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Polycyclic Aromatic Hydrocarbons, Organic Carbon and Nitrogen Content of Wastewater Suspended Solids - Data Summary Report

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Environment Canada
Fraser Pollution Abatement
Fraser River Action Plan

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1. INTRODUCTION

The Fraser River Action Plan, a six-year basin-wide program, was initiated in 1991 tc assess the condition of the river (FRAP, 1992). Determining the quality and quantity of wastewater discharges and estimating contaminant loadings was a component of Environmental Protection Branch's contribution to the program.

Polycyclic aromatic hydrocarbons (PAHs), because of their low aqueous solubilities, entering the aquatic environment rapidly become adsorbed to organic and inorganic particulate matter (Neff, 1979, Nagpal 1993). Depending on the octanol-water partition coefficient K_{ow}, which provides a direct estimate of partitioning tendency from water to organic media, the higher K_{ow} compounds would expected to be largely found associated with the organically rich and fine suspended matter in some wastewaters. PAHs may adsorb to either inorganic or organic surfaces although adsorption to organic materials predominates (NRC, 1983). Merriman, 1988 identified PAHs associated with centrifuged pulp mill effluent suspended solids but not in the centrifuge-clarified water fraction. Dunn and Stich, 1976 identified a sharp gradient of benzo(a)pyrene [B(a)P] in sediment samples toward the Iona Island sewage treatment plant (STP) outfall. They concluded the STP was the major contributor to the Fraser River estuary PAH burden. Several high molecular weight PAHs (e.g., B[a]P) are of particular environmental interest as they are known to be carcinogenic (Nagpal, 1993).

This report includes the results a limited number of centrifuge-concentrated suspended solids samples which were collected over 1993 to 1995, in an effort to more completely characterize a variety of wastewater sources for PAHs and other organic contaminants (Figure 1 and 2). On several occasions, the centrifuging was conducted concurrently with more "traditional" wastewater (whole effluent) characterization studies (IRC, 1994; GVRD, 1994; ND&M, 1994). That data is also presented for comparative purposes.

2. SUSPENDED SOLIDS COLLECTION

An Envirodat Sedisamp System II Model 100IL (modified Alfa-Laval MAB103B) continuous-flow centrifuge was used to collect a concentrated suspended solids sample at the point of effluent discharge into the receiving environment. The centrifuge was operated at 4L/minute and long enough to collect a 300-500g (wet weight) sample . Centrifuge operation, clean-up procedures and sample handling procedures are reported in detail elsewhere (Mitchell, 1994).

Centrifuging was conducted concurrently with whole effluent sampling on five occasions (three pulp mill and two combined sewer overflow discharges). On one occasion, a 50L sample of centrifuge-clarified municipal sewage effluent was passed through a solid phase extraction (XAD-2 resin) system described by Sekela et al., 1995.

Figure 1: Location of Wastewater Sources for Suspended Solids

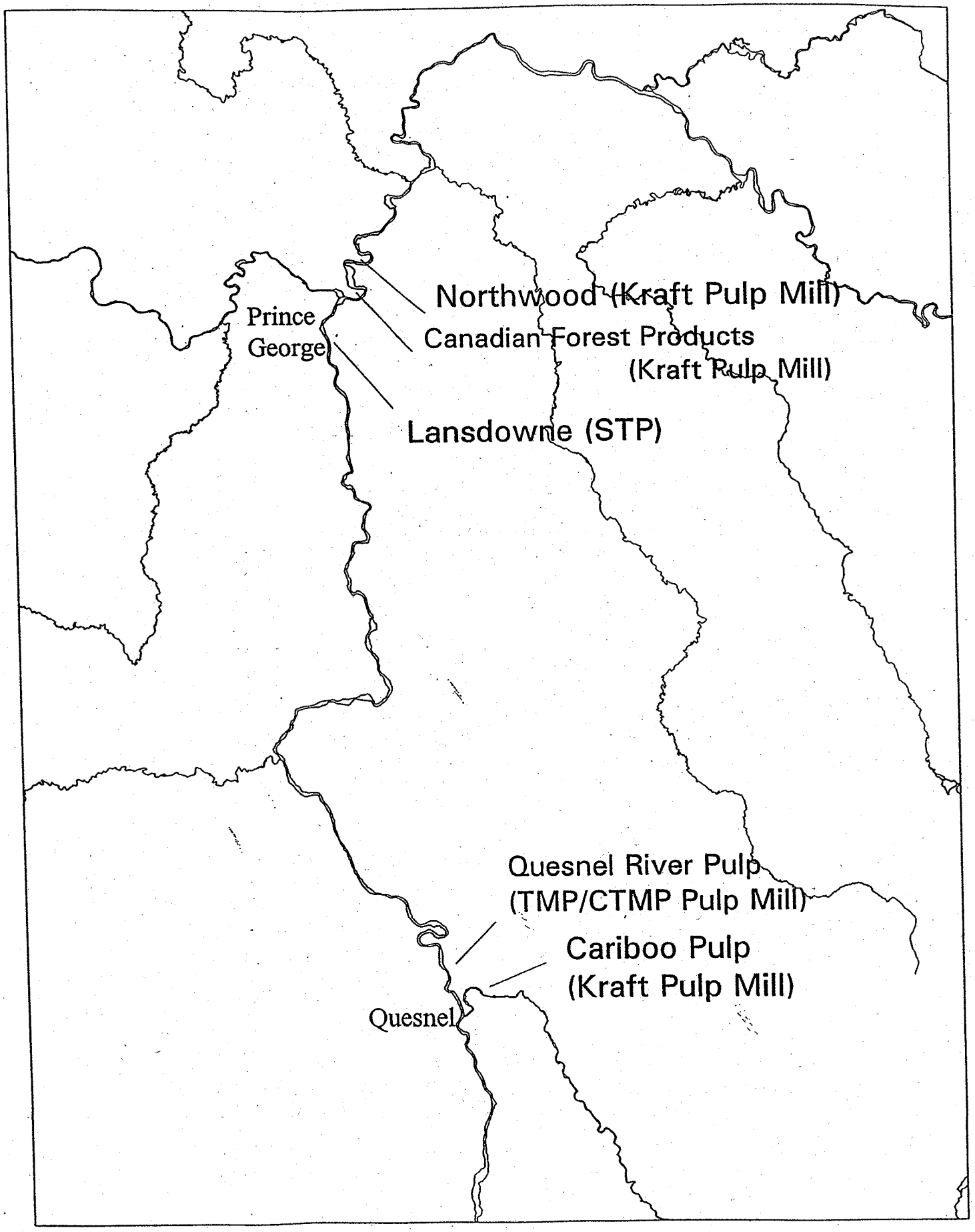
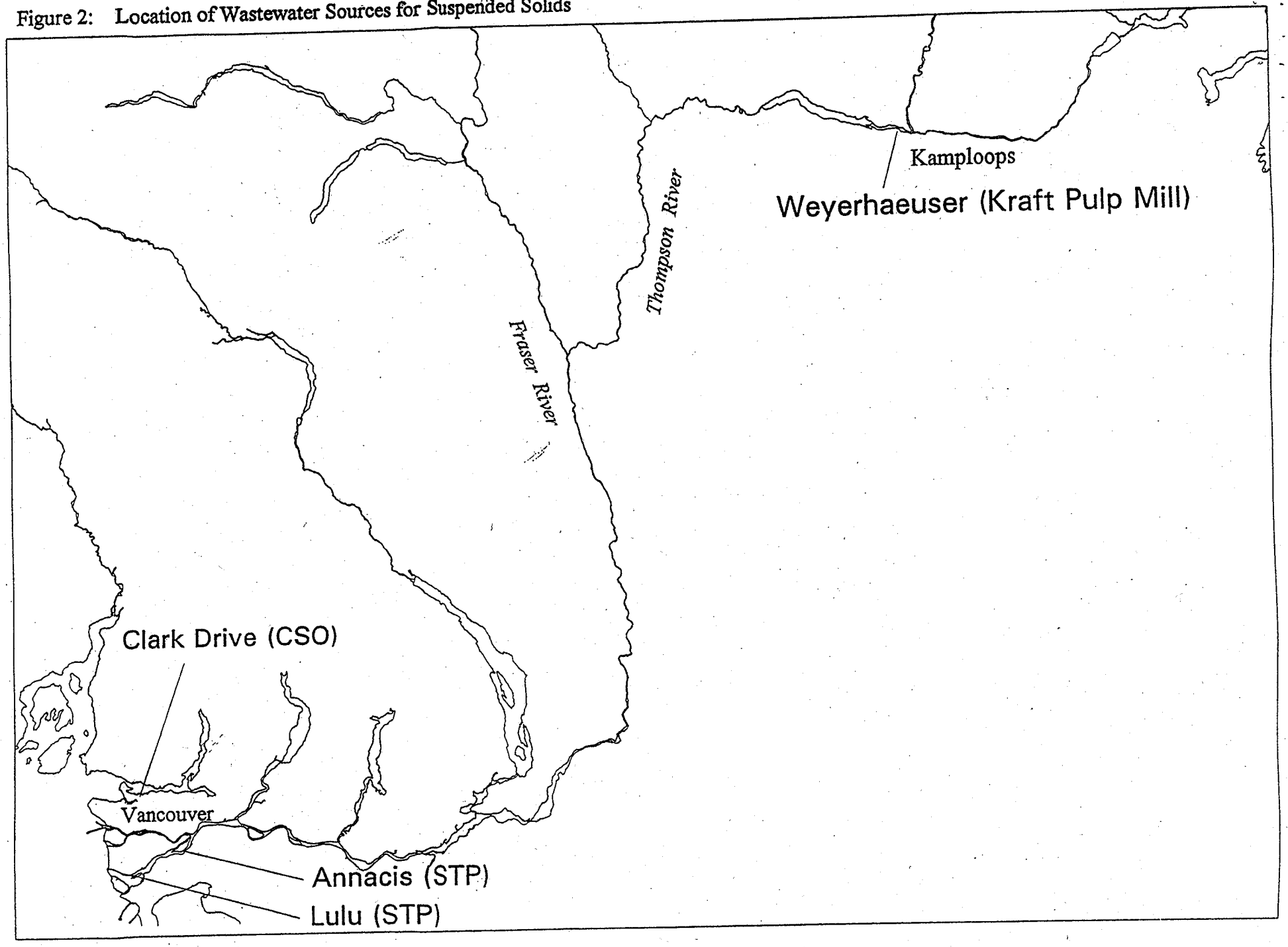


Figure 2: Location of Wastewater Sources for Suspended Solids



3. ANALYTICAL METHODS FOR SUSPENDED SOLIDS

3.1 Suspended Solids PAHs

3.1.1 AXYS (Axys Analytical Services) - PH-S-01/Ver.1, PH-S-02/Ver.1 and PH-S-01/Ver.2

Each sample was spiked with an aliquot of surrogate standard solution containing nine perdeuterated PAHs to allow quantification of the target analytes and measure extraction efficiency.

A subsample of wet material was weighted into a round-bottom flask, spiked with an aliquot of surrogate standard solution and digested by refluxing with alcoholic potassium hydroxide solution. The liquid digest was extracted with pentane and backwashed with extracted water. The pentane extract was cleaned up by column chromatography on silica gel. The second fraction (eluted with dichloromethane), contained the PAHs. An aliquot of recovery standard solution containing three perdeuterated PAHs was added just prior to instrumental analysis by high resolution gas chromatography with low resolution (quadrupole) mass spectrometric detection (HRGC/LRMS) (Appendix 1).

Three samples required repeat analysis due to initial poor surrogate recoveries. To improve surrogate recoveries, a different extraction procedure (PH-S-02) was used for these samples. Samples were ground with sodium sulphate, packed in a glass chromatographic column and eluted with methanol and dichloromethane. The eluate was backwashed with dilute base and extracted water. Extracts were solvent-exchanged to iso-octane and cleaned up and analyzed as described above.

Samples analyzed by method PH-S-01/Ver.2 were treated as described above but did not include analysis of the alkylated forms of naphthalene and phenanthrene.

The wastewater sources sampled along with the respective PAH analytical methods are listed in Table 1 for: Nwood (Northwood Pulp Mill), Canfor (Canadian Forest Products Pulp Mill), QRP (Quesnel River Pulp Mill), Cboo (Cariboo Pulp Mill), Landsdowne (Prince George Central STP), Annacis and Lulu (GVRD STPs) and Clark Drive (GVRD Combined Sewer Overflow to Burrard Inlet).

3.1.2 ASL (Analytical Service Laboratories)

The combined sewer overflow (CSO) sample collected on March 22, 1993 was analyzed as part of a Greater Vancouver Regional District project (GVRD, 1994). The method was described as being a procedure adapted by ASL from U.S.

EPA Methods 3540, 3630, and 8270. The procedure involved a triple solvent extraction with dichloromethane and clean-up using silica gel column chromatogaphy. The final extract was analyzed by capillary column gas chromatography with mass spectrometric detection.

Table 1: Wastewater Sources and PAH Methods for Suspended Solids

Sample Source	Method	Sample Source	Method	Sample Source	Method
PULP MILLS		MUNICIPAL SEWAGE		COMBINED SEWER OVERFLOW	
Nwood		Landsdowne	PH-S-01/Ver.1		
04/11/93	PH-S-01/Ver.1	03/11/93		Clark Drive	ASL
25/10/94	PH-S-02/Ver.1	Annacis	PH-S-02/Ver.1	22/03/93*	PH-S-01/Ver.1
Canfor		03/03/94**	PH-S-01/Ver.2	06/04/94*	
05/11/93	PH-S-01/Ver.1	22/08/95	PH-S-01/Ver.2		
23/11/93*	PH-S-01/Ver.1	21/11/95			
QRP		Lulu	PH-S-01/Ver.1		
01/11/93*	PH-S-01/Ver.1	12/05/94			
Cboo					
02/11/93*	PH-S-02/Ver.1				
Wey					
08/11/93*	PH-S-02/Ver.1				

* whole effluent samples collected , ** centrifuge-clarified effluent sample collected.

3.2 Suspended Solids Carbon and Nitrogen

Carbon and nitrogen analyses were carried out with a gas chromatography unit (Carlo Erba 1104) in which the sample is burned and the amount of the resulting gases are measured by thermal conductivity (Canadian Microanalytical Service, 1996). The procedure measures both organic and inorganic carbon. An analysis of two of the sewage solids after acid (HCl) addition to remove the inorganic fraction indicated that without the "inorganic component, the actual "organic" carbon component of the sample increased, by approximately 17%.

4. ANALYTICAL METHODS FOR EFFLUENTS

4.1 Whole Effluent PAHs

The method for the March 22, 1993 CSO sample was carried out in accordance with U.S. EPA Method 3510/8270 which involved the extraction of the sample with methylene chloride followed by silica column chromatography cleanup. The resulting extract was analyzed by capillary column gas chromatography with mass spectrometric detection (GVRD, 1994).

The three pulp mill samples and the April 06, 1994 CSO sample were treated as follows. The one litre sample was spiked with deuterated surrogates and liquid-liquid extracted with dichloromethane. If necessary, the extract was cleaned up by silica gel column chromatography. PAHs were analyzed with a Hewlett Packard 5970 GC/MS using selected ion monitoring (SIM) (Philip Analytical Services, 1996, IRC, 1994).

4.2 Centrifuge-clarified Effluent PAHs

The centrifuge-clarified sewage sample was analyzed by AXYS using method PH-C-05/Ver.1.

5. RESULTS

The quality assurance data for the spiked sediment samples and marine reference sample NRC-HS6, as provided by AXYS, are summarized in Appendix 2a. AXYS reported, that while the October 12, 1994 naphthalene d-8 surrogate recovery was lower than the normally accepted standard, the sample data were not compromised by this as the spike showed. The marine reference sample results did not indicate any extreme excursions from the expected values.

The individual sample results are reported in Appendix 2b. The data represent surrogate recovery corrected results but which have not been corrected for the procedural blanks results. The procedural blank results are also included with Appendix 2b for comparative purposes. There was nothing in the procedural blank results that indicated that any of the sample results would be seriously affected and required correction. The suspended solids contaminant loading was calculated (dry weight contaminant concentration **x** the daily loading of suspended solids) and is presented in units of grams per day. The whole effluent loading was calculated from the effluent concentration and the daily effluent volume discharged. For the CSO results, the loading is expressed on a daily (24h) basis for comparative purposes only. The actual CSO annual loading, which depends upon the actual number of hours of discharge per year and varies annually with rainfall, would be the most appropriate comparison with the annual loading of the other wastewaters. This would of course require a large enough data set to adequately represent the whole year, which the results of this report do not.

For naphthalene and phenanthrene, the unsubstituted and alkylated results are reported together in Appendix 2c.

6. DISCUSSION

The highly organic nature of the suspended solids discharged from the wastewaters tested is clearly evident and ranged from a low of ~25% for the

CSO to as high ~50% for the pulp mills (Table 2). The nitrogen content of the suspended solids ranged from a low of ~3% for the CSO to ~7.5 % for the pulp mills and STPs. These discharges represent major sources of particulate carbon into the Fraser system.

Table 2: Daily Loading of Carbon and Nitrogen Associated with Suspended Solids

TSS Source	Carbon		Nitrogen		
PULP MILLS	(%)	(kg/d)	(%)	(kg/d)	C:N RATIO
Nwood					
04/11/93	39.4	3890	6.32	620	6.2
25/10/94	47.7	6060	7.74	980	6.2
Canfor					
05/11/93	52.4	7570	5.46	790	9.6
23/11/93	51.9	8810	6.13	1040	8.5
QRP					
01/11/93	47.4	6580	5.08	710	9.3
Cboo					
02/11/93	37.1	1220	4.43	150	8.4
Wey					
08/11/93	42.9	3800	6.99	620	6.1
MUNICIPAL SEWAGE					
Landsdowne					
03/11/93	41.6	355	7.60	65	5.5
Annacis					
03/03/94	41.3	10470	5.26	1330	7.9
22/08/95	42.2	10870	7.00	1800	6.0
21/11/95	41.6	12960	6.15	1770	6.8
Lulu					
12/05/94	47.6	2000	6.64	280	7.2
COMBINED SEWER OVERFLOW					
06/04/94	24.5	5530	3.18	720	7.7

Of the six lower molecular weight PAHs (LMWPs), other than for QRP (TMP/CTMP pulp mill), phenanthrene was identified in all wastewaters and had the highest loading (Table 3). Although the data set cannot be considered extensive, it indicates that overall, the larger municipal sewage discharges in the lower Fraser and CSOs are major contributors of LWMPs. In the upper Fraser, the kraft pulp mills are an apparent source of phenanthrene and fluorene.

Generally, more LMWPs were identified in suspended solids samples than in whole effluent samples. However, the fact that different laboratories were involved could be a factor and, inpart, account for this difference. Because of the differences in laboratories and small volume sample (1L) used for analysis, it wasn't considered useful to try to estimate the proportion of LWMPs in the solid vs "soluble" fractions based on these results.

In one case the same laboratory was used where the suspended solids sample and a 50L centrifuge-clarified municipal sewage effluent sample for solid phase extraction were collected concurrently. The relative proportion of LMWPs associated with the solids was estimated to be: acenaphthylene (70%), acenaphthene (7%), fluorene (19%), phenanthrene (33%) and anthracene (19%).

Of the eleven high molecular weight PAHs (HMWPs), other than for QRP (TMP/CTMP pulp mill), fluoranthene, pyrene and chrysene were identified in all wastewaters (Table 4). The lower Fraser municipal discharges appear to be a main source of HMWPs into the Fraser system. A large fraction of the pulp mill samples were reported as NDRs (peak detected but did not meet quantification criteria). The results demonstrate that centrifuge-concentrated suspended solids samples have an overall higher number of positive identifications then do whole effluent 24-h composite 1L samples.

There was a close match between the HMWPs positive identifications for the suspended solids sample and the high volume solid phase extraction sample. As might be expected, these higher K_{ow} compounds were found to be largely associated with the organically rich solids: fluoranthene (59%), pyrene (63%), benz(a)anthracene (80%), chrysene (81%), benzofluoranthenes (96%), benzo(e)pyrene (96%) and benzo(a)pyrene (96%).

A higher proportion of alkylated to unsubstituted naphthalene and phenanthrene indicate a petroleum source (Nagpal, 1993). This was most evident at the Prince George Landsdowne STP and the Canfor pulp mill (Table 5). Dayton & Knight, 1993 reported that the Prince George STP had an ongoing problem with diesel fuel entering the plant from a transit bus washing source and this likely accounts for the observed results. Canfor receives treated wastewater from the Husky Oil Refinery, into the mill's treatment system, and this may account, in part, for the observed results. The kraft pulp mills in the upper Fraser appear to a definite source of alkylated phenanthrene whereas, in the lower Fraser, CSOs are a definite source (Table 6).

Table 3: Estimated Loading of Lower Molecular Weight Polycyclic Aromatic Hydrocarbons Associated with Suspended Solids from Various Wastewater Sources

TSS Source/PAH	Naphthalene (g/d)	Acenaphthylene (g/d)	Acenaphthene (g/d)	Fluorene (g/d)	Phenanthrene (g/d)	Anthracene (g/d)	Positive IDs
PULP MILLS							
Nwood							
04/11/93	0.21	NDR	0.38	0.55	3.16	NDR	4/6
25/10/94	NDR	NDR	1.27	1.78	9.15	6.35	4/6
Canfor							
05/11/93	1.74	NDR	NDR	0.88	4.05	NDR	3/6
05/11/93 (dupl)	(1.74)	(NDR)	(0.58)	(0.97)	(4.19)	(NDR)	4/6
23/11/93	0.61	<	0.34	1.20	3.73	NDR	4/6
23/11/93 (whole)*	<	<	<	-	<	<	0/5
QRP							
01/11/93	0.22	NDR	NDR	0.11	NDR	NDR	2/6
01/11/93 (whole)*	-	-	-	-	-	-	3/6
Cboo							
02/11/93	0.49	0.08	0.53	0.79	3.03	8.22	6/6
Wey							
08/11/93	2.48	1.06	0.55	1.68	8.78	1.15	6/6
08/11/93 (whole)*	<	<	<	10.3	15.5	6.87	3/6
MUNICIPAL SEWAGE							
Landsdowne							
03/11/93	0.06	<	NDR	0.15	0.22	NDR	3/6
03/11/93 (dupl)	(0.06)	(NDR)	(NDR)	(0.16)	(0.21)	(NDR)	3/6
Annacis							
03/03/94	55.7	15.7	7.60	14.2	43.1	3.55	6/6
03/03/94 (XAD-2)**	-	6.78	95.0	58.8	85.9	15.4	5/5
22/08/95	13.5	NDR	13.7	12.4	56.3	9.24	5/6
21/11/95	87.9	40.6	10.4	9.46	76.6	12.2	6/6
Lulu							
12/05/94	9.22	10.1	0.26	1.68	54.5	6.70	6/6
COMBINED SEWER OVERFLOW**							
22/03/93	4.87	2.51	3.02	4.92	35.9	6.38	6/6
22/03/93 (whole)***	64.1	<	<	<	40.8	<	2/6
06/04/94	8.56	0.92	1.67	3.83	27.0	11.7	6/6
06/04/94 (whole)***	24.6	<	2.05	4.10	14.3	<	4/6

Table 4: Estimated Loading of High Molecular Weight Polycyclic Aromatic Hydrocarbons Associated with Suspended Solids from Various Wastewater Sources

TSS Source/PAH	Fluoranthene (g/d)	Pyrene (g/d)	Benz(a)anthracene (g/d)	Chrysene (g/d)	Benzofluoranthenes (g/d)	Benzo(e)pyrene (g/d)	Positive IDs
PULP MILLS							
Nwood							
04/11/93	1.58	1.48	0.40	0.68	NDR	NDR	4/6
25/10/94	0.37	0.24	NDR	0.08	NDR	0.43	4/6
Canfor							
05/11/93	1.59	2.75	NDR	1.59	NDR	0.64	4/6
05/11/93 (dupl)	(1.17)	(2.02)	(NDR)	(1.17)	(NDR)	(NDR)	3/6
23/11/93	1.63	1.87	NDR	1.87	NDR	NDR	3/6
23/11/93 (whole)*	<	<	<	<	-	-	0/4
QRP							
01/11/93	0.12	NDR	NDR	NDR	<	<	1/6
01/11/93 (whole)*	<	-	-	-	-	-	4/6
Cboo							
02/11/93	2.80	2.17	NDR	0.56	NDR	NDR	3/6
Wey							
08/11/93	9.75	7.18	NDR	3.01	2.30	1.51	5/6
08/11/93 (whole)*	8.59	<	<	<	-	-	1/4
MUNICIPAL SEWAGE							
Landsdowne							
03/11/93	0.22	0.50	NDR	0.15	NDR	NDR	3/6
03/11/93 (dupl)	(0.29)	(0.49)	(NDR)	(0.15)	(NDR)	(NDR)	3/6
Annacis							
03/03/94	32.9	30.4	7.09	8.61	16.2	5.82	6/6
03/03/94 (XAD 2)**	22.6	17.6	1.81	2.08	0.68	0.24	6/6
22/08/95	29.3	24.8	4.51	4.51	3.38	1.64	6/6
21/11/95	63.1	47.3	6.98	9.91	NDR	10.6	5/6
Lulu							
12/05/94	62.8	75.4	NDR	12.6	24.3	13.0	5/6
COMBINED SEWER OVERFLOW****							
22/03/93	45.6	47.4	19.1	20.0	-	-	4/4
22/03/93 (whole)***	<	58.3	<	<	-	-	1/4
06/04/94	31.5	31.5	10.6	21.4	-	-	4/4
06/04/94 (whole)***	10.2	16.4	4.10	4.10	-	-	4/4

Table 4 cont'd : Estimated Loading of Higher Molecular Weight Polycyclic Aromatic Hydrocarbons Associated with Suspended Solids from Various Wastewater Sources

TSS Source/PAH	Benzo(a)pyrene (g/d)	Perylene (g/d)	Dibenz(ah)anthracene (g/d)	Indeno(1,2,3-cd)pyrene (g/d)	Benzo(ghi)perylene (g/d)	Positive IDs
PULP MILLS						
Nwood						
04/11/93	NDR	NDR	NDR	NDR	NDR	0/5
25/10/94	NDR	0.80	<	<	NDR	1/5
Canfor						
05/11/93	NDR	NDR	NDR	NDR	NDR	0/5
05/11/93 (dupl)	(NDR)	(NDR)	(NDR)	(NDR)	(NDR)	0/5
23/11/93	NDR	NDR	NDR	NDR	NDR	0/5
23/11/93 (whole)*	<	-	<	<	<	0/4
QRP						
01/11/93	<	<	<	<	NDR	0/5
01/11/93 (whole)*	-	-	-	-	-	0/4
Cboo						
02/11/93	0.30	NDR	<	NDR	NDR	1/5
Wey						
08/11/93	NDR	NDR	NDR	NDR	NDR	0/5
08/11/93 (whole)*	<	-	<	<	<	0/4
MUNICIPAL SEWAGE						
Landsdowne						
03/11/93	0.05	NDR	NDR	NDR	0.06	2/5
03/11/93 (dupl)	(0.05)	(NDR)	(NDR)	(NDR)	(NDR)	1/5
Annacis						
03/03/94	5.82	NDR	NDR	NDR	NDR	1/5
03/03/94 (XAD-2)**	0.22	<	<	<	<	1/5
22/08/95	1.51	NDR	NDR	NDR	0.92	2/5
21/11/95	6.98	NDR	NDR	4.28	NDR	2/5
Lulu						
12/05/94	16.8	2.72	NDR	11.7	23.0	4/5
COMBINED SEWER OVERFLOW**						
22/03/93	20.1	20.4	1.00	4.59	5.66	5/5
22/03/93 (whole)***	<	<	<	<	<	0/5
06/04/94	13.3	3.61	2.48	13.5	15.8	5/5
06/04/94 (whole)***	<	-	<	<	<	0/4

Table 5: Ratio of Alkylated to Unsubstituted PAH for Naphthalene and Phenanthrene

TSS Source	Naphthalene Alkylated:Unsubstituted	Phenanthrene Alkylated:Unsubstituted	Alkylated Phenanthrene:Naphthalene
PULP MILLS			
Nwood			
04/11/93	26.6	19.3	11.1
25/10/94	-	5.6	5.9
Canfor			
05/11/93	17.3	46.8	6.3
23/11/93	58.6	59.5	6.2
QRP			
01/11/93	2.1	-	-
Cboo			
02/11/93	5.1	6.3	7.5
Wey			
08/11/93	4.1	11.8	10.3
MUNICIPAL SEWAGE			
Landsdowne			
03/11/93	150	80.4	2.1
Annacis			
03/03/94	2.4	0.4	0.1
Lulu			
12/05/94	3.6	0.3	0.5
COMBINED SEWER OVERFLOW			
06/04/94	23.7	10.4	1.4

Table 6: Daily Loading of Alkylated and Unsubstituted PAH for Naphthalene and Phenanthrene

TSS Source	Naphthalene (g/d)		Phenanthrene (g/d)	
PULP MILLS	Unsubsituted	Alkylated	Unsubstituted	Alkylated
Nwood				
04/11/93	0.21	5.51	3.16	60.9
25/10/94	-	8.65	9.15	51.1
Canfor				
05/11/93	1.74	31.4	4.19	196.7
23/11/93	0.61	35.8	3.73	222.3
QRP				
01/11/93	0.22	0.47	NDR	<
Cboo				
02/11/93	0.49	2.53	3.03	19.1
Wey				
08/11/93	2.48	10.1	8.78	103.7
MUNICIPAL SEWAGE				
Landsdowne				
03/11/93	0.06	8.45	0.22	8.45
Annacis				
03/03/94	55.7	131.7	43.1	17.5
Lulu				
12/05/94	9.22	33.1	54.5	17.2
COMBINED SEWER OVERFLOW				
06/04/94	8.56	202.8	27.0	279.9

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7. ACKNOWLEDGEMENTS

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APPENDICES

1 Analysis of Polycyclic Aromatic Hydrocarbons (PAHs) in Sludge Sample

2 (a) Quality Assurance Results
(b) PAH Results
(c) Alkylated PAH Results

APPENDIX 1

ANALYSIS OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) IN SLUDGE SAMPLES

Prior to extraction samples were spiked with an aliquot of surrogate standard solution containing perdeuterated acenaphthene, chrysene, naphthalene, perylene, phenanthrene, pyrene, dibenz[ah]anthracene, benzo[ghi]perylene and benzo[a]pyrene.

1. Extraction

Sludge samples were analyzed wet and an additional subsample taken for gravimetric moisture determination in order to report the data on a dry weight basis.

1.1 Base Digestion Extraction

A homogenized subsample (approximately 10 g wet) was placed in a round-bottomed flask with methanol, potassium hydroxide solution and an aliquot of surrogate standard solution. The mixture was digested under reflux for 1 hr, cooled and extracted water added. The solution was reheated under reflux, then allowed to cool.

The digest liquid was decanted into a separatory funnel and the remaining solids rinsed with methanol. The digest (plus rinses) was extracted with pentane. The pentane extract was washed with extracted water, dried over anhydrous sodium sulphate and reduced in volume prior to cleanup on a silica gel column.

1.2 Alternate Column Elution Extraction

A homogenized subsample (approximately 10 g) was placed in a beaker containing anhydrous sodium sulphate and spiked with an aliquot of internal standard solution. The sample was ground to a free flowing powder, transferred to a glass chromatographic column and eluted with methanol followed by dichloromethane. The methanol and dichloromethane extracts were combined and an aliquot of iso-octane added. The extract was washed with a sodium hydroxide solution followed by extracted water, dried over anhydrous sodium sulphate and reduced in volume. Activated copper was added for sulphur removal prior to column cleanup.

2. Column Chromatography Cleanup

The sample was loaded onto a silica gel column and eluted with pentane followed by dichloromethane. The dichloromethane fraction contained the PAHs.

This fraction was concentrated to a small volume, transferred to a microvial and an aliquot of recovery standard containing perdeuterated benzo[b]fluoranthene, fluoranthene, and acenaphthylene was added prior to GC/MS analysis.

3. Instrumental Analysis

Analysis of the extract was conducted using a Finnigan Incos 50 mass spectrometer equipped with a Varian 3400 gas chromatograph, a CTC autosampler and a DG 10 Data system. A 30 metre Restek$_X$-5 chromatographic column (0.25 mm i.d. x 0.25 µm film thickness) was used for GC separation. The mass spectrometer was operated at unit mass resolution in the EI mode (70 eV) using Multiple Ion Detection (MID) to enhance sensitivity, acquiring two characteristic ions for each target analyte and surrogate standard. A split/splitless injection sequence was used.

APPENDIX 2

Appendix 2a: (i) Quality Assurance Samples for PAHs - Spiked Sediment Matrix
(ii) Quality Assurance Samples for PAHs - NRC HS6 Marine Sediment

Compound (%) Recovery	(i) July 11/94*	(i) Oct 12/94*
Naphthalene	92	92
Acenaphthylene	105	145
Acenaphthene	100	113
Fluorene	96	100
Phenanthrene	100	113
Anthracene	104	100
Fluoranthene	100	132
Pyrene	100	119
Benz(a)anthracene	100	119
Chrysene	100	114
Benzofluoranthenes	107	119
Benzo(e)pyrene	109	123
Benzo(a)pyrene	105	111
Perylene	105	124
Dibenz(ah)anthracene	108	108
Indeno(1,2,3-cd)pyrene	111	100
Benzo(ghi)perylene	105	110
Surrogate Standard (%) Recovery		
Naphthalene d-8	59	10
Acenaphthene - d-10	67	27
Phenanthrene d-10	86	49
Pyrene d-10	91	59
Chrysene d-12	77	77
Benzo(a)pyrene d-12	68	76
Perylene d-12	63	66
Dibenz(ah)anthracene d-14	58	96
Benzo(ghi)perylene d-12	60	92

*July 11/94: QRP (Nov 1/93), PG STP (Nov 3/93), NWood (Nov 4/93), Canfor (Nov 5/93), Canfor (Nov 23/93),.
*Oct 12/94: Cboo (Nov 2/93), Weyer (Nov 8/93), Annac (Mar 3/94).

Appendix 2a cont'd:

Compound	Certified Value (ng/g) low	mean	high	(ii) Sep 16/94	(ii) Apr 26/95	(ii) Oct 2/95	(ii) Feb 5/96
Naphthalene	3000	4100	5200	4700	3500	4500	4300
Acenaphthylene	140	190	240	180	190	230	220
Acenaphthene	160	230	300	130	160	160	110
Fluorene	350	470	590	430	360	340	230
Phenanthrene	2400	3000	3600	3600	2900	3300	3300
Anthracene	700	1100	1500	950	820	1000	900
Fluoranthene	2890	3540	4190	3600	3100	3400	3600
Pyrene	2400	3000	3600	3000	2300	2700	2800
Benz(a)anthracene	1500	1800	2100	1800	1400	1700	1800
Chrysene	1700	2000	2300	2700	2200	2300	2400
Benzofluoranthenes	3480	4230	4980	5600	4000	4500	5400
Benzo(e)pyrene				2000	1500	1600	1900
Benzo(a)pyrene	1800	2200	2600	1900	1700	1900	1600
Perylene				470	440	500	440
Dibenz(ah)anthracene	330	490	650	480	410	450	410
Indeno(1,2,3-cd)pyrene	1370	1950	2530	2600	2000	2100	2100
Benzo(ghi)perylene	1060	1780	2500	1700	1500	1600	1700
Surrogate Standard (%) Recovery							
Naphthalene d-8				-	50	73	77
Acenaphthene - d-10				-	63	74	73
Phenanthrene d-10				-	86	80	82
Pyrene d-10				-	92	90	89
Chrysene d-12				-	74	85	85
Benzo(a)pyrene d-12				-	110	89	83
Perylene d-12				-	120	86	84
Dibenz(ah)anthracene d-14				-	120	62	81
Benzo(ghi)perylene d-12				-	120	58	78

Sept 16/94: Lulu (May 12/94), Clark (Apr 6/94).
Oct 2/94: Annac (Aug 22/95).

Apr 26/94: Nwood (Oct 25/94).
Feb 5/96: (Annac Nov 21/95).

Appendix 2b: NORTHWOOD - NOVEMBER 04 1993 - BIOSOLIDS PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	21		0.21
Acenaphthylene	(pbndr 1.1)	4.07	NDR 8.2		
Acenaphthene	(pb 1.6)	3.98	38		0.38
Fluorene	(pb 1.7)	4.18	56		0.55
Phenanthrene	(pbndr 2.9)	4.46	320		3.16
Anthracene	(pbndr 1.9)	4.5	NDR 63		
Fluoranthene	(pbndr 0.81)	4.9	160		1.58
Pyrene	(pbndr 0.68)	4.88	150		1.48
Benz(a)anthracene		5.63	41		0.40
Chrysene		5.63	69		0.68
Benzofluoranthenes			NDR 27		
Benzo(e)pyrene		6.21	NDR 33		
Benzo(a)pyrene		6.06	NDR 16		
Perylene		6.21	NDR 10		
Dibenz(ah)anthracene		6.86	NDR 7.2		
Indeno(1,2,3-cd)pyrene		6.58	NDR 6.1		
Benzo(ghi)perylene		6.78	NDR 20		

Flow = m3/d	
TSS =mg/l	
Mill reported daily TSS Loading kg/d	9875

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.55

Appendix 2b: NORTHWOOD - OCTOBER 25 1994 - BIOSOLIDS PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 2.6)	3.37	NDR 32		
Acenaphthylene	(pb 0.48)	4.07	NDR 3.9		
Acenaphthene		3.98	100		1.27
Fluorene		4.18	140		1.78
Phenanthrene	(pbndr 0.68)	4.46	720		9.15
Anthracene		4.5	500		6.35
Fluoranthene	(pbndr 0.2)	4.9	430		0.37
Pyrene	(pbndr 0.23)	4.88	280		0.24
Benz(a)anthracene		5.63	NDR 86		
Chrysene		5.63	93		0.08
Benzofluoranthenes			NDR 140		
Benzo(e)pyrene		6.21	34		0.43
Benzo(a)pyrene		6.06	NDR 16		
Perylene		6.21	63		0.80
Dibenz(ah)anthracene		6.86	<24		
Indeno(1,2,3-cd)pyrene		6.58	<13		
Benzo(ghi)perylene		6.78	NDR 24		

Flow = m3/d	
TSS = mg/l	
Mill reported daily TSS Loading kg/d	12709

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.66

Appendix 2b: CANFOR - NOVEMBER 05 1993 - BIOSOLIDS PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	120		1.74
Acenaphthylene	(pbndr 1.1)	4.07	NDR 6.9		
Acenaphthene	(pb 1.6)	3.98	NDR 45		
Fluorene	(pb 1.7)	4.18	61		0.88
Phenanthrene	(pbndr 2.9)	4.46	280		4.05
Anthracene	(pbndr 1.9)	4.5	NDR 33		
Fluoranthene	(pbndr 0.81)	4.9	110		1.59
Pyrene	(pbndr 0.68)	4.88	190		2.75
Benz(a)anthracene		5.63	NDR 27		
Chrysene		5.63	110		1.59
Benzofluoranthenes			NDR 42		
Benzo(e)pyrene		6.21	44		0.64
Benzo(a)pyrene		6.06	NDR 6.2		
Perylene		6.21	NDR 7.2		
Dibenz(ah)anthracene		6.86	NDR 3.0		
Indeno(1,2,3-cd)pyrene		6.58	NDR 6.0		
Benzo(ghi)perylene		6.78	NDR 13		

Flow = m3/d	
TSS = mg/l	
Mill reported daily TSS Loading kg/d	14464

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.15

Appendix 2b: CANFOR - NOVEMBER 05 1993 - BIOSOLIDS PAH RESULTS
Blind Duplicate

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	120		1.74
Acenaphthylene	(pbndr 1.1)	4.07	NDR 5.3		
Acenaphthene	(pb 1.6)	3.98	40		0.58
Fluorene	(pb 1.7)	4.18	67		0.97
Phenanthrene	(pbndr 2.9)	4.46	290		4.19
Anthracene	(pbndr 1.9)	4.5	NDR 31		
Fluoranthene	(pbndr 0.81)	4.9	81		1.17
Pyrene	(pbndr 0.68)	4.88	140		2.02
Benz(a)anthracene		5.63	NDR 31		
Chrysene		5.63	81		1.17
Benzofluoranthenes			NDR 35		
Benzo(e)pyrene		6.21	NDR 41		
Benzo(a)pyrene		6.06	NDR 14		
Perylene		6.21	NDR 3.5		
Dibenz(ah)anthracene		6.86	NDR 4.1		
Indeno(1,2,3-cd)pyrene		6.58	NDR 4.2		
Benzo(ghi)perylene		6.78	NDR 13		

Flow = m3/d	
TSS = mg/l	
Mill reported daily TSS Loading kg/d	14464

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.24

Appendix 2b: CANFOR - NOVEMBER 23 1993 - BIOSOLIDS PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	36		0.61
Acenaphthylene	(pbndr 1.1)	4.07	<0.45		
Acenaphthene	(pb 1.6)	3.98	20		0.34
Fluorene	(pb 1.7)	4.18	71		1.20
Phenanthrene	(pbndr 2.9)	4.46	220		3.73
Anthracene	(pbndr 1.9)	4.5	NDR 15		
Fluoranthene	(pbndr 0.81)	4.9	96		1.63
Pyrene	(pbndr 0.68)	4.88	110		1.87
Benz(a)anthracene		5.63	NDR 34		
Chrysene		5.63	110		1.87
Benzofluoranthenes			NDR 24		
Benzo(e)pyrene		6.21	NDR 40		
Benzo(a)pyrene		6.06	NDR 13		
Perylene		6.21	NDR 2.8		
Dibenz(ah)anthracene		6.86	NDR 13		
Indeno(1,2,3-cd)pyrene		6.58	NDR 4.3		
Benzo(ghi)perylene		6.78	NDR 9.8		

Flow = m3/d	
TSS =mg/l	
Mill reported daily TSS Loading kg/d	16968

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.21

Appendix 2b: QUESNEL RIVER PULP - NOVEMBER 01 1993 - BIOSOLIDS PAH RESULTS

Compound		log Kow	Solids (ng/g)	Whole Effluent* (ug/L)	(g/d)	Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	16	<0.01		0.22
Acenaphthylene	(pbndr 1.1)	4.07	NDR 1.6	0.03	0.73	
Acenaphthene	(pb 1.6)	3.98	NDR 3.0	<0.01		
Fluorene	(pb 1.7)	4.18	7.9	<0.01		0.11
Phenanthrene	(pbndr 2.9)	4.46	NDR 15	0.06	1.45	
Anthracene	(pbndr 1.9)	4.5	NDR 3.1	0.04	0.97	
Fluoranthene	(pbndr 0.81)	4.9	8.5	0.02	0.48	0.12
Pyrene	(pbndr 0.68)	4.88	NDR 8.9	0.01	0.24	
Benz(a)anthracene		5.63	NDR 1.4	0.03	0.73	
Chrysene		5.63	NDR 3.0	<0.01		
Benzofluoranthenes			<1.3	-		
Benzo(e)pyrene		6.21	<1.4	-		
Benzo(a)pyrene		6.06	<1.6	<0.01		
Perylene		6.21	<1.6	-		
Dibenz(ah)anthracene		6.86	<3.3	0.02	0.48	
Indeno(1,2,3-cd)pyrene		6.58	<1.9	<0.01		
Benzo(ghi)perylene		6.78	NDR 3.2	<0.02		

Flow = m3/d	
TSS = mg/l	
Mill reported daily TSS Loading kg/d	13870

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 0.81

Appendix 2b: CARIBOO - NOVEMBER 02 1993 - BIOSOLIDS PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 9.0)	3.37	150		0.49
Acenaphthylene	(pbndr 2.0)	4.07	25		0.08
Acenaphthene		3.98	160		0.53
Fluorene	(pbndr 3.0)	4.18	240		0.79
Phenanthrene	(pb 8.0)	4.46	920		3.03
Anthracene	(pbndr 3.0)	4.5	2500		8.22
Fluoranthene	(pbndr 2.0)	4.9	850		2.80
Pyrene	(pbndr 2.0)	4.88	660		2.17
Benz(a)anthracene	(pbndr 0.7)	5.63	NDR 130		
Chrysene	(pbndr 0.8)	5.63	170		0.56
Benzofluoranthenes			NDR 180		
Benzo(e)pyrene		6.21	NDR 68		
Benzo(a)pyrene		6.06	92		0.30
Perylene		6.21	NDR 13		
Dibenz(ah)anthracene		6.86	<31		
Indeno(1,2,3-cd)pyrene		6.58	NDR 30		
Benzo(ghi)perylene	(pbndr 2.0)	6.78	NDR 65		

Flow = m3/d	
TSS = mg/l	
Mill reported daily TSS Loading kg/d	3289

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.97

Appendix 2b: WEYERHAEUSER - NOVEMBER 08 1993 - BIOSOLIDS PAH RESULTS

Compound		log Kow	Solids (ng/g)	Whole Effluent* (ug/L)	(g/d)	Solids (g/d)
Naphthalene	(pbndr 9.0)	3.37	280	<0.01		2.48
Acenaphthylene	(pbndr 2.0)	4.07	120	<0.01		1.06
Acenaphthene		3.98	62	<0.01		0.55
Fluorene	(pbndr 3.0)	4.18	190	0.06	10.31	1.68
Phenanthrene	(pb 8.0)	4.46	990	0.09	15.46	8.78
Anthracene	(pbndr 3.0)	4.5	130	0.04	6.87	1.15
Fluoranthene	(pbndr 2.0)	4.9	1100	0.05	8.59	9.75
Pyrene	(pbndr 2.0)	4.88	810	<0.01		7.18
Benz(a)anthracene	(pbndr 0.7)	5.63	NDR 150	<0.01		
Chrysene	(pbndr 0.8)	5.63	340	<0.01		3.01
Benzofluoranthenes			260			2.30
Benzo(e)pyrene		6.21	170			1.51
Benzo(a)pyrene		6.06	NDR 69	<0.01		
Perylene		6.21	NDR 15			
Dibenz(ah)anthracene		6.86	NDR 210	<0.01		
Indeno(1,2,3-cd)pyrene		6.58	NDR 44	<0.01		
Benzo(ghi)perylene	(pbndr 2.0)	6.78	NDR 150	<0.02		
	(n)				n = 4	n = 11

Flow = 171,800 m3/d	
TSS = 30mg/l	
Mill reported daily TSS kg/d	8865

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.12

Appendix 2b: WEYERHAEUSER - NOVEMBER 08 1993 - BIOSOLIDS PAH RESULTS

(duplicate)

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 9.0)	3.37	200		1.77
Acenaphthylene	(pbndr 2.0)	4.07	92		0.82
Acenaphthene		3.98	49		0.43
Fluorene	(pbndr 3.0)	4.18	180		1.60
Phenanthrene	(pb 8.0)	4.46	930		8.24
Anthracene	(pbndr 3.0)	4.5	140		1.24
Fluoranthene	(pbndr 2.0)	4.9	1000		8.87
Pyrene	(pbndr 2.0)	4.88	690		6.12
Benz(a)anthracene	(pbndr 0.7)	5.63	NDR 140		
Chrysene	(pbndr 0.8)	5.63	350		3.10
Benzofluoranthenes			280		2.48
Benzo(e)pyrene		6.21	180		1.60
Benzo(a)pyrene		6.06	NDR 78		
Perylene		6.21	NDR 17		
Dibenz(ah)anthracene		6.86	<19		
Indeno(1,2,3-cd)pyrene		6.58	NDR 62		
Benzo(ghi)perylene	(pbndr 2.0)	6.78	NDR 180		

Flow = 171,800 m3/d	
TSS = 30mg/l	
Mill reported daily TSS kg/d	8865

pb = procedural blank (solids) detectable quantity (ng/g)

< = sample detection limit

NDR/ndr = peak detected but did not meet quantification criteria

Sample size g dry wt. = 1.12

Appendix 2b: LANDSDOWNE STP - NOVEMBER 03 1993 - BIOSOLIDS PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	66		0.06
Acenaphthylene	(pbndr 1.1)	4.07	< 0.3		
Acenaphthene	(pb 1.6)	3.98	NDR 38		
Fluorene	(pb 1.7)	4.18	180		0.15
Phenanthrene	(pbndr 2.9)	4.46	260		0.22
Anthracene	(pbndr 1.9)	4.5	NDR 29		
Fluoranthene	(pbndr 0.81)	4.9	260		0.22
Pyrene	(pbndr 0.68)	4.88	580		0.50
Benz(a)anthracene		5.63	NDR 94		
Chrysene		5.63	180		0.15
Benzofluoranthenes			NDR 130		
Benzo(e)pyrene		6.21	NDR 72		
Benzo(a)pyrene		6.06	56		0.05
Perylene		6.21	NDR 16		
Dibenz(ah)anthracene		6.86	NDR 9.0		
Indeno(1,2,3-cd)pyrene		6.58	NDR 47		
Benzo(ghi)perylene		6.78	76		0.06

Flow = 28460 m3/d	
TSS = 30mg/l	
Daily TSS Loading kg/d	854

pb = procedural blank (solids) detectable quantity (ng/g)

< = sample detection limit

NDR/ndr = peak detected but did not meet quantification criteria

Sample size g dry wt. = 1.27

Appendix 2b: LANDSDOWNE STP - NOVEMBER 03 1993 - BIOSOLIDS PAH RESULTS

(duplicate)

Compound		log.Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	70		0.06
Acenaphthylene	(pbndr 1.1)	4.07	NDR 5.3		
Acenaphthene	(pb 1.6)	3.98	NDR 40		
Fluorene	(pb 1.7)	4.18	190		0.16
Phenanthrene	(pbndr 2.9)	4.46	250		0.21
Anthracene	(pbndr 1.9)	4.5	NDR 25		
Fluoranthene	(pbndr 0.81)	4.9	340		0.29
Pyrene	(pbndr 0.68)	4.88	570		0.49
Benz(a)anthracene		5.63	NDR 98		
Chrysene		5.63	180		0.15
Benzofluoranthenes			NDR 130		
Benzo(e)pyrene		6.21	NDR 72		
Benzo(a)pyrene		6.06	57		0.05
Perylene		6.21	NDR 16		
Dibenz(ah)anthracene		6.86	NDR 9.3		
Indeno(1,2,3-cd)pyrene		6.58	NDR 50		
Benzo(ghi)perylene		6.78	NDR 72		

Flow = 28460 m3/d	
TSS = 30mg/l	
Daily TSS Loading kg/d	854

pb = procedural blank (solids) detectable quantity (ng/g)

< = sample detection limit

NDR/ndr = peak detected but did not meet quantification criteria

Sample size g dry wt. = 1.27

Appendix 2b: ANNACIS STP - MARCH 03 1994 - BIOSOLIDS PAH RESULTS

Compound		log Kow	Solids (ng/g)	XAD -2 Column* (ng/L)	Solids (g/d)	XAD-2 (g/d)	Total (g/d)	Solids (%) Total
Naphthalene	(pbndr 9.0)	3.37	2200	NR	55.71	NR		
Acenaphthylene	(pbndr 2.0)	4.07	620	15	15.70	6.78	22.48	70
Acenaphthene		3.98	300	210	7.60	94.96	102.56	7
Fluorene	(pbndr 3.0)	4.18	560	130	14.18	58.79	72.97	19
Phenanthrene	(pb 8.0)	4.46	1700	190	43.05	85.92	128.97	33
Anthracene	(pbndr 3.0)	4.5	140	34	3.55	15.38	18.92	19
Fluoranthene	(pbndr 2.0)	4.9	1300	50	32.92	22.61	55.53	59
Pyrene	(pbndr 2.0)	4.88	1200	39	30.39	17.64	48.02	63
Benz(a)anthracene	(pbndr 0.7)	5.63	280	4	7.09	1.81	8.90	80
Chrysene	(pbndr 0.8)	5.63	340	4.6	8.61	2.08	10.69	81
Benzofluoranthenes			640	1.5	16.21	0.68	16.89	96
Benzo(e)pyrene		6.21	230	0.53	5.82	0.24	6.06	96
Benzo(a)pyrene		6.06	230	0.49	5.82	0.22	6.05	96
Perylene		6.21	NDR 53	<0.14				
Dibenz(ah)anthracene		6.86	NDR 130	<0.2				
Indeno(1,2,3-cd)pyrene		6.58	NDR 290	<0.35				
Benzo(ghi)perylene	(pbndr 2.0)	6.78	NDR 190	<0.32				
	(n)		(n =13)	(n = 12)				

Flow = 452210 m3/d	
TSS = 56mg/l	
XAD-2 Sample Size = 50L	
Daily TSS Loading kg/d	25324

pb = procedural blank (solids) detectable quantity (ng/g)

< = sample detection limit

NDR/ndr = peak detected but did not meet quantification criteria

Sample size g dry wt. = 2.63

Appendix 2b: ANNACIS - AUGUST 22 1995 - BIOSOLIDS PAH RESULTS

Compound (sample size 2.70g dry)		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pb 2.3)	3.37	600		13.52
Acenaphthylene		4.07	NDR 34		
Acenaphthene		3.98	610		13.74
Fluorene		4.18	550		12.39
Phenanthrene		4.46	2500		56.33
Anthracene		4.5	410		9.24
Fluoranthene		4.9	1300		29.29
Pyrene		4.88	1100		24.79
Benz(a)anthracene		5.63	200		4.51
Chrysene		5.63	200		4.51
Benzofluoranthenes			150		3.38
Benzo(e)pyrene		6.21	73		1.64
Benzo(a)pyrene		6.06	67		1.51
Perylene		6.21	NDR 22		
dibenz(ah)anthracene		6.86	NDR 5.6		
Indeno(1,2,3-cd)pyrene		6.58	NDR 24		
Benzo(ghi)perylene		6.78	41		0.92

Flow = 408850 m3/d	
TSS = 63mg/L	
Daily TSS Loading kg/d	25758

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 2.70

Appendix 2b: ANNACIS - NOVEMBER 21 1995 - BIOSOLIDS PAH RESULTS

Compound (sample size 3.32g dry)		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pb 8.3)	3.37	3900		87.87
Acenaphthylene	(pb 2.6)	4.07	1800		40.56
Acenaphthene	(pbndr 1.8)	3.98	460		10.36
Fluorene	(pbndr 1.1)	4.18	420		9.46
Phenanthrene	(pbndr 5.8)	4.46	3400		76.61
Anthracene	(pb 3.6)	4.5	540		12.17
Fluoranthene	(pb 4.9)	4.9	2800		63.09
Pyrene	(pb 4.0)	4.88	2100		47.32
Benz(a)anthracene		5.63	310		6.98
Chrysene	(pbndr 3.0)	5.63	440		9.91
Benzofluoranthenes			NDR 100		
Benzo(e)pyrene		6.21	470		10.59
Benzo(a)pyrene		6.06	310		6.98
Perylene		6.21	NDR 37		
dibenz(ah)anthracene		6.86	NDR 30		
Indeno(1,2,3-cd)pyrene		6.58	190		4.28
Benzo(ghi)perylene		6.78	NDR 550		

Flow = 472113 m3/d	
TSS = 66/mg/L	
Daily TSS Loading kg/d	31160

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 3.32

Appendix 2b: LULU STP - MAY 12 1994 - BIOSOLIDS PAH RESULTS

Compound	log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	3.37	2200		9.22
Acenaphthylene	4.07	2500		10.47
Acenaphthene	3.98	71		0.30
Fluorene	4.18	390		1.63
Phenanthrene	4.46	14000		58.64
Anthracene	4.5	1700		7.12
Fluoranthene	4.9	15000		62.83
Pyrene	4.88	19000		79.59
Benz(a)anthracene	5.63	NDR 2100		
Chrysene	5.63	3200		13.40
Benzofluoranthenes		5600		23.46
Benzo(e)pyrene	6.21	3100		12.99
Benzo(a)pyrene	6.06	4000		16.76
Perylene	6.21	650		2.72
Dibenz(ah)anthracene	6.86	NDR 190		
Indeno(1,2,3-cd)pyrene	6.58	2700		11.31
Benzo(ghi)perylene	6.78	5100		21.36

Flow = 54400 m3/d	
TSS = 77mg/l	
Daily TSS Loading kg/d	4189

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 3.03

Appendix 2b: LULU STP - MAY 12 1994 - BIOSOLIDS PAH RESULTS
(duplicate)

Compound	log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	3.37	2200		9.22
Acenaphthylene	4.07	2400		10.05
Acenaphthene	3.98	63		0.26
Fluorene	4.18	400		1.68
Phenanthrene	4.46	13000		54.45
Anthracene	4.5	1600		6.70
Fluoranthene	4.9	15000		62.83
Pyrene	4.88	18000		75.40
Benz(a)anthracene	5.63	NDR 2100		
Chrysene	5.63	3000		12.57
Benzofluoranthenes		5800		24.30
Benzo(e)pyrene	6.21	3100		12.99
Benzo(a)pyrene	6.06	4000		16.76
Perylene	6.21	650		2.72
Dibenz(ah)anthracene	6.86	NDR 190		
Indeno(1,2,3-cd)pyrene	6.58	2800		11.73
Benzo(ghi)perylene	6.78	5500		23.04

Flow = 54400 m3/d	
TSS = 77mg/l	
Daily TSS Loading kg/d	4189

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 3.03

Appendix 2b: CLARK DRIVE - MARCH 22 1993 - BIOSOLIDS PAH RESULTS

(GVRD/ASL)

Compound (sample size ??g dry)	log Kow	Solids (ng/g)	Whole Effluent* (ug/L)	(g/d)	Solids (g/d)
Naphthalene	3.37	190	0.11	64.08	4.87
Acenaphthylene	4.07	98	<0.05		2.51
Acenaphthene	3.98	118	<0.05		3.02
Fluorene	4.18	192	<0.05		4.92
Phenanthrene	4.46	1400	0.07	40.78	35.88
Anthracene	4.5	249	<0.05		6.38
Fluoranthene	4.9	1780	<0.10		45.62
Pyrene	4.88	1850	0.1	58.25	47.42
Benz(a)anthracene	5.63	745	<0.05		19.10
Chrysene	5.63	781	<0.10		20.02
Benzofluoranthenes					
Benzo(e)pyrene	6.21				
Benzo(a)pyrene	6.06	783	<0.05		20.07
Perylene	6.21	797	<0.10		20.43
dibenz(ah)anthracene	6.86	39	<0.25		1.00
Indeno(1,2,3-cd)pyrene	6.58	179	<0.25		4.59
Benzo(ghi)perylene	6.78	221	<0.25		5.66
(n)				n = 3	n = 15

Flow = 70,793 m^3/175min (582,525m^3/24h)	pb = procedural blank (solids) detectable quantity (ng/g)
TSS = 44 mg/L	< = sample detection limit
Daily TSS Loading kg/d 25632	NDR/ndr = peak detected but did not meet quantification criteria
Daily loading estimated from 2hr:55min sample event	Sample size g dry wt. = ??

* Data from GVRD

Appendix 2b: CLARK DRIVE - APRIL 6 1994 - BIOSOLIDS PAH RESULTS

Compound (sample size 3.48g dry)	log Kow	Solids (ng/g)	Whole Effluent* (ug/L)	(g/d)	Solids (g/d)
Naphthalene	3.37	380	0.12	24.58	8.56
Acenaphthylene	4.07	41	<0.01		0.92
Acenaphthene	3.98	74	0.01	2.05	1.67
Fluorene	4.18	170	0.02	4.10	3.83
Phenanthrene	4.46	1200	0.07	14.34	27.04
Anthracene	4.5	520	<0.01		11.72
Fluoranthene	4.9	1400	0.05	10.24	31.54
Pyrene	4.88	1400	0.08	16.38	31.54
Benz(a)anthracene	5.63	470	0.02	4.10	10.59
Chrysene	5.63	950	0.02	4.10	21.41
Benzofluoranthenes		1500			33.80
Benzo(e)pyrene	6.21	620			13.97
Benzo(a)pyrene	6.06	590	<0.01		13.29
Perylene	6.21	160			3.61
dibenz(ah)anthracene	6.86	110	<0.01		2.48
Indeno(1,2,3-cd)pyrene	6.58	600	<0.01		13.52
Benzo(ghi)perylene	6.78	700	<0.02		15.77
(n)				n = 8	n = 17

Flow = 24,179 m^3/170min (204,810m^3/24h)	pb = procedural blank (solids) detectable quantity (ng/g)
TSS = 110 mg/l	< = sample detection limit
Daily TSS Loading kg/d 22532	NDR/ndr = peak detected but did not meet quantification criteria
Daily loading estimated from 2hr:50min sample event	Sample size g dry wt. = 3.48

* data from GVRD

Appendix 2c: NORTHWOOD - NOVEMBER 04 1993 - BIOSOLIDS ALKYATED PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	21		0.21
C1 naphthalenes			38		0.38
C2 naphthalenes			100		0.99
C3 naphthalenes			420		4.15
C4 naphthalenes			<0.53		
C1-C4 total			558		5.51
Ratio of C1-C4 : Unsubstituted			26.6		
Phenanthrene	(pbndr 2.9)	4.46	320		3.16
C1 phen,anth			870		8.59
C2 phen,anth			2600		25.68
C3 phen,anth			1500		14.81
C4 phen,anth			1200		11.85
C1-C4 total			6170		60.93
Ratio of C1-C4 : Unsubstituted			19.3		
Ratio of Phen C1-C4 : Naph C1-C4			11.1		

Flow = m3/d	
TSS =mg/l	
Mill reported daily TSS Loading kg/d	9875

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.55

Appendix 2c: NORTHWOOD - OCTOBER 25 1994 - BIOSOLIDS ALKYLATED PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 2.6)	3.37	NDR 32		
C1 naphthalenes			81		1.03
C2 naphthalenes			210		2.67
C3 naphthalenes			390		4.96
C4 naphthalenes			<0.36		
C1-C4 total			681		8.65
Ratio of C1-C4 : Unsubstituted			#VALUE!		
Phenanthrene	(pbndr 0.68)	4.46	720		9.15
C1 phen,anth			<0.56		
C2 phen,anth			1900		24.15
C3 phen,anth			1400		17.79
C4 phen,anth			720		9.15
C1-C4 total			4020		51.09
Ratio of C1-C4 : Unsubstituted			5.6		
Ratio of Phen C1-C4 : Naph C1-C4			5.9		

Flow = m3/d	
TSS = mg/l	
Mill reported daily TSS Loading kg/d	12709

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.66

Appendix 2c: CANFOR - NOVEMBER 05 1993 - BIOSOLIDS ALKYLATED PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	120		1.74
C1 naphthalenes			440		6.36
C2 naphthalenes			430		6.22
C3 naphthalenes			1200		17.36
C4 naphthalenes			<0.62		
C1-C4 total			2070		29.94
Ratio of C1-C4 : Unsubstituted			17.3		
Phenanthrene	(pbndr 2.9)	4.46	280		4.05
C1 phen,anth			1200		17.36
C2 phen,anth			5200		75.21
C3 phen,anth			3100		44.84
C4 phen,anth			3600		52.07
C1-C4 total			13100		189.48
Ratio of C1-C4 : Unsubstituted			46.8		
Ratio of Phen C1-C4 : Naph C1-C4			6.3		

Flow = m3/d	
TSS = mg/l	
Mill reported daily TSS Loading kg/d	14464

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.15

Appendix 2c: CANFOR - NOVEMBER 05 1993 - BIOSOLIDS ALKYLATED PAH RESULTS
Blind Duplicate

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	120		1.74
C1 naphthalenes			440		6.36
C2 naphthalenes			430		6.22
C3 naphthalenes			1300		18.80
C4 naphthalenes			<0.7		
C1-C4 total			2170		31.39
Ratio of C1-C4 : Unsubstituted			18.1		
Phenanthrene	(pbndr 2.9)	4.46	290		4.19
C1 phen,anth			1300		18.80
C2 phen,anth			5000		72.32
C3 phen,anth			3500		50.62
C4 phen,anth			3800		54.96
C1-C4 total			13600		196.71
Ratio of C1-C4 : Unsubstituted			46.9		
Ratio of Phen C1-C4 : Naph C1-C4			6.3		

Flow = m3/d	
TSS = mg/l	
Mill reported daily TSS Loading kg/d	14464

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.15

Appendix 2c: CANFOR - NOVEMBER 23 1993 - BIOSOLIDS ALKYLATED PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	36		0.61
C1 naphthalenes			170		2.88
C2 naphthalenes			240		4.07
C3 naphthalenes			1700		28.85
C4 naphthalenes			<0.83		
C1-C4 total			2110		35.80
Ratio of C1-C4 : Unsubstituted			58.6		
Phenanthrene	(pbndr 2.9)	4.46	220		3.73
C1 phen,anth			1100		18.66
C2 phen,anth			4700		79.75
C3 phen,anth			3700		62.78
C4 phen,anth			3600		61.08
C1-C4 total			13100		222.28
Ratio of C1-C4 : Unsubstituted			59.5		
Ratio of Phen C1-C4 : Naph C1-C4			6.2		

Flow = m3/d	
TSS =mg/l	
Mill reported daily TSS Loading kg/d	16968

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.21

Appendix 2c: QUESNEL RIVER PULP - NOVEMBER 01 1993 - BIOSOLIDS ALKYLATED PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	16		0.22
C1 naphthalenes			34		0.47
C2 naphthalenes			<2.4		
C3 naphthalenes			<1.8		
C4 naphthalenes			<1.6		
C1-C4 total			34		0.47
Ratio of C1-C4 : Unsubstituted			2.1		
Phenanthrene	(pbndr 2.9)	4.46	NDR 15		
C1 phen,anth			<0.93		
C2 phen,anth			<2.3		
C3 phen,anth			<1.1		
C4 phen,anth			<5.3		
C1-C4 total					
Ratio of C1-C4 : Unsubstituted			#VALUE!		
Ratio of Phen C1-C4 : Naph C1-C4			0.0		

Flow = m3/d	
TSS = mg/l	
Mill reported daily TSS Loading kg/d	13870

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 0.81

Appendix 2c: CARIBOO - NOVEMBER 02 1993 - BIOSOLIDS ALKYLATED PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 9.0)	3.37	150		0.49
C1 naphthalenes			230		0.76
C2 naphthalenes			180		0.59
C3 naphthalenes			360		1.18
C4 naphthalenes			<2.0		
C1-C4 total			770		2.53
Ratio of C1-C4 : Unsubstituted			5.1		
Phenanthrene	(pb 8.0)	4.46	920		3.03
C1 phen,anth			1100		3.62
C2 phen,anth			2700		8.88
C3 phen,anth			<1.0		
C4 phen,anth			2000		6.58
C1-C4 total			5800		19.08
Ratio of C1-C4 : Unsubstituted			6.3		
Ratio of Phen C1-C4 : Naph C1-C4			7.5		

Flow = m3/d	
TSS = mg/l	
Mill reported daily TSS Loading kg/d	3289

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.97

Appendix 2c: WEYERHAEUSER - NOVEMBER 08 1993 - BIOSOLIDS ALKYLATED PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 9.0)	3.37	280		2.48
C1 naphthalenes			140		1.24
C2 naphthalenes			320		2.84
C3 naphthalenes			680		6.03
C4 naphthalenes			<11		
C1-C4 total			1140		10.11
Ratio of C1-C4 : Unsubstituted			4.1		
Phenanthrene	(pb 8.0)	4.46	990		8.78
C1 phen,anth			2400		21.28
C2 phen,anth			5700		50.53
C3 phen,anth			<30		
C4 phen,anth			3600		31.91
C1-C4 total			11700		103.72
Ratio of C1-C4 : Unsubstituted			11.8		
Ratio of Phen C1-C4 : Naph C1-C4			10.3		

Flow = 171,800 m3/d	
TSS = 30mg/l	
Mill reported daily TSS kg/d	8865

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.12

Appendix 2c: WEYERHAEUSER - NOVEMBER 08 1993 - BIOSOLIDS ALKYLATED PAH RESULTS

(duplicate)

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 9.0)	3.37	200		1.77
C1 naphthalenes			120		1.06
C2 naphthalenes			210		1.86
C3 naphthalenes			520		4.61
C4 naphthalenes			<3.0		
C1-C4 total			850		7.54
Phenanthrene	(pb 8.0)	4.46	930		8.24
C1 phen,anth			2100		18.62
C2 phen,anth			4100		36.35
C3 phen,anth			<2.0		
C4 phen,anth			2700		23.94
C1-C4 total			8900		78.90

Flow = 171,800 m3/d
TSS = 30mg/l
Mill reported daily TSS kg/d 8865

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.12

Appendix 2c: LANDSDOWNE STP - NOVEMBER 03 1993 - BIOSOLIDS ALKYLATED PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	66		0.06
C1 naphthalenes			180		0.15
C2 naphthalenes			820		0.70
C3 naphthalenes			3300		2.82
C4 naphthalenes			5600		4.78
C1-C4 total			9900		8.45
Ratio of C1-C4 : Unsubstituted			150.0		
Phenanthrene	(pbndr 2.9)	4.46	260		0.22
C1 phen,anth			2100		1.79
C2 phen,anth			10000		8.54
C3 phen,anth			6900		5.89
C4 phen,anth			1900		1.62
C1-C4 total			20900		17.84
Ratio of C1-C4 : Unsubstituted			80.4		
Ratio of Phen C1-C4 : Naph C1-C4			2.1		

Flow = 28460 m3/d
TSS = 30mg/l
Daily TSS Loading kg/d 854

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.27

Appendix 2c: LANDSDOWNE STP - NOVEMBER 03 1993 - BIOSOLIDS ALKYLATED PAH RESULTS

(duplicate)

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 5.1)	3.37	70		0.06
C1 naphthalenes			190		0.16
C2 naphthalenes			840		0.72
C3 naphthalenes			3300		2.82
C4 naphthalenes,			6600		5.64
C1-C4 total			10930		9.33
Phenanthrene	(pbndr 2.9)	4.46	250		0.21
C1 phen,anth			2200		1.88
C2 phen,anth			10000		8.54
C3 phen,anth			7000		5.98
C4 phen,anth			2000		1.71
C1-C4 total			21200		18.10

Flow = 28460 m3/d
TSS = 30mg/l
Daily TSS Loading kg/d 854

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 1.27

Appendix 2c: ANNACIS STP - MARCH 03 1994 - BIOSOLIDS ALKYLATED PAH RESULTS

Compound		log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	(pbndr 9.0)	3.37	2200		55.71
C1 naphthalenes	(pb 8.0)		1600		40.52
C2 naphthalenes			1600		40.52
C3 naphthalenes			2000		50.65
C4 naphthalenes			<20		
C1-C4 total			5200		131.68
Ratio of C1-C4 : Unsubstituted			2.4		
Phenanthrene	(pb 8.0)	4.46	1700		43.05
C1 phen,anth			690		17.47
C2 phen,anth			<15		
C3 phen,anth			<12		
C4 phen,anth			<19		
C1-C4 total			690		17.47
Ratio of C1-C4 : Unsubstituted			0.4		
Ratio of Phen C1-C4 : Naph C1-C4			0.1		

Flow = 452210 m3/d
TSS = 56mg/l
XAD-2 Sample Size = 50L
Daily TSS Loading kg/d 25324

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 2.63

Appendix 2c: LULU STP - MAY 12 1994 - BIOSOLIDS ALKYLATED PAH RESULTS

Compound	log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	3.37	2200		9.22
C1 naphthalenes		1700		7.12
C2 naphthalenes		2800		11.73
C3 naphthalenes		2400		10.05
C4 naphthalenes		1200		5.03
C1-C4 total		8100		33.93
Phenanthrene	4.46	14000		58.64
C1 phen,anth		1300		5.45
C2 phen,anth		1500		6.28
C3 phen,anth		1500		6.28
C4 phen,anth		-		
C1-C4 total		4300		18.01

Flow = 54400 m3/d	pb = procedural blank (solids) detectable quantity (ng/g)
TSS = 77mg/l	< = sample detection limit
Daily TSS Loading kg/d 4189	NDR/ndr = peak detected but did not meet quantification criteria
	Sample size g dry wt. = 3.03

Appendix 2c: LULU STP - MAY 12 1994 - BIOSOLIDS ALKYLATED PAH RESULTS
(duplicate)

Compound	log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	3.37	2200		9.22
C1 naphthalenes		1600		6.70
C2 naphthalenes		2600		10.89
C3 naphthalenes		2500		10.47
C4 naphthalenes		1200		5.03
C1-C4 total		7900		33.09
Ratio of C1-C4 : Unsubstituted		3.6		
Phenanthrene	4.46	13000		54.45
C1 phen,anth		1300		5.45
C2 phen,anth		1400		5.86
C3 phen,anth		1400		5.86
C4 phen,anth		-		
C1-C4 total		4100		17.17
Ratio of C1-C4 : Unsubstituted		0.3		
Ratio of Phen C1-C4 : Naph C1-C4		0.5		

Flow = 54400 m3/d	pb = procedural blank (solids) detectable quantity (ng/g)
TSS = 77mg/l	< = sample detection limit
Daily TSS Loading kg/d 4189	NDR/ndr = peak detected but did not meet quantification criteria
	Sample size g dry wt. = 3.03

Appendix 2c: CLARKE DRIVE - APRIL 6 1994 - BIOSOLIDS ALKYLATED PAH RESULTS

Compound (sample size 3.48g dry)	log Kow	Solids (ng/g)		Solids (g/d)
Naphthalene	3.37	380		8.56
C1 naphthalenes		1100		24.79
C2 naphthalenes		2700		60.84
C3 naphthalenes		3200		72.10
C4 naphthalenes		2000		45.06
C1-C4 total		9000		202.79
Ratio of C1-C4 : Unsubstituted		23.7		
Phenanthrene	4.46	1200		27.04
C1 phen,anth		2300		51.82
C2 phen,anth		4100		92.38
C3 phen,anth		5300		119.42
C4 phen,anth		720		16.22
C1-C4 total		12420		279.85
Ratio of C1-C4 : Unsubstituted		10.4		
Ratio of Phen C1-C4 : Naph C1-C4		1.4		

Flow = 24,179 m^3/170min
TSS = 110 mg/l
Daily TSS Loading kg/d 22532
Daily loading estimated from 2hr:50min sample event

pb = procedural blank (solids) detectable quantity (ng/g)
< = sample detection limit
NDR/ndr = peak detected but did not meet quantification criteria
Sample size g dry wt. = 3.48