. MAT.	SCOTT D/S
Moisture	0.1	%(W/W)	33.9	31.3	<	<	36.9
Part. Size 200 Mesh	0.1	"	32.8	45.4	—	—	34.4
Part. Size 400 Mesh	0.1	"	23.2	18.5	—	—	28
Part. Size <400 Mesh	0.1	"	44	36.1	—	—	37.6
Carbon Tot Inorganic	500	ug/g	5700	1200	580	6200	1200
Carbon Total	500	"	20000	13000	580	16000	12000
Pentachlorophenol	0.005	ug/g	—	—	—	—	<
Tetrachlorophenols	0.005	"	—	—	—	—	<
Trichlorophenols	0.005	"	—	—	—	—	< 0.010
Surrogate Recovery							
Dibromophenol		%	—	—	—	—	193*
Tribromophenol		"	—	—	—	—	130
Silver	1	ug/g	<	<	<	<	<
Aluminum	2	"	32700	33600	3	44500	30000
Arsenic	0.2	"	—	—	—	—	—
Arsenic	10	"	24	11	<	32	13
Barium	0.1	"	204	206	0.1	207	203
Beryllium	0.1	"	0.7	0.8	<	1.4	0.7
Bismuth	2	"	<	<	<	<	<
Calcium	1	"	33800	11600	23	24800	11100
Cadmium	0.1	"	1	0.8	<	3.8	0.8
Cobalt	0.3	"	12.9	14.2	<	11.5	12.4
Chromium	0.2	"	35.8	47.4	1.3	57.7	45.6
Copper	0.1	"	39.2	40.2	0.6	85.6	30.2
Iron	0.3	"	37000	40400	12.6	39200	34500
Potassium	40	"	5820	5790	<	12100	5170
Magnesium	2	"	12500	13200	6	10900	11500
Manganese	0.2	"	513	549	<	469	445
Molybdenum	0.4	"	<	<	<	1.6	2.6
Sodium	1	"	1730	1920	38	564	1070
Nickel	0.8	"	42.9	46.2	<	37.3	41.3
Phosphorus	4	"	802	860	<	855	728
Lead	2	"	12	12	<	146	11
Sulphur	3	"	774	887	<	3290	581
Antimony	1.5	"	2.4	1.7	<	<	3.5
Selenium	10	"	<	<	<	<	<
Tin	2	"	11	<	<	5	<
Strontium	0.1	"	119	76.2	0.1	67.3	68.9
Tellurium	2	"	<	<	<	<	<
Titanium	0.3	"	1600	1550	<	422	1450
Thallium	2	"	<	<	<	5.4	<
Vanadium	0.3	"	64.4	69.3	<	58.4	60.5
Zinc	0.2	"	82.7	86	0.5	401	85.2
Zirconium	0.3	"	8.6	11.7	<	14.2	10.1

Zenon Environmental Laboratories - Certificate of Analysis

Reported to: Norecol Dames & Moore
Attention: Annette Smith
Sample State: Soils

Quote #: AV93-038
Project #: FREMP Sediment Assay

Zenon ID:	93003702	93003703	93003704	93003705	93003706
Client ID:	LAF.OF Duplicate	LAF. NO.	BLANK #1	REF. MAT.	SCOTT D/S

Parameter	MDC	Unit					
PAH							
Naphthalene	0.001	ug/g	---	---	---	---	---
Acenaphthylene	0.001	"	---	---	---	---	---
Acenaphthene	0.001	"	---	---	---	---	---
Fluorene	0.001	"	---	---	---	---	---
Phenanthrene	0.001	"	---	---	---	---	---
Anthracene	0.001	"	---	---	---	---	---
Total low MW PAH's	0.001	"	---	---	---	---	---
Fluoranthene	0.001	"	---	---	---	---	---
Pyrene	0.001	"	---	---	---	---	---
Benzo(c)phenanthrene	0.001	"	---	---	---	---	---
Benz(a)anthracene	0.001	"	---	---	---	---	---
Chrysene	0.001	"	---	---	---	---	---
Benzo(b+k)fluoranthene	0.001	"	---	---	---	---	---
Benzo(j)fluoranthene	0.001	"	---	---	---	---	---
7,12-Dimethylb(a)anthrene	0.005	"	---	---	---	---	---
Benzo(a)pyrene	0.001	"	---	---	---	---	---
3-Methylcholanthrene	0.002	"	---	---	---	---	---
Indeno(1,2,3-c,d)pyrene	0.002	"	---	---	---	---	---
Dibenz(a,h)anthracene	0.002	"	---	---	---	---	---
Benzo(g,h,i)perylene	0.002	"	---	---	---	---	---
Dibenzo(a,l)pyrene	0.005	"	---	---	---	---	---
Dibenzo(a,i)pyrene	0.005	"	---	---	---	---	---
Dibenzo(a,h)pyrene	0.005	"	---	---	---	---	---
Total high MW PAH's	0.005	"	---	---	---	---	---
Total PAH's	0.005	"	---	---	---	---	---
Surrogate Recovery							
Acenaphthene d10		%	---	---	---	---	---
Phenanthrene d10		"	---	---	---	---	---
Chrysene d12		"	---	---	---	---	---
Perylene d12		"	---	---	---	---	---

Sampled on : 93/02/16 93/02/16 93/02/23 93/02/23 93/02/19

NOTES:

CP MDC's raised due to sample dilutions
 ** Surrogate diluted out
 * Surrogate recovery high due to co-elution
 MDC = Minimum Detectable Concentration
 < = Less than MDC
 Organic results are not corrected for surrogate recoveries
 Results are blank corrected

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:
Attention:
Sample State:

Norecol Dames & Moore
Annette Smith
Soils

Quote #:
Project #:

AV93-038
FREMP Sediment Assay

			Zenon ID: 93003707	93003708	93003709	93003710	93003711
			Client ID: SCOTT U/S	SCOTT OF	SCOTT OF Duplicate	ROB 100E	ROB 100W
Parameter	MDC	Unit					
Moisture	0.1	%(W/W)	22.6	30.7	32.2	22.9	26.7
Part. Size 200 Mesh	0.1	"	67.8	47.5	47.6	72	56.2
Part. Size 400 Mesh	0.1	"	15.8	25	24.6	17.2	30.8
Part. Size <400 Mesh	0.1	"	16.4	27.5	27.8	10.8	13.1
Carbon Tot Inorganic	500	ug/g	1100	1400	2000	1300	1300
Carbon Total	500	"	7500	9800	9300	9200	7900
Pentachlorophenol	0.005	ug/g	<	<	<	—	—
Tetrachlorophenols	0.005	"	<	<	<	—	—
Trichlorophenols	0.005	"	<	<	< 0.010	—	—
Surrogate Recovery							
Dibromophenol		%	155*	64	134*	—	—
Tribromophenol		"	122	78	119	—	—
Silver	1	ug/g	<	<	<	<	<
Aluminum	2	"	26800	28600	28400	26500	24600
Arsenic	0.2	"	—	—	—	—	—
Arsenic	10	"	<	22	16	15	<
Barium	0.1	"	185	193	193	155	139
Beryllium	0.1	"	0.6	0.6	0.7	0.6	0.6
Bismuth	2	"	<	<	<	<	<
Calcium	1	"	12100	11800	11800	12100	11500
Cadmium	0.1	"	0.5	0.7	0.6	0.6	0.5
Cobalt	0.3	"	11.6	11.9	12.2	10	9.8
Chromium	0.2	"	47.3	51.1	48.4	53.3	46.3
Copper	0.1	"	25.4	28.3	27	18.6	16.2
Iron	0.3	"	34500	34700	35000	31600	29500
Potassium	40	"	4400	4690	4740	4860	4310
Magnesium	2	"	10900	11300	11200	11300	10900
Manganese	0.2	"	435	465	466	360	340
Molybdenum	0.4	"	<	<	<	<	<
Sodium	1	"	972	1040	1010	3630	3190
Nickel	0.8	"	40.5	41	41.1	36.3	34.9
Phosphorus	4	"	718	744	752	793	730
Lead	2	"	8	10	11	5	6
Sulphur	3	"	520	485	480	915	695
Antimony	1.5	"	<	<	2	<	2.6
Selenium	10	"	<	<	<	<	<
Tin	2	"	6	2	<	3	6
Strontium	0.1	"	70.9	73.2	72.2	72.4	67.4
Tellurium	2	"	<	<	<	<	<
Titanium	0.3	"	1510	1470	1630	1680	1600
Thallium	2	"	<	2.9	2.3	4.5	3.3
Vanadium	0.3	"	62.1	63.6	64.4	62.2	59.1
Zinc	0.2	"	73.2	80.8	75.8	60.6	55.7
Zirconium	0.3	"	9.8	10.5	8.9	5.9	7.3

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:	Norecol Dames & Moore	Quote #:	AV93-038
Attention:	Annette Smith	Project #:	FREMP Sediment Assay
Sample State:	Soils		

Zenon ID:	93003707	93003708	93003709	93003710	93003711
Client ID:	SCOTT U/S	SCOTT OF	SCOTT OF Duplicate	ROB 100E	ROB 100W

Parameter	MDC	Unit					
PAH							
Naphthalene	0.001	ug/g	---	---	---	0.065	0.048
Acenaphthylene	0.001	"	---	---	---	<	<
Acenaphthene	0.001	"	---	---	---	<	<
Fluorene	0.001	"	---	---	---	0.035	0.035
Phenanthrene	0.001	"	---	---	---	0.11	0.11
Anthracene	0.001	"	---	---	---	0.093	0.093
Total low MW PAH's	0.001	"	---	---	---	0.3	0.29
Fluoranthene	0.001	"	---	---	---	0.013	0.014
Pyrene	0.001	"	---	---	---	0.017	0.018
Benzo(c)phenanthrene	0.001	"	---	---	---	<	<
Benz(a)anthracene	0.001	"	---	---	---	0.012	0.012
Chrysene	0.001	"	---	---	---	0.025	0.027
Benzo(b+k)fluoranthene	0.001	"	---	---	---	0.013	0.014
Benzo(j)fluoranthene	0.001	"	---	---	---	<	<
7,12-Dimethylb(a)anthrene	0.005	"	---	---	---	<	<
Benzo(a)pyrene	0.001	"	---	---	---	0.007	0.008
3-Methylcholanthrene	0.002	"	---	---	---	<	<
Indeno(1,2,3-c,d)pyrene	0.002	"	---	---	---	0.003	0.003
Dibenz(a,h)anthracene	0.002	"	---	---	---	<	<
Benzo(g,h,i)perylene	0.002	"	---	---	---	0.008	0.009
Dibenzo(a,l)pyrene	0.005	"	---	---	---	<	<
Dibenzo(a,i)pyrene	0.005	"	---	---	---	<	<
Dibenzo(a,h)pyrene	0.005	"	---	---	---	<	<
Total high MW PAH's	0.005	"	---	---	---	0.098	0.11
Total PAH's	0.005	"	---	---	---	0.4	0.39
Surrogate Recovery							
Acenaphthene d10		%	---	---	---	66	67
Phenanthrene d10		"	---	---	---	73	73
Chrysene d12		"	---	---	---	74	72
Perylene d12		"	---	---	---	73	72

Sampled on : 93/02/19 93/02/19 93/02/19 93/02/15 93/02/15

NOTES:

CP MDC's raised due to sample dilutions

** Surrogate diluted out

* Surrogate recovery high due to co-elution

MDC = Minimum Detectable Concentration

< = Less than MDC

Organic results are not corrected for surrogate recoveries

Results are blank corrected

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:
Attention:
Sample State:

Norecol Dames & Moore
Annette Smith
Soils

Quote #: AV93-038
Project #: FREMP Sediment Assay

Zenon ID:	93003712	93004558	93004559	93004560	93004561
Client ID:	ROB 25M	DOM 1 OF	DOM 2 DS	DOM 3 DS	DOM 3 DS Duplicate

Parameter	MDC	Unit					
Moisture	0.1	%(W/W)	22.4	42.1	42.7	38.6	39.1
Part. Size 200 Mesh	0.1	"	92.5	17.6	18.4	28.8	27.9
Part. Size 400 Mesh	0.1	"	4.2	33.3	29.7	30.4	30.8
Part. Size <400 Mesh	0.1	"	3.3	49	51.9	40.8	41.3
Carbon Tot Inorganic	500	ug/g	1200	2900	2800	2100	2400
Carbon Total	500	"	9700	10000	9900	9000	8500
Pentachlorophenol	0.005	ug/g	—	0.009	0.01	0.009	< 0.050
Tetrachlorophenols	0.005	"	—	< 0.010	< 0.050	< 0.050	< 0.050
Trichlorophenols	0.005	"	—	< 0.050	< 0.050	< 0.050	< 0.050
Surrogate Recovery							
Dibromophenol		%	—	NA**	68	95	NA**
Tribromophenol		"	—	NA**	81	86	NA**
Silver	1	ug/g	<	<	<	<	<
Aluminum	2	"	25600	30000	31400	26700	26200
Arsenic	0.2	"	—	5.9	6.4	5.2	5.2
Arsenic	10	"	18	—	—	—	—
Barium	0.1	"	145	201	212	179	172
Beryllium	0.1	"	0.6	0.6	0.6	0.5	0.5
Bismuth	2	"	<	<	<	<	<
Calcium	1	"	12200	11800	11900	10900	10900
Cadmium	0.1	"	0.5	0.7	0.6	0.6	0.5
Cobalt	0.3	"	10.2	13.3	13.1	11.9	12.1
Chromium	0.2	"	57.8	38.2	34.5	36.8	36.7
Copper	0.1	"	18.2	33.4	32	27.5	34.8
Iron	0.3	"	31700	39100	38900	36100	36100
Potassium	40	"	4690	4780	5220	3990	3830
Magnesium	2	"	11800	12000	12300	11100	11000
Manganese	0.2	"	356	521	542	467	464
Molybdenum	0.4	"	<	<	<	<	<
Sodium	1	"	7250	928	930	784	733
Nickel	0.8	"	36.7	40.7	41	38.1	37.5
Phosphorus	4	"	776	786	814	774	774
Lead	2	"	5	10	9	8	8
Sulphur	3	"	1280	527	479	466	472
Antimony	1.5	"	3.4	<	<	<	<
Selenium	10	"	<	<	<	<	<
Tin	2	"	4	<	<	<	<
Strontium	0.1	"	76.6	71.5	72.8	66.5	64.7
Tellurium	2	"	<	<	<	<	<
Titanium	0.3	"	1570	1510	1570	1470	1410
Thallium	2	"	3	<	2.3	<	<
Vanadium	0.3	"	62.2	63	64.4	62.1	61.1
Zinc	0.2	"	58.7	82.2	81.8	72.5	75.7
Zirconium	0.3	"	9.6	8.7	6.8	6.7	7.4

Zenon Environmental Laboratories - Certificate of Analysis

Reported to: Norecol Dames & Moore
Attention: Annette Smith
Sample State: Soils

Quote #: AV93-038
Project #: FREMP Sediment Assay

Zenon ID:	93003712	93004558	93004559	93004560	93004561
Client ID:	ROB 25M	DOM 1 OF	DOM 2 DS	DOM 3 DS	DOM 3 DS Duplicate

Parameter	MDC	Unit					
PAH							
Naphthalene	0.001	ug/g	0.013	0.014	0.015	0.011	0.007
Acenaphthylene	0.001	"	<	0.002	<	<	<
Acenaphthene	0.001	"	<	0.014	0.059	0.005	0.003
Fluorene	0.001	"	0.007	0.014	0.014	0.006	0.004
Phenanthrene	0.001	"	0.026	0.058	0.058	0.027	0.02
Anthracene	0.001	"	<	0.011	0.007	0.005	0.003
Total low MW PAH's	0.001	"	0.046	0.11	0.15	0.054	0.037
Fluoranthene	0.001	"	0.004	0.13	0.079	0.027	0.026
Pyrene	0.001	"	0.005	0.11	0.078	0.023	0.023
Benzo(c)phenanthrene	0.001	"	<	0.008	0.007	0.002	0.002
Benz(a)anthracene	0.001	"	0.003	0.036	0.032	0.009	0.006
Chrysene	0.001	"	0.007	0.035	0.036	0.012	0.014
Benzo(b+k)fluoranthene	0.001	"	0.004	0.053	0.046	0.016	0.013
Benzo(j)fluoranthene	0.001	"	<	0.004	0.004	0.001	0.003
7,12-Dimethylb(a)anthrene	0.005	"	<	<	<	<	<
Benzo(a)pyrene	0.001	"	0.004	0.018	0.017	0.006	0.004
3-Methylcholanthrene	0.002	"	<	<	<	<	<
Indeno(1,2,3-c,d)pyrene	0.002	"	<	0.008	0.007	0.003	0.002
Dibenz(a,h)anthracene	0.002	"	<	<	<	<	<
Benzo(g,h,i)perylene	0.002	"	0.002	0.01	0.009	<	<
Dibenzo(a,l)pyrene	0.005	"	<	<	<	<	<
Dibenzo(a,i)pyrene	0.005	"	<	<	<	<	<
Dibenzo(a,h)pyrene	0.005	"	<	<	<	<	<
Total high MW PAH's	0.005	"	0.029	0.41	0.32	0.099	0.093
Total PAH's	0.005	"	0.075	0.52	0.47	0.15	0.13
Surrogate Recovery							
Acenaphthene d10		%	60	59	59	59	60
Phenanthrene d10		"	68	65	64	65	64
Chrysene d12		"	74	71	76	79	83
Perylene d12		"	73	73	75	76	79

Sampled on : 93/02/15 93/03/02 93/03/02 93/03/02 93/03/02

NOTES:

CP MDC's raised due to sample dilutions

** Surrogate diluted out

* Surrogate recovery high due to co-elution

MDC = Minimum Detectable Concentration

< = Less than MDC

Organic results are not corrected for surrogate recoveries

Results are blank corrected

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:
Attention:
Sample State:

Norecol Dames & Moore
Annette Smith
Soils

Quote #:
Project #:

AV93-038
FREMP Sediment Assay

Parameter	MDC	Unit	Zenon ID:	93004562	93004563	93004564	93004565
			Client ID:	BLANK #3	REF. MAT.	PORT. U/S	PORT. MID. NB
Moisture	0.1	%(W/W)	—	—	—	40.7	40.2
Part. Size 200 Mesh	0.1	"	—	—	—	32.9	55.8
Part. Size 400 Mesh	0.1	"	—	—	—	28.1	23.3
Part. Size <400 Mesh	0.1	"	—	—	—	39	20.9
Carbon Tot Inorganic	500	ug/g	<	6300	3300	2900	
Carbon Total	500	"	<	8900	12000	8900	
Pentachlorophenol	0.005	ug/g	<	—	0.02	0.007	
Tetrachlorophenols	0.005	"	<	—	< 0.050	< 0.050	
Trichlorophenols	0.005	"	<	—	< 0.050	< 0.050	
Surrogate Recovery							
Dibromophenol		%	109	—	89	NA**	
Tribromophenol		"	92	—	76	NA**	
Silver	1	ug/g	<	<	<	<	
Aluminum	2	"	2	44800	29800	25200	
Arsenic	0.2	"	<	19	<	<	
Arsenic	10	"	—	—	—	—	
Barium	0.1	"	<	211	201	169	
Beryllium	0.1	"	<	1.3	0.6	0.5	
Bismuth	2	"	<	<	<	<	
Calcium	1	"	28	24600	12700	11900	
Cadmium	0.1	"	<	3.7	0.5	0.5	
Cobalt	0.3	"	<	10.8	13.7	11.4	
Chromium	0.2	"	1.3	37.4	39.7	39.3	
Copper	0.1	"	1.3	89.7	31.9	27.8	
Iron	0.3	"	6.7	39400	38000	34800	
Potassium	40	"	<	13000	4870	4050	
Magnesium	2	"	4	11000	12500	11000	
Manganese	0.2	"	<	470	503	429	
Molybdenum	0.4	"	<	2.2	<	<	
Sodium	1	"	33	592	822	821	
Nickel	0.8	"	<	35.8	42	38.2	
Phosphorus	4	"	28	855	769	700	
Lead	2	"	<	145	9	7	
Sulphur	3	"	56	2750	579	407	
Antimony	1.5	"	<	<	<	<	
Selenium	10	"	<	<	<	<	
Tin	2	"	<	<	<	<	
Strontium	0.1	"	<	69.4	68.9	67	
Tellurium	2	"	<	<	<	<	
Titanium	0.3	"	<	473	1440	1610	
Thallium	2	"	<	<	<	<	
Vanadium	0.3	"	<	57.8	62.8	61.6	
Zinc	0.2	"	3	401	79.8	72	
Zirconium	0.3	"	<	8.3	8.3	5	

Quote #: AV93-038
Project #: FREMP Sediment Assay

Parameter	MDC	Unit				
PAH						
Naphthalene	0.001	ug/g	<	---	---	---
Acenaphthylene	0.001	"	<	---	---	---
Acenaphthene	0.001	"	<	---	---	---
Fluorene	0.001	"	<	---	---	---
Phenanthrene	0.001	"	<	---	---	---
Anthracene	0.001	"	<	---	---	---
Total low MW PAH's	0.001	"	<	---	---	---
Fluoranthene	0.001	"	<	---	---	---
Pyrene	0.001	"	<	---	---	---
Benzo(c)phenanthrene	0.001	"	<	---	---	---
Benz(a)anthracene	0.001	"	<	---	---	---
Chrysene	0.001	"	<	---	---	---
Benzo(b+k)fluoranthene	0.001	"	<	---	---	---
Benzo(j)fluoranthrene	0.001	"	<	---	---	---
7,12-Dimethylb(a)anthrene	0.005	"	<	---	---	---
Benzo(a)pyrene	0.001	"	<	---	---	---
3-Methylcholanthrene	0.002	"	<	---	---	---
Indeno(1,2,3-c,d)pyrene	0.002	"	<	---	---	---
Dibenz(a,h)anthracene	0.002	"	<	---	---	---
Benzo(g,h,i)perylene	0.002	"	<	---	---	---
Dibenzo(a,l)pyrene	0.005	"	<	---	---	---
Dibenzo(a,i)pyrene	0.005	"	<	---	---	---
Dibenzo(a,h)pyrene	0.005	"	<	---	---	---
Total high MW PAH's	0.005	"	<	---	---	---
Total PAH's	0.005	"	<	---	---	---
Surrogate Recovery						
Acenaphthene d10		%	61	---	---	---
Phenanthrene d10		"	64	---	---	---
Chrysene d12		"	97	---	---	---
Perylene d12		"	79	---	---	---

NOTES:

CP MDC's raised due to sample dilutions

• Surrogate diluted out

- Surrogate recovery high due to co-elution

MDC = Minimum Detectable Concentration

< - Less than MDC

Organic results are not corrected for surrogate recoveries

Results are blank corrected

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:

Norecol Dames & Moore

Quote #:

AV93-038

Attention:

Annette Smith

Project #:

FREMP Sediment Assay

Sample State:

Soils

Zenon ID: 93004566	93004567	93004568	93004569
Client ID: PORT. D/S	FRAS. U/S	FRAS OF	FRAS. D/S

Parameter	MDC	Unit				
Moisture	0.1	%(W/W)	34.6	43.5	48	38
Part. Size 200 Mesh	0.1	"	46.4	12.9	22.9	21
Part. Size 400 Mesh	0.1	"	26.6	29.8	25	25.2
Part. Size <400 Mesh	0.1	"	27	57.3	52.3	53.8
Carbon Tot Inorganic	500	ug/g	3300	2900	2600	2600
Carbon Total	500	"	9500	11000	11000	10000
Pentachlorophenol	0.005	ug/g	0.013	0.009	0.02	0.013
Tetrachlorophenols	0.005	"	<0.050	< 0.050	< 0.050	< 0.050
Trichlorophenols	0.005	"	<0.050	< 0.050	< 0.050	< 0.050
Surrogate Recovery						
Dibromophenol		%	NA**	104	118	82
Tribromophenol		"	NA**	84	141*	73
Silver	1	ug/g	<	<	<	<
Aluminum	2	"	29900	31200	31400	31200
Arsenic	0.2	"	<	<	<	<
Arsenic	10	"	—	—	—	—
Barium	0.1	"	205	207	207	221
Beryllium	0.1	"	0.6	0.6	0.6	0.6
Bismuth	2	"	<	<	<	<
Calcium	1	"	13300	11700	11200	12000
Cadmium	0.1	"	0.6	0.7	0.8	0.8
Cobalt	0.3	"	12.6	13	13.3	13.9
Chromium	0.2	"	34.1	28.9	36.1	41.4
Copper	0.1	"	28.1	30.1	32.7	33.5
Iron	0.3	"	36700	38300	38800	39200
Potassium	40	"	5330	5190	5140	4880
Magnesium	2	"	12400	12100	12200	12100
Manganese	0.2	"	459	530	471	533
Molybdenum	0.4	"	<	<	<	<
Sodium	1	"	948	901	908	805
Nickel	0.8	"	40.2	39.4	41.1	42.6
Phosphorus	4	"	729	785	768	828
Lead	2	"	8	9	10	8
Sulphur	3	"	486	446	616	511
Antimony	1.5	"	<	<	<	<
Selenium	10	"	<	<	<	<
Tin	2	"	<	<	<	<
Strontium	0.1	"	71.1	71.2	70.3	73.4
Tellurium	2	"	<	<	<	<
Titanium	0.3	"	1610	1610	1590	1560
Thallium	2	"	2.3	<	<	<
Vanadium	0.3	"	62.3	63.8	65.2	67.9
Zinc	0.2	"	72.4	79.1	85.5	79.9
Zirconium	0.3	"	7.4	7.6	8.9	10.3

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:	Norecol Dames & Moore	Quote #:	AV93-038
Attention:	Annette Smith	Project #:	FREMP Sediment Assay
Sample State:	Soils		

Zenon ID: 93004566	93004567	93004568	93004569
Client ID: PORT. D/S	FRAS. U/S	FRAS OF	FRAS. D/S

Parameter	MDC	Unit				
PAH						
Naphthalene	0.001	ug/g	---	---	---	---
Acenaphthylene	0.001	"	---	---	---	---
Acenaphthene	0.001	"	---	---	---	---
Fluorene	0.001	"	---	---	---	---
Phenanthrene	0.001	"	---	---	---	---
Anthracene	0.001	"	---	---	---	---
Total low MW PAH's	0.001	"	---	---	---	---
Fluoranthene	0.001	"	---	---	---	---
Pyrene	0.001	"	---	---	---	---
Benzo(c)phenanthrene	0.001	"	---	---	---	---
Benz(a)anthracene	0.001	"	---	---	---	---
Chrysene	0.001	"	---	---	---	---
Benzo(b+k)fluoranthene	0.001	"	---	---	---	---
Benzo(j)fluoranthene	0.001	"	---	---	---	---
7,12-Dimethylb(a)anthrene	0.005	"	---	---	---	---
Benzo(a)pyrene	0.001	"	---	---	---	---
3-Methylcholanthrene	0.002	"	---	---	---	---
Indeno(1,2,3-c,d)pyrene	0.002	"	---	---	---	---
Dibenz(a,h)anthracene	0.002	"	---	---	---	---
Benzo(g,h,i)perylene	0.002	"	---	---	---	---
Dibenzo(a,l)pyrene	0.005	"	---	---	---	---
Dibenzo(a,i)pyrene	0.005	"	---	---	---	---
Dibenzo(a,h)pyrene	0.005	"	---	---	---	---
Total high MW PAH's	0.005	"	---	---	---	---
Total PAH's	0.005	"	---	---	---	---
Surrogate Recovery						
Acenaphthene d10		%	---	---	---	---
Phenanthrene d10		"	---	---	---	---
Chrysene d12		"	---	---	---	---
Perylene d12		"	---	---	---	---

Sampled on : 93/03/02 00 93/03/02 93/03/02 93/03/02

NOTES:

CP MDC's raised due to sample dilutions

** Surrogate diluted out

* Surrogate recovery high due to co-elution

MDC = Minimum Detectable Concentration

< = Less than MDC

Organic results are not corrected for surrogate recoveries

Results are blank corrected

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:
Attention:
Sample State:

Norecol Dames & Moore
Annette Smith
Soils

Quote #: AV93-038
Project #: FREMP Sediment Assay

			Zenon ID: 93004769	93004770	93004771	93004772
			Client ID: TREE ISL OF	TREE ISL 50m D/S	TREE ISL 150M D/S	MACBLO. OF
Parameter	MDC	Unit				
Moisture	0.1	%(W/W)	41.7	36.1	41.9	37.6
Part. Size 200 Mesh	0.1	"	52.5	16.2	12.1	36.7
Part. Size 400 Mesh	0.1	"	18	28.5	29	29.1
Part. Size <400 Mesh	0.1	"	29.5	55.4	58.9	34.2
Carbon Tot Inorganic	500	ug/g	4700	2500	3900	3700
Carbon Total	500	"	16000	9900	12000	9000
Pentachlorophenol	0.005	ug/g	—	—	—	<
Tetrachlorophenols	0.005	"	—	—	—	<
Trichlorophenols	0.005	"	—	—	—	<
Surrogate Recovery						
Dibromophenol		%	—	—	—	102
Tribromophenol		"	—	—	—	109
Silver	1	ug/g	<	<	<	<
Aluminum	2	"	29600	30900	32000	30000
Arsenic	0.2	"	<	<	<	<
Arsenic	10	"	—	—	—	—
Barium	0.1	"	197	239	212	207
Beryllium	0.1	"	0.5	0.6	0.6	0.6
Bismuth	2	"	<	<	<	<
Calcium	1	"	19700	12000	11800	12200
Cadmium	0.1	"	0.8	0.8	1.1	0.7
Cobalt	0.3	"	12.9	13.7	13.8	12.7
Chromium	0.2	"	41.6	43.2	37.6	36.5
Copper	0.1	"	35.2	34	35.4	30.8
Iron	0.3	"	37100	37500	40300	37700
Potassium	40	"	4690	4650	5210	5320
Magnesium	2	"	11900	11400	13100	12300
Manganese	0.2	"	623	553	571	494
Molybdenum	0.4	"	<	<	<	<
Sodium	1	"	1080	958	1160	1110
Nickel	0.8	"	41.3	44.3	43.9	40.9
Phosphorus	4	"	785	806	802	750
Lead	2	"	19	8	18	8
Sulphur	3	"	531	489	570	536
Antimony	1.5	"	<	<	<	1.6
Selenium	10	"	<	<	<	<
Tin	2	"	<	<	<	<
Strontium	0.1	"	81.9	75.9	71.2	72.6
Tellurium	2	"	<	<	<	<
Titanium	0.3	"	1480	1430	1420	1670
Thallium	2	"	<	<	<	<
Vanadium	0.3	"	64.8	67	62.6	66.2
Zinc	0.2	"	207	87.6	148	75.6
Zirconium	0.3	"	9.3	12	9.9	7.6

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Reported to:	Norecol Dames & Moore	Quote #:	AV93-038
Attention:	Annette Smith	Project #:	FREMP Sediment Assay
Sample State:	Soils		

			Zenon ID: 93004769	93004770	93004771	93004772
			Client ID: TREE ISL	TREE ISL	TREE ISL	MACBLO.
			OF	50m D/S	150M D/S	OF
Parameter	MDC	Unit				
PAH						
Naphthalene	0.001	ug/g	---	---	---	---
Acenaphthylene	0.001	"	---	---	---	---
Acenaphthene	0.001	"	---	---	---	---
Fluorene	0.001	"	---	---	---	---
Phenanthrene	0.001	"	---	---	---	---
Anthracene	0.001	"	---	---	---	---
Total low MW PAH's	0.001	"	---	---	---	---
Fluoranthene	0.001	"	---	---	---	---
Pyrene	0.001	"	---	---	---	---
Benzo(c)phenanthrene	0.001	"	---	---	---	---
Benz(a)anthracene	0.001	"	---	---	---	---
Chrysene	0.001	"	---	---	---	---
Benzo(b+k)fluoranthene	0.001	"	---	---	---	---
Benzo(j)fluoranthrene	0.001	"	---	---	---	---
7,12-Dimethylb(a)anthrene	0.005	"	---	---	---	---
Benzo(a)pyrene	0.001	"	---	---	---	---
3-Methylcholanthrene	0.002	"	---	---	---	---
Indeno(1,2,3-c,d)pyrene	0.002	"	---	---	---	---
Dibenz(a,h)anthracene	0.002	"	---	---	---	---
Benzo(g,h,i)perylene	0.002	"	---	---	---	---
Dibenzo(a,l)pyrene	0.005	"	---	---	---	---
Dibenzo(a,i)pyrene	0.005	"	---	---	---	---
Dibenzo(a,h)pyrene	0.005	"	---	---	---	---
Total high MW PAH's	0.005	"	---	---	---	---
Total PAH's	0.005	"	---	---	---	---
Surrogate Recovery						
Acenaphthene d10		%	---	---	---	---
Phenanthrene d10		"	---	---	---	---
Chrysene d12		"	---	---	---	---
Perylene d12		"	---	---	---	---

Sampled on : 93/03/06 93/03/06 93/03/06 93/03/06

NOTES:

CP MDC's raised due to sample dilutions

** Surrogate diluted out

* Surrogate recovery high due to co-elution

MDC = Minimum Detectable Concentration

< = Less than MDC

Organic results are not corrected for surrogate recoveries

Results are blank corrected

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:

Norecol Dames & Moore

Quote #:

AV93-038

Attention:

Annette Smith

Project #:

FREMP Sediment Assay

Sample State:

Soils

Parameter	MDC	Unit	Zenon ID:	93004773	93004774	93004775	93004776
			Client ID:	MACBLO. 100M D/S	MACBLO. 200M D/S	MACBLO. 200M D/S Duplicate	BLANK 4
Moisture	0.1	%(W/W)		43.7	39	39.5	—
Part. Size 200 Mesh	0.1	"		28	24.4	28.4	—
Part. Size 400 Mesh	0.1	"		28	31.1	29.4	—
Part. Size <400 Mesh	0.1	"		43.9	44.5	42.2	—
Carbon Tot Inorganic	500	ug/g		2900	2900	3300	<
Carbon Total	500	"		11000	11000	11000	<
Pentachlorophenol	0.005	ug/g		<	<	<	<
Tetrachlorophenols	0.005	"		<	<	<	<
Trichlorophenols	0.005	"		<	<	<	<
Surrogate Recovery							
Dibromophenol		%		108	169*	71	76
Tribromophenol		"		125	112*	84	84
Silver	1	ug/g		<	<	<	<
Aluminum	2	"		30500	29200	29800	3
Arsenic	0.2	"		<	<	<	<
Arsenic	10	"		—	—	—	—
Barium	0.1	"		202	199	201	<
Beryllium	0.1	"		0.6	0.5	0.5	<
Bismuth	2	"		<	<	<	<
Calcium	1	"		12100	12000	11900	28
Cadmium	0.1	"		0.6	0.7	0.6	<
Cobalt	0.3	"		13.7	13	13.5	<
Chromium	0.2	"		50.2	48.2	41	1.3
Copper	0.1	"		32.8	32.1	32.3	1.1
Iron	0.3	"		38300	37700	37900	7
Potassium	40	"		4900	4590	4800	<
Magnesium	2	"		12700	12500	12500	6
Manganese	0.2	"		525	496	498	<
Molybdenum	0.4	"		<	<	<	<
Sodium	1	"		1100	1100	1120	37
Nickel	0.8	"		42.1	42.2	42.6	<
Phosphorus	4	"		774	766	768	61
Lead	2	"		9	8	9	<
Sulphur	3	"		552	548	557	28
Antimony	1.5	"		<	<	<	<
Selenium	10	"		<	<	<	<
Tin	2	"		<	<	<	<
Strontium	0.1	"		70.1	71.6	71.3	<
Tellurium	2	"		<	<	<	<
Titanium	0.3	"		1260	1310	1400	0.4
Thallium	2	"		<	<	<	<
Vanadium	0.3	"		61.8	63.1	63.5	<
Zinc	0.2	"		82.5	83.3	83.8	1.4
Zirconium	0.3	"		9.4	10.4	10.2	<

Zenon Environmental Laboratories - Certificate of Analysis

Reported to:	Norecol Dames & Moore	Quote #:	AV93-038
Attention:	Annette Smith	Project #:	FREMP Sediment Assay
Sample State:	Soils		

			Zenon ID: 93004773	93004774	93004775	93004776
			Client ID: MACBLO.	MACBLO.	MACBLO.	BLANK 4
			100M D/S	200M D/S	200M D/S	
					Duplicate	
Parameter	MDC	Unit				
PAH						
Naphthalene	0.001	ug/g	---	---	---	---
Acenaphthylene	0.001	"	---	---	---	---
Acenaphthene	0.001	"	---	---	---	---
Fluorene	0.001	"	---	---	---	---
Phenanthrene	0.001	"	---	---	---	---
Anthracene	0.001	"	---	---	---	---
Total low MW PAH's	0.001	"	---	---	---	---
Fluoranthene	0.001	"	---	---	---	---
Pyrene	0.001	"	---	---	---	---
Benzo(c)phenanthrene	0.001	"	---	---	---	---
Benzo(a)anthracene	0.001	"	---	---	---	---
Chrysene	0.001	"	---	---	---	---
Benzo(b+k)fluoranthene	0.001	"	---	---	---	---
Benzo(j)fluoranthene	0.001	"	---	---	---	---
7,12-Dimethylb(a)anthrene	0.005	"	---	---	---	---
Benzo(a)pyrene	0.001	"	---	---	---	---
3-Methylcholanthrene	0.002	"	---	---	---	---
Indeno(1,2,3-c,d)pyrene	0.002	"	---	---	---	---
Dibenz(a,h)anthracene	0.002	"	---	---	---	---
Benzo(g,h,i)perylene	0.002	"	---	---	---	---
Dibenzo(a,l)pyrene	0.005	"	---	---	---	---
Dibenzo(a,i)pyrene	0.005	"	---	---	---	---
Dibenzo(a,h)pyrene	0.005	"	---	---	---	---
Total high MW PAH's	0.005	"	---	---	---	---
Total PAH's	0.005	"	---	---	---	---
Surrogate Recovery						
Acenaphthene d10		%	---	---	---	---
Phenanthrene d10		"	---	---	---	---
Chrysene d12		"	---	---	---	---
Perylene d12		"	---	---	---	---

Sampled on : 93/03/06 93/03/06 93/03/06 93/03/06

NOTES:

CP MDC's raised due to sample dilutions

* Surrogate diluted out

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