Deer Island effluent characterization studies: January 1995- December 1995

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Deer Island Effluent Characterization Studies
January 1995 - December 1995

by

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EXECUTIVE SUMMARY

As part of the MWRA Harbor and Outfall Monitoring Project, concentrations of selected nutrients, trace metals, and anthropogenic organic compounds were monitored in the effluent of the Massachusetts Water Resources Authority (MWRA) Deer Island Wastewater Treatment Plant as well as in the influent and effluents of the Deer Island Secondary Pilot Plant. Throughout this report, 1993/4 data will be referenced. This data comes from the 1995 Battelle report written by Hunt *et al.*, (1995).

Composite samples of the Deer Island effluent were collected twice each month between January and December of 1995. The samples were analyzed for Ag, Cd, Cr, Cu, Hg, Mo, Ni, Pb, and Zn; an extended list of 43 polynuclear aromatic hydrocarbons (PAHs); C_{10} to C_{14} linear alkyl benzenes (LABs); 20 polychlorinated biphenyl (PCB) congeners; and 17 persistent chlorinated pesticides, and *Clostridium perfringens*.

Discrete grab samples were also collected bimonthly for nutrient analysis. These samples were analyzed for the major forms of nitrogen (NH_4, NO_2, NO_3, total dissolved nitrogen, particulate organic nitrogen), and phosphorus (PO_4, total dissolved phosphorus, and particulate organic phosphorus), as well as urea, dissolved silica, biogenic silica, dissolved and particulate organic carbon and stable isotopes of nitrogen and sulfur.

The influent, primary and secondary effluent channels of the pilot plant were sampled. Sample collections and analyses were carried out as described in the Deer Island effluent CW/QUAPP.

Ultratrace techniques capable of providing detection limits in the low parts-per-trillion (ng/L) for organic compounds and low parts-per-billion (µg/L) for trace metals were used for trace metals and organic contaminant analyses. Routine analytical methods for nutrients in seawater and effluents were used.

Effluent Characterization

Toxics - The Deer Island effluent concentrations of organic and metal contaminants were similar in 1995 to concentrations reported in 1993/4. Total PAH concentrations measured in the 1995 effluent ranged from 4,204 - 54,932 ng/L. Three additional PAH analytes were measured in 1995, however they were excluded from these totals for comparability with previous studies. Concentrations of other parameters ranged as follows: 7 - 255 ng/L for total PCBs; 0 - 18 ng/L for total chlordanes; 4 - 57 ng/L for lindane; and 6,120 - 16,540 ng/L for total LABs. Concentrations (in µg/L) of metals ranged as follows: 1.3 - 5.8 for Ag; 0.3 - 1.7 for Cd; 3.1 - 185 for Cr; 46.7 - 103.0 for Cu; 0.03 - 0.3 for Hg; 9.2 - 26.9 for Mo; 3.4 - 20.4 for Ni; 4.3 - 29.2 for Pb; and 49.4 - 136.4 for Zn.

Undiluted Deer Island effluent concentrations of organic compounds did not exceed the EPA acute criteria. Concentrations of p,p'- DDT continued to exceed the EPA marine chronic criteria but at a slightly lower frequency than the 1993/4 data. The chronic criteria was exceeded in 80% of samples collected in 1995 versus 91% of samples collected in 1993 and 1994. The number of heptachlor samples exceeding the chronic criteria however, increased from less than 3% of the samples in 1994/3 to about 24% of samples in 1995. No other organics exceeded either the acute or chronic criteria. Undiluted effluent concentrations of Ag and Cu in 1995 continued to exceed the acute criteria in the majority of the samples: 87% and 100% respectively versus 97% and 100% in 1993/4. Zn exceeded the acute and chronic criteria in 3 and 4 out of 23 samples respectively: 13% and 17% in 1995 compared to 20% and 40% in 1993/4. Hg continued to be in excess of the chronic criteria for all

samples, Pb in 65% of samples, and Ni in less than 9% for all samples. Frequencies for excesses in 1993 and 1994 for these concentration levels were 100%, 85% and approximately 5% of samples taken for Hg, Pb, and Ni respectively. Considering the effluent dilution that will occur at the Mass Bay discharge, as well as the reduction in concentrations due to secondary treatment, effluent contaminant concentrations will be expected to be reduced to levels well below the applicable criteria in the immediate vicinity of the discharge.

Nutrients - Concentrations of total nitrogen, ammonia, nitrate plus nitrite, total phosphorus, and phosphate concentrations in the Deer Island primary treatment plant effluents in 1995 were similar to concentrations previously reported in 1993/4. The concentrations ranged as follows: 516 - 2250 µM for total nitrogen; 379 - 1986 µM for dissolved nitrogen; 215 - 2022 µM for ammonia; and 137 - 310 µM for particulate nitrogen. Ammonia contributed the largest fraction of total nitrogen, 69% annually. Ammonia also comprised 91% annually of the total dissolved nitrogen. Phosphate concentrations were also similar to those reported previously and ranged (in µM) as follows: 41 - 313 for total phosphorus; 12 - 310 for dissolved phosphorus; 0.4 - 31.6 for phosphate; and 0.6 - 38 for particulate phosphorus. Biogenic Si concentrations ranged from 11-33 µM and contributed an average of 6.2% of the total biologically available Si concentrations in the effluents. The 1995 concentrations of dissolved and particulate organic carbon ranged between 7 - 61 mg/L and 16 - 42 mg/L respectively; the dissolved form continues to comprise an average of approximately 60% of the total organic carbon content in Deer Island effluents.

Effluent Variability - Following historic trends, concentrations of nutrients were generally higher in the summer/fall when the flow was lower. However the silicate and carbon concentrations were generally lower in the summer. The seasonal variation for nutrients in 1995 was not as pronounced as in 1994 because the flow variations in 1995 was less than that of 1994 and maybe complicated by the use of grab versus composite samples. Variability in the treatment plant effluents was evident on a daily and monthly basis as reported previously in Uhler *et al.* (1994) and Hunt *et al.* (1995). Seasonal trends were noted as previously reported in the 1994 data for PAHs; PAH average concentrations were higher in the winter/spring period. Average PCB, chlordanes, DDTs and lindane concentrations however, were lower in the winter/spring period. Seasonal averages in the metals were generally higher in the winter/spring for Ag, Cd, Ni, and Zn data.

Loading - The 1995 total estimated input of contaminants and nutrients to the Boston Harbor/Massachusetts Bay system is consistent with estimates developed in 1993 by Alber and Chan (1994), Shea (1993a) and Uhler *et al.* (1994). The 1995 nitrogen estimates ranged from 13 metric tons (mtons) of nitrite/year to 10,003 mtons total nitrogen/year. The total nitrogen loading is less than the hypotheses/warning level of 12,500 mtons/year currently being discussed. Other estimates for 1995 of nutrient loading were 1476 mtons total phosphorus/year; 5,087 mtons dissolved silicate/year, and 35,251 mtons total organic carbon/year. Nutrient loadings estimated for 1995 were similar to the ranges provided in Alber and Chan (1994) for the 1993 data. These 1995 nutrient loadings have, however, increased from an estimated total of 38,700 mtons/yr in 1994 to 51,817 mtons/yr.

Organic contaminant inputs ranged from non-detections of dieldrin to 8873 Kg PAHs/year. Total chlordanes and 4,4' - DDT in 1995 were down from 1994 by approximately 50% while total DDT decreased significantly from 32 Kg/year in 1994 to 5.6 Kg/year in 1995. Lindane loading increased slightly while PCBs remained nearly the same with a slight decrease from 26 to 25 Kg/year in 1995.

Cu and Zn continue to predominate among the metals discharged, with loadings of 31 and 37 mtons/year, respectively in 1995, down from 38 and 44 mtons/year in 1994. Other metals were discharged at rates similar and somewhat lower than 1994, with the exception of Cr which showed an increase to 7,861 Kg/year from 2,100 Kg/year due to two high concentrations measured in January and February.

Effluent Tracers - The PAHs in the effluent were primarily petrogenic in nature, as reported previously in Uhler *et al.* (1994) and Hunt *et al.* (1995). The distribution of total PAH was dominated by low-molecular-weight compounds similar to refined petroleum products. The LABs were similar in composition throughout the year but the distribution found in 1995 was different than reported in 1994. The N/P ratio in the effluents averaged 17.5 and is consistent with the terrestrial source of the organic material. Similarly, the stable isotope nitrogen and sulfur isotope ratios of particulate matter filtered from the effluent are typical of terrestrial sources. The $\delta^{15}N$ ranged from -.9 to 3.6‰ with an annual average of 0.24‰ and the $\delta^{24}S$ ranged from 3.1 to 7.4‰ (annual average=4.7‰) which are down from 1994 levels. *Clostridium perfringens* spores in the effluent were also measured and the geometric mean was 4029 spores/100 mL (range between 0.036 to 1.6 x 10^4) which is down from the 1994 levels of around 1 x 10^4 spores/100 mL.

Pilot Treatment Plant

Treatment Plant Effectiveness - Processing at the pilot secondary treatment facility was successfully conducted throughout 1995. Biological secondary treatment was found to have very high removal efficiency in relation to the primary effluent, averaging greater than 85% removed for total PAHs, total DDTs, and total chlordane. High removal efficiencies (70-85%) were estimated for total LABs, Ag, Cu, Pb, and particulate organic carbon. Intermediate (20-70%) removal efficiencies were indicated for total PCB, Zn, total phosphorus, and dissolved organic carbon. Lindane, Cd, Cr, Hg and biogenic silica were also estimated to be in the intermediate removal efficiency range. Inefficiently (<20%) removed contaminants include: Mo, Ni, and total nitrogen. The 1995 secondary treatment plant data are consistent with the removal efficiencies used in the EPA Supplemental Environmental Impact Statement for the MWRA Massachusetts Bay outfall to make predictions of impact.

Loading - Contaminant loading reductions approximating the removal efficiencies listed above can be expected. The removal efficiencies estimated from the 1995 pilot plant secondary treatment sample concentrations indicate that the loading of toxic contaminants to Massachusetts Bay will be significantly reduced. The removal efficiency of dissolved and particulate organic carbon is somewhat less than previously reported (~90% relative to the present primary effluent) in Hunt *et al.* (1995) but remains significant at an average reduction of 69% and 85% respectively. This reduction will continue to have significant impacts on the cBOD in the effluent and thus oxygen demand in the receiving waters.

Effluent Quality - The pilot plant results continue to indicate as in Hunt *et al.* (1995) that the quality of the effluent will be excellent. Should concentrations remain at their current levels, Cu will be the only compound that will exceed EPA acute marine water quality criteria within the secondary effluent prior to discharge. Hg, heptachlor and p,p'- DDT are expected to exceed the chronic criteria only. It is expected that these concentration levels will drop to levels below EPA acute and chronic marine water quality criteria in the immediate vicinity of the diffuser, Hunt *et al.* (1995).

Secondary Effluent Characteristics - The 1995 ratio of nitrogen to phosphorus (N/P), is about 17.5 for the primary effluent. Secondary treatment, however, will increase this ratio to approximately 30 because of phosphorus being more efficiently removed from the effluent. As a result of this differential removal, the quality of the MWRA sewage sludge as fertilizer will likely increase as more phosphorus is transferred to the sludge. In contrast, more efficient removal of toxic compounds could potentially degrade the quality of the sludge. The altered N/P ratio of the secondary effluent is expected to pose less of an effect than the discharge of primary effluent on the productivity of receiving waters.

Monitoring - The results of the secondary treatment plant program indicate that trace toxic contaminants in the secondary effluent will be very low. As a result, the monitoring program should focus on the effluent quality rather than on the receiving water quality because of the predicted low concentrations of contaminants and the expected dilution rates. Detection of toxic contaminants in the water column will become extremely difficult. In addition, there will be a substantial reduction in the organic carbon loading which will reduce oxygen demand in the receiving waters. Measurement of contaminant concentrations in the sediment and biota in the diffuser vicinity remain the most cost-effective method for evaluating contaminant fate and potential for impact.

1.0 INTRODUCTION

Wastewater from the Greater Boston Metropolitan Area is treated at two primary treatment plants in Boston Harbor, one on Deer Island and one on Nut Island. Sewage effluent from the Deer Island plant is currently discharge near the mouth of the Harbor just off the Deer Island facility (Figure 1). Sewage effluent from the Nut Island plant is currently discharged just north of the Nut Island peninsula. As part of the Boston Harbor cleanup, the Massachusetts Water Resources Authority (MWRA) is upgrading these primary treatment facilities and constructing a secondary treatment plant at Deer Island. These upgrades are expected to significantly improve the quality of effluent that will be discharged from the existing Deer Island outfall and from the new ocean outfall located in Massachusetts Bay.

In 1995, as part of the comprehensive baseline assessment for the Harbor and Outfall Monitoring Project, the MWRA conducted bi-monthly monitoring of effluent from the Deer Island plant. The agency also evaluated secondary effluent from its 1 MGD pilot treatment plant. This report summarizes the results of monthly effluent characterization sampling between January and December 1995, and also pilot treatment plant studies during this same time period.

The monitoring objectives were to evaluate:

- *Selected trace metal and persistent anthropogenic organic contaminant concentrations in the current primary effluent.* The contaminants listed in Table 1 are of particular concern because they are subject to established EPA Water Quality Criteria, they have been detected in the MWRA effluent or otherwise found in receiving waters or sediments of Boston Harbor and Massachusetts Bay, or they can serve as tracers of sewage effluents.

- *Effluent nutrient concentrations plus other parameters related to eutrophication issues.* Discharge of nutrients in general, and nitrogen in particular, can influence the primary productivity of coastal ecosystems. If discharged in excess, these nutrients can lead to eutrophic conditions in the receiving waters. Available effluent nutrient data were limited to selected measurements of dissolved inorganic forms (ammonia, nitrate, nitrite, and orthophosphate), total Kjeldahl nitrogen, and total phosphorus concentrations (Alber and Chan, 1994). These measurements were inadequate for the water quality model being developed by MWRA. Therefore, beginning in December 1993, MWRA initiated bi-monthly monitoring of the Deer Island effluent for all major nutrient forms (Table 1). The agency also selected other parameters (*e.g., Clostridium perfringens* spores and stable isotopes of nitrogen and sulfur) that provide more information on the transfer of effluents in the receiving environment or into organisms.

- *Short-term (e.g., 2-3 day) variability in the concentrations/loadings of effluent contaminants and nutrients.* Twenty-four hour composite bi-monthly samples of Deer

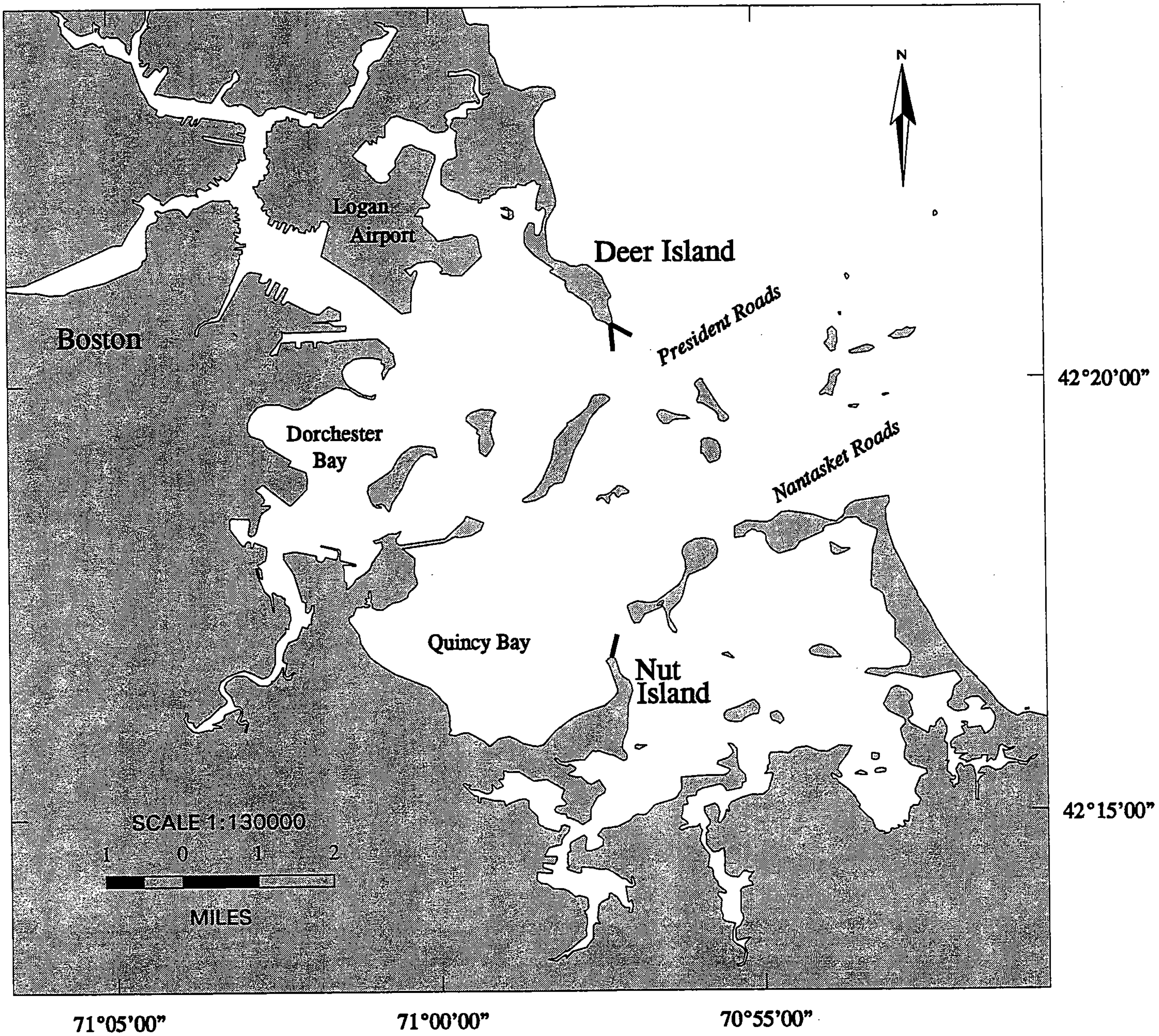


Figure 1
Location of Deer Island in Boston Harbor

Table 1
Organic and trace metal analytes for the Deer Island effluent characterization task.

Polynuclear Aromatic Hydrocarbons

Naphthalene (C0N)
C1Naphthalenes (C1N)
C2Naphthalenes (C2N)
C3Naphthalenes (C3N)
C4Naphthalenes (C4N)
Benzothiazole (BTHOL)
Acenaphthylene (ACEY)
Acenaphthene (ACE)
Biphenyl (BIP)
Dibenzo Furan (DBF)
Fluorene (C0F)
C1Fluorenes (C1F)
C2Fluorenes (C2F)
C3Fluorenes (C3F)
Phenanthrene (C0P)
Anthracene (C0A)
C1Phenanthrenes/Anthracenes (C1P/A)
C2Phenanthrenes/Anthracenes (C2P/A)
C3Phenanthrenes/Anthracenes (C3P/A)
C4Phenanthrenes/Anthracenes (C4P/A)
Dibenzothiophene (C0D)
C1Dibenzothiophenes (C1D)
C2Dibenzothiophenes (C2D)
C3Dibenzothiophenes (C3D)
Fluoranthene (FLANT)
Pyrene (PYR)
C1Fluoranthenes/Pyrenes (C1F/P)
C2Fluoranthenes/Pyrenes (C2F/P)
C3Fluoranthenes/Pyrenes (C3F/P)
Benzo(a)anthracene (BAA)
Chrysene (C0C)
C1Chrysenes (C1C)
C2Chrysenes (C2C)
C3Chrysenes (C3C)
C4Chrysenes (C4C)
Benzo(b)fluoranthene (BBF)
Benzo(k)fluoranthene (BKF)
Benzo(e)pyrene (BEP)
Benzo(a)pyrene (BAP)
Perylene (PER)
Indeno(1,2,3-cd)pyrene (IND)
Dibenzo(a,h)anthracene (DAH)
Benzo(g,h,i)perylene (BGP)

Linear Alkyl Benzenes

C10Linear Alkyl Benzenes (C10)
C11Linear Alkyl Benzenes (C11)
C12Linear Alkyl Benzenes (C12)
C13Linear Alkyl Benzenes (C13)
C14Linear Alkyl Benzenes (C14)

Trace Metals

Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Lead (Pb)
Mercury (Hg)
Molybdenum (Mo)
Nickel (Ni)
Silver (Ag)
Zinc (Zn)

Pesticides

Aldrin
Alpha-Chlordane
Dieldrin
Endrin
Gamma-BHC
Heptachlor
Heptachloroepoxide
Hexachlorobenzene
Mirex
Trans-Nonachlor
2,4'-DDD
2,4'-DDE
2,4'-DDT
4,4'-DDD
4,4'-DDE
4,4'-DDT
DDMU

Polychlorinated Biphenyls

2,4,-Cl2 (8)
2,2',5-Cl3 (18)
2,4,4'-Cl3 (28)
2,2',3,5'-Cl4 (44)
2,2',5,5'-Cl4 (52)
2,3',4,4'-Cl4 (66)
3,3',4,4'-Cl4 (77)
2,2',4,5,5'-Cl5 (101)
2,3,3',4,4'-Cl5 (105)
2,3',4,4',5-Cl5 (118)
3,3',4,4',5-Cl5 (126)
2,2',3,3',4,4'-Cl6 (128)
2,2',3,4,4',5'-Cl6 (138)
2,2',4,4',5,5'-Cl6 (153)
2,2',3,3',4,4',5-Cl7 (170)
2,2',3,4,4',5,5'-Cl7 (180)
2,2',3,4,5,5',6-Cl7 (187)
2,2',3,3',4,4',5,6-Cl8 (195)
2,2',3,3',4,4',5,5',6-Cl9 (206)
Decachlorobiphenyl-Cl10 (209)

Nutrients

Dissolved Inorganic Nutrients
(NH3, NO2, NO3, PO4, Si, TKN)
Dissolved Organic Nutrients
(N,P)
Dissolved Organic Carbon (DOC)
Particulate Organic Carbon (POC)
Particulate Organic Nitrogen (PON)
Particulate Organic Phosphorus (POP)
Biogenic Silica
Total Suspended Solids (TSS)
Urea

Stable Isotopes

del 15n(air)
del 34s(ctd)

Clostridium Perfringens

- Island effluent were collected each month at two-day intervals. The objective was to monitor short-term fluctuations in the concentrations/loadings of target metals, organic compounds, nutrients, and tracers in the waste stream. Short-term fluctuations could indicate episodic inputs of contaminants that might be overlooked by a one-time sampling strategy. Changes in nutrient forms could also be evaluated.

- *Long-term (e.g., monthly and seasonal) changes in the concentrations/loadings of effluent contaminants and nutrients.* Monthly effluent sampling was conducted to investigate possible seasonal influences on the composition of the effluent, For example, certain organic compounds such as pesticides might be used more frequently during certain months of the year. The result could be elevated concentrations/loadings of those compounds during those time periods.

- *Possible chemical "fingerprints," unique to the effluent, that might suggest potential contaminant sources or changes caused by the secondary treatment process.* Information about unique metals and organic compounds in the effluent can be useful for tracking the fate of both the discharge plume and certain contaminants in the aquatic environment. Moreover, a characteristic pattern in the distribution of certain contaminants might suggest the effluent source. For example, the distribution of polynuclear aromatic hydrocarbons (PAHs) would reveal the predominant type of petroleum hydrocarbons in the waste stream. These PAHs, in turn, might be linked to a specific source or source type. However, modifications in treatment processes or levels could alter PAH distributions. Pinpointing contaminant sources, therefore, requires an understanding of both treatment modifications and chemical fingerprints.

- *Comparability of effluent analysis results from ultra-trace metal and organic contaminant techniques versus analytical results based on standard procedures used to support National Pollutant Discharge Elimination System (NPDES) methods.* Since this objective was addressed in the 1993 annual effluent characterization study (Uhler *et al.*, 1994), it is not dealt with in this report.

The MWRA pilot treatment plant was constructed to help MWRA evaluate the operation of the new primary and secondary treatment plants, as well as other treatment alternatives such as Chemically Enhanced Primary Treatment (CEPT). The goal was to ensure that MWRA achieves the highest effluent quality from the Deer Island treatment plant.

The treatment plant study objectives for 1995 were to:

- *Evaluate the effectiveness of the plant's primary and secondary treatment processes for removal of metals, organic contaminants, and nutrients.*

- *Estimate future effluent quality once full secondary treatment is implemented.*

Meeting these objectives required sampling and analysis of pilot plant influent, as well as primary and secondary effluents.

2.0 METHODS

2.1 Sample Collection

2.1.1 Deer Island Effluent

From January through December 1995, MWRA collected effluent samples monthly from the Deer Island treatment plant. Twenty-four-hour composite samples were collected using Isco automated samplers. Every month, two composite samples were collected two days apart. The composite effluents were subsampled as follows:

- 2.5 L for trace organic analysis (PAHs, pesticides, PCBs)
- 500 mL for trace metal analysis (Ag, Cd, Cr, Cu, Mo, Ni, Pb, Zn)
- 500 mL for Hg analysis

Discrete grab samples were collected for nutrient and stable nitrogen and sulfur isotopes analysis. Additional effluent was also collected for use as matrix spike quality control samples. The composite samples for contaminant analysis were stored on ice and shipped by courier to the Arthur D. Little or Envitec Laboratory. The nutrient samples and other effluent tracer samples were filtered as necessary immediately upon collection, and the aqueous phase was preserved as described in the Detailed Effluent Characterization CW/QAPP, Table 1 (Butler et al., 1995). The samples were shipped on ice to their specified laboratories (pp. 8 + 11, Butler et al., 1995). *Clostridium perfringens* samples were shipped on ice to Biological Analytical Laboratory, Inc., in North Kingston, RI. Particulate matter for stable isotope analysis was collected on a filter, then frozen. Samples were usually dried at the MWRA laboratory but also on occasion at ENSR's Acton office, then transferred to the Marine Biological Laboratory at Woods Hole for analysis.

All bottles for trace metal and Hg analyses were rigorously cleaned in dilute, high-purity acids to ensure that extraneous contaminants were not added to the samples. For the metals, sample-preserving acids were included in the bottles that were transferred to the control of MWRA. Samples for organics analysis were collected in 2.5-L amber-glass I-Chem bottles. Liquid phases for nutrient analysis were stored in either polyethylene or glass, depending upon the parameter of interest. *Clostridium perfringens* samples were collected in 250-mL polypropylene bottles containing sodium thiosulfate, a chlorine neutralizer.

The composite samples were processed and analyzed for total metals (Ag, Cd, Cr, Cu, Hg, Mo, Ni, Pb, and Zn), an extended list of 43 PAHs, C_{10} to C_{14} LABs, 20 PCB congeners, and 17 chlorinated pesticides (Table 1). Subsamples for *Clostridium perfringens* spores, were taken from the composite samples. Grab samples to measure nutrients and stable nitrogen and sulfur isotopes were collected on the day that the Isco samplers were deployed. Duplicate samples were taken for all nutrient forms. The grab samples were processed for measurement of dissolved and particulate organic carbon (DOC and POC), respectively; the major forms of nitrogen (particulate nitrogen, NH_3, NO_2, NO_3, TKN, and dissolved organic nitrogen [by difference]); phosphate (dissolved PO_4, total dissolved phosphorus, dissolved organic phosphorus [by difference], and particulate organic phosphorus), and two forms of silicate (dissolved and biogenic). Dissolved inorganic nutrients and total dissolved nitrogen and phosphorus were filtered through 0.4-µm Nuclepore filters; DOC and POC/PON samples were filtered through Whatman GF/F glass-fiber filters (details of the filtration steps can be found in the appendices to West and Doering (1994). Biogenic silica samples were filtered through poretic filters. The samples for metals, organic contaminants, and *Clostridium perfringens* analysis were packed in ice and shipped to the analytical laboratories for final processing, analysis, or archiving. Samples for *Clostridium perfringens* analysis were delivered to BAL within 24 h of collection. Samples for metals and organics analysis were shipped on the second day of collection. Samples for nutrient analysis were shipped either within 24 h or on the second day of collection. Upon receipt, samples were processed to meet EPA holding times and to otherwise ensure measurement integrity (*e.g.*, samples for organic compounds were extracted within 14 days, and Hg was analyzed within 30 days).

2.1.2 Pilot Treatment Plant

Table 2 summarizes the sample collection dates, sample types, and number of samples collected. The first study was conducted in January 1995. Pilot plant sampling continued through December 1995.

During each sampling event, automated Isco samplers were used to collect 24-h composite samples from the pilot plant influent (except as noted in Table 2) and from the effluents of the primary and secondary treatment channels. MWRA personnel collected all samples and performed the sample filtration for all dissolved nutrient samples.

The composite samples were processed and analyzed for the same contaminants that were measured in the effluent samples: metals, PAHs, C_{10} to C_{14} LABs, PCB congeners and chlorinated pesticides. Sample processing and storage bottles were the same as described for the effluent samples. No

Table 2

Sample Collection dates, type, and MWRA ID

Date	Sample Type	ENSR ID Prefix	MWRA ID	Parameters Analysed					
01/11/95	R	E95A1	39500225	Organics	Trace metals	mercury	Clost. perfringens		
01/13/95	R	E95A2	39500226	Organics	Trace metals	mercury	Clost. perfringens		
01/25/95	PI	E95A3	39500974	Organics	Trace metals	mercury		nutrients	
01/25/95	PP	E95A4	39500976	Organics	Trace metals	mercury		nutrients	
01/25/95	PS	E95A5	39500975	Organics	Trace metals	mercury		nutrients	
02/15/95	R	E95B1	39501905	Organics	Trace metals	mercury			
02/15/95	R	E95B1	39501907				Clost. perfringens	nutrients	stable isotopes (N&S)
02/17/95	R	E95B2	39501906	Organics	Trace metals	mercury			
03/01/95	PI	E95C1	39502240	Organics	Trace metals	mercury	Clost. perfringens		
03/01/95	PP	E95C2	39502241	Organics	Trace metals	mercury	Clost. perfringens		
03/01/95	PS	E95C3	39502243	Organics	Trace metals	mercury	Clost. perfringens		
03/14/95	R	E95C4	39502737	Organics	Trace metals	mercury	Clost. perfringens		
03/14/95	R	E95C4	39502824					nutrients	stable isotopes (N&S)
03/16/95	R	E95C5	39502738	Organics	Trace metals	mercury	Clost. perfringens		
04/12/95	R	E95D1	39503798	Organics	Trace metals	mercury	Clost. perfringens		
04/12/95	R	E95D1	39503799					nutrients	stable isotopes (N&S)
04/14/95	R	E95D2	39503922		Trace metals	mercury	Clost. perfringens		
04/14/95	R	E95D2	39503923					nutrients	stable isotopes (N&S)
05/10/95	R	E95E1	39504846					nutrients	stable isotopes (N&S)
05/10/95	R	E95E1	39504845	Organics	Trace metals	mercury	Clost. perfringens		
05/10/95	PI	E95E2	39504810	Organics	Trace metals	mercury			
05/11/95	PI	E95E2	39504920					nutrients	
05/10/95	PP	E95E3	39504812	Organics	Trace metals	mercury			
05/11/95	PP	E95E3	39504918					nutrients	
05/10/95	PS	E95E4	39504814	Organics	Trace metals	mercury			
05/11/95	PS	E95E4	39504919					nutrients	
05/12/95	R	E95E5	39504917					nutrients	stable isotopes (N&S)
05/12/95	R	E95E5	39504916	Organics	Trace metals	mercury	Clost. perfringens		
06/14/95	R	E95F1	39505816	Organics	Trace metals	mercury	Clost. perfringens		
06/14/95	R	E95F1	39505819					nutrients	stable isotopes (N&S)
06/14/95	PI	E95F2	39505820	Organics	Trace metals	mercury			
06/15/95	PI	E95F2	39505823					nutrients	
06/14/95	PP	E95F3	39505821	Organics	Trace metals	mercury			
06/15/95	PP	E95F3	39505824					nutrients	
06/14/95	PS	E95F4	39505822	Organics	Trace metals	mercury			
06/15/95	PS	E95F4	39505825					nutrients	
06/16/95	R	E95F5	39505818					nutrients	stable isotopes (N&S)
06/16/95	R	E95F5	39505817	Organics	Trace metals	mercury	Clost. perfringens		
07/12/95	R	E95G1	39506613					nutrients	stable isotopes (N&S)
07/12/95	R	E95G1	39506615	Organics	Trace metals	mercury	Clost. perfringens		
07/12/95	PI	E95G2	39506625	Organics	Trace metals	mercury		nutrients	
07/12/95	PP	E95G3	39506626	Organics	Trace metals	mercury			
07/13/95	PP	E95G3	39506629					nutrients	
07/12/95	PS	E95G4	39506627	Organics	Trace metals	mercury			
07/13/95	PS	E95G4	39506630					nutrients	
07/14/95	R	E95G5	39506614					nutrients	stable isotopes (N&S)
07/14/95	R	E95G5	39506616	Organics	Trace metals	mercury	Clost. perfringens		
08/16/95	R	E95H1	39506685	Organics	Trace metals	mercury	Clost. perfringens	nutrients	stable isotopes (N&S)
08/16/95	PI	E95H2	39506691	Organics	Trace metals	mercury			
08/17/95	PI	E95H2	39506692					nutrients	
08/16/95	PP	E95H3	39506689	Organics	Trace metals	mercury			
08/17/95	PP	E95H3	39506693					nutrients	
08/16/95	PS	E95H4	39506690	Organics	Trace metals	mercury			
08/17/95	PS	E95H4	39506694					nutrients	
08/18/95	R	E95H5	39506688					nutrients	stable isotopes (N&S)

Table 2 (cont.)

Sample Collection dates, type, and MWRA ID

Date	Sample Type	ENSR ID Prefix	MWRA ID	Parameters Analysed					
08/18/95	R	E95H5	39506686	Organics	Trace metals	mercury	Clost. perfringens		
09/13/95	R	E95I1	39508689					nutrients	stable isotopes (N&S)
09/13/95	R	E95I1	39508687	Organics	Trace metals	mercury	Clost. perfringens		
09/13/95	PI	E95I2	39508681	Organics	Trace metals	mercury			
09/14/95	PI	E95I2	39508684					nutrients	
09/13/95	PP	E95I3	39508682	Organics	Trace metals	mercury			
09/14/95	PP	E95I3	39508685					nutrients	
09/13/95	PS	E95I4	39508683	Organics	Trace metals	mercury			
09/14/95	PS	E95I4	39508686					nutrients	
09/15/95	R	E95I5	39508690					nutrients	
10/12/95	R	E95J1	39509592					nutrients	stable isotopes (N&S)
10/12/95	R	E95J1	39509590	Organics	Trace metals	mercury	Clost. perfringens		
10/12/95	PI	E95J2	39509599	[1]Organics	Trace metals	mercury			
10/13/95	PI	E95J2	39509594					nutrients	
10/12/95	PP	E95J3	39509598	Organics	Trace metals	mercury			
10/13/95	PP	E95J3	39509595					nutrients	
10/12/95	PS	E95J4	39509597	[2]Organics	Trace metals	mercury			
10/13/95	PS	E95J4	39509596					nutrients	
10/16/95	R	E95J5	39509591	[3]Organics	Trace metals	mercury	Clost. perfringens		
10/16/95	R	E95J5	39509593					nutrients	
11/15/95	R	E95K1	39510518					[4]nutrients	stable isotopes (N&S)
11/15/95	R	E95K1	39510520	Organics	Trace metals	mercury	Clost. perfringens		
11/15/95	PI	E95K2	39510512	Organics	Trace metals	mercury			
11/16/95	PI	E95K2	39510517				[5]Clost. perfringens	[4]nutrients	
11/16/95	PP	E95K3	39510516					[4]nutrients	
11/15/95	PP	E95K3	39510513	Organics	Trace metals	mercury			
11/15/95	PS	E95K4	39510514	Organics	Trace metals	mercury			
11/16/95	PS	E95K4	39510515					[4]nutrients	
11/17/95	R	E95K5	39510519		Trace metals	mercury	Clost. perfringens	[4]nutrients	stable isotopes (N&S)
12/13/95	R	E95L1	39511231					nutrients	stable isotopes (N&S)
12/13/95	R	E95L1	39511229	Organics	Trace metals	mercury	Clost. perfringens		
12/13/95	PI	E95L2	39511226	Organics	Trace metals	mercury			
12/14/95	PI	E95L2	39511233					nutrients	
12/13/95	PP	E95L3	39511227	Organics	Trace metals	mercury			
12/14/95	PP	E95L3	39511234					nutrients	
12/13/95	PS	E95L4	39511228	Organics	Trace metals	mercury			
12/14/95	PS	E95L4	39511235					nutrients	
12/15/95	R	E95L5	39511230	Organics	Trace metals	mercury	Clost. perfringens		
12/15/95	R	E95L5	39511232					nutrients	

Notes:
[1] insufficient volume due to failed samplers
[2] insufficient volume due to damaged container
[3] mislabeled E95JAA
[4] Urea sample not frozen
[5] noted as R sampling despite K2(rather than K5 label)

R = Routine Deer Island Sampling
PI = Pilot Plant Influent
PP = Pilot Plant Primary effluent
PS = Pilot Plant Secondary Effluent

samples were processed for stable nitrogen, sulfur isotope analysis, or *Clostridium perfringens* spore enumeration.

2.2 Sample Analysis

The analytical methods are described in detail in Butler *et al.* (1995), and West and Doering (1994), and also briefly summarized below. Method detection limits (MDLs) are listed in Table 3. The interested reader is referred to the above-referenced Combined Work/Quality Assurance Project Plans for additional details on sample analysis.

Metals and Organic Contaminants - Because concentrations of most target metals and anthropogenic organic compounds in the MWRA effluent were known to be in the low nanogram-per-liter range for organics and in the low microgram-per-liter range for metals (Uhler *et al.*, 1994), analytical methods were specially modified to measure ultra-trace levels of contaminants in fresh and marine water matrices. These concentration ranges were consistently achieved during the analytical program, although selected organic analytes fell below the listed MDLS.

The extraction techniques for organic contaminant analysis followed EPA Method 3510. Sample cleanup and instrumental analysis techniques, modifications, or derivations of several standard EPA methods are from the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends (NS&T) Program (Table 3). Over the last eight years, these methods have been developed and refined by Battelle, NOAA, and the National Institute of Standards and Testing (NIST) scientists to support the low-level contaminant measurement requirements of the NS&T program. These techniques have become the methods of choice for many monitoring programs.

Trace metal concentrations in effluent were determined using standard EPA techniques modified for ultra-clean analysis. Total recoverable metals concentrations were determined using modified EPA 600-01-79-020m Section 4.1.4. Ag, Cd, Cu, Ni, Pb, and Zn concentrations were determined by inductively coupled plasma mass spectrophotometry (ICP-MS). Total recoverable Mo concentrations were determined using modified EPA Method 246.2 techniques. Hg was measured using cold vapor atomic absorption spectroscopy (CVAAS). Required MDLs for the effluents were consistently met.

Nutrients - Albro *et al.* (1993) describe analytical methods used to measure nutrients common to the MWRA Harbor and Outfall Monitoring Project 1992-1994 baseline water quality monitoring program. When using these methods for influent and effluent sampling, the major change was in the sample

TABLE 3

Method Detection Limit (MDL) Goals

Parameter	MDL Goal[1]	NPDES MDL[2]	Water Quality Criteria[3]
Metals	(µg/L)	(µg/L)	(µg/L)
Ag	0.50	10.0	2.3
Cd	0.50	4.0	9.3
Cu	0.50	10.0	2.9
Cr	1.0	10.0	50.0[4]
Hg	0.005	0.2	0.025
Mo	0.50	80	NA
Ni	1.00	10.0	8.3
Pb	0.50	1.0	5.6
Zn	2.00	6.0	86
Organic Analytes	(ng/L)	(ng/L)	(ng/L)
PCBs	1	500	30
LABs	50	NA	NA
PAH	10	10,000	16-710
Pesticides	1	50-100	1-30
Nutrients[5]	µg/L	µg/L	µg/L
Ammonia	11	NA	NA
Nitrate	13	NA	NA
Nitrite	10	NA	NA
Phosphate	0.86	NA	NA
Silicate	2000	NA	NA
Total Dissolved Nitrogen	13	NA	NA
Total Dissolved Organic Phosphorus	6.2	NA	NA
Urea	500	NA	NA
Dissolved Organic Carbon	48	NA	NA
Particulate Carbon	4	NA	NA
Particulate Nitrogen	3	NA	NA
Particulate Phosphorus	.6	NA	NA
Biogenic Silica	.05	NA	NA

[1] **MDL goals are based on past project performance and the goal of detecting concentrations extant in the effluent or at least 5 times less than the corresponding lowest salt water aquatic life criteria.**

[2] **NPDES MDLs are typical MDLs reported by MWRA in their NPDES monitoring reports; the listed MDLs meet the EPA Contract Laboratory Program (CLP) requirements.**

[3] **Water quality criteria listed are the lowest salt water aquatic life criteria published by EPA. Criteria listed for PAH and pesticides are the range of individual values; PAH criteria are lowest observed effects levels. Human health criteria are generally lower than the aquatic life criteria.**

[4] **As chromium VI.**

NA means Not Available.

[5] **Nutrients are dissolved if not noted otherwise.**

dilution required to bring many of the analytes into the linear working range of the method. Subsequently, EPA NPDES methodology was adopted for influent and effluent analysis in 1995. Method detection limits were consistently met during the effluent analysis program (Table 3).

2.2.1 Trace Organic Contaminants

Influent and effluent samples were serially extracted for PAHs, LABs, chlorinated pesticides, and PCBs following EPA Method 3510. Each 2-L effluent sample was transferred to a 3-L separatory funnel. The sample bottle was rinsed with dichloromethane (DCM) and the rinseate was added to the separatory funnel to ensure that any organic compounds adhering to the wall of the bottle were scavenged. The appropriate chlorinated hydrocarbon, PAH, and LAB surrogate internal standards were added to the sample, which was serially extracted three times with 120-mL portions of DCM. The first phase of extract cleanup utilized modified EPA Method 3610. The extract was passed through a 20-g alumina column and eluted with 50 mL of DCM. The filtrate was reduced in volume to about 1 mL using Kuderna-Danish and nitrogen concentration techniques. The concentrated extract was further cleaned using size-exclusion (gel permeation) high-performance liquid chromatography (HPLC) (modified EPA Method 3640). Gel permeation HPLC cleanup removes common biogenic contaminants that can interfere with low-level instrumental analysis. The post-HPLC extract was concentrated to approximately 0.5 mL under nitrogen, recovery internal standards were added, and the final extract was split for analysis. One half was used for PAH and LAB analysis; the other half was solvent-exchanged with isooctane and used for PCB and pesticide analysis.

Sample extracts were analyzed for PAH and LAB compounds by selected ion monitoring (SIM) gas chromatography mass spectrometry (GC/MS) following a modification of EPA Method 8270. PAH compounds were analyzed by monitoring for the most intense parent ion plus one confirmation ion for each target compound. LAB compounds were analyzed as five separate LAB groups (those with alkyl chains containing 10, 11, 12, 13, and 14 carbon atoms) by monitoring the characteristic LAB m/*z* 91 molecular ion during the GC/MS analysis and summing the structural homologues within each group (Eganhouse *et al.*, 1983). Pesticides and PCB congeners were analyzed by capillary gas chromatography with electron capture detection (GC/ECD) using EPA Method 8080, modified to include additional analytes. All analytes were quantified using the internal standard method.

2.2.2 Trace Metals

EPA sample preparation procedures (Section 4.1.4 of 600-01-79-020, March 1983) for determining total recoverable metals were used to analyze metals in the effluent. For all metals except Hg, 100 mL of the sample was spiked with 5 mL of hydrochloric acid, and the sample was reduced in volume by evaporation to ~10-20 mL. The solution was then filtered through a Nuclepore 0.4-µm membrane. To increase sensitivity, the filtrate was not diluted back to 100 mL. To reduce sample contamination, all sample preparation was performed in a Class-100 clean room, and all sample containers and sample preparation equipment were rigorously cleaned according to the procedures of Patterson and Settle (1976). All effluent samples were directly analyzed by ICPMS for Ag, Cd, Cr, Cu, Mo, Ni, Pb, and Zn. Mo was analyzed by EPA Method 246.2.

A modification of EPA Method 245.1 was used for Hg analysis. The samples were prepared by digesting approximately 50 mL of sample with $KMnO_4$ and $K_2S_2O_8$, and reduced to elemental Hg with $SnCl_2$. Hg measurements were made using CVAAS.

2.2.3 Nutrients

Dissolved Inorganic Nutrients - Concentrations of dissolved inorganic nutrients were determined on samples that were passed through a 0.4-µm Nuclepore membrane filter. Ammonia analysis was based on the reaction with Nessler reagent. Nitrite was measured by measuring the colored azo dye by diazotizing with sulfanilamide and coupling with N-(1-naphthyl)-ethylenediamine dihydrochloride. The total concentration of nitrate and nitrite was determined by reducing all nitrate in the sample to nitrite and analyzing for nitrite as above. The concentration of nitrate was obtained by difference. The reduction was accomplished using a cadmium column (Morris and Riley, 1963). Phosphate analysis was based on the molybdate blue procedure of Murphy and Riley (1962). The colorimetric analysis of silicate was based on that of Brewer and Riley (1966).

Particulate Carbon and Nitrogen - Particulate matter was collected on a Whatman GF/F glass-fiber filter. The organic carbon and nitrogen content of particulate matter on the filter was determined by igniting the filter at high temperature (1050°C) in a Carlo Erba Model-1106 CHN elemental analyzer. Combustion released carbon and nitrogen in gaseous forms which were then quantified using gas chromatography with a thermal conductivity detector.

Dissolved Organic Nitrogen and Phosphorus - Dissolved organic nitrogen or phosphorus concentrations could not be measured directly. The dissolved organic concentration of these parameters is currently determined as the difference between the total dissolved concentration and total dissolved inorganic concentration in the sample. The procedures for defining the concentrations of dissolved inorganic nitrogen and phosphorus are described above. The Valderrama (1981) method was used to determine the concentrations of total dissolved nitrogen and phosphorus. This wet-chemical technique utilizes persulphate to oxidize organic nitrogen and phosphorus to nitrate and phosphate. The concentrations of the latter were then determined colorimetrically on a Technicon Autoanalyzer, as described above.

Dissolved Organic Carbon - Dissolved organic carbon concentrations were determined by persulphate digestion (Lambert and Oviatt, 1986) using an O.I. Model-700 TOC Analyzer. Some doubt concerning the accuracy of this method has been voiced in the literature and recent work suggests that the higher concentrations obtained by high-temperature combustion more nearly reflect true levels of DOC in nature (Sugimura and Suzuki, 1988). The method used for analyzing effluents was intercalibrated with an Ionics high-temperature combustion instrument. This study demonstrated that both fresh- and salt-water samples agreed to within 6%. Thus bias is not suspected in these effluent samples, and internal consistency with the water column monitoring program is retained.

Particulate Phosphate - Methods used to measure particulate phosphate were modified from Solorzano and Sharp (1980). The filter containing the particles was placed in a scintillation vial, 2 mL of 0.017 M $MgSO_4$ was added, and the sample was dried and baked at 450°C. HCl was then added and the phosphorus concentration in the sample was determined colorimetrically as described for the inorganic phosphate analysis.

Biogenic Silica - Particulate matter for determining biogenic silica concentrations was extracted using a wet alkaline digestion (Knauss *et al.*, 1983). Particulates retained on a 0.4-μm Poretics membrane filter were digested with 0.2 N NaOH and neutralized with 0.2 N HCl. The silica dissolved by this procedure was measured colorimetrically using a Technicon II Autoanalyzer, and biogenic silica concentrations were calculated.

Urea - Urea was determined colorimetrically by heating the sample with diacetyl monoxime and thiosemicarbazide under acidic conditions.

2.2.4 *Clostridium perfringens*

Clostridium perfringens spores were enumerated by membrane filtration, using serial half-log dilutions of the effluent according to the procedure developed by Bisson and Cabelli (1979). The effluent was filtered using sterile filtration apparatus and membrane filters rinsed with sterile phosphate-buffered saline (PBS). The filters were incubated for 18-24 h at 44.5°C, exposed to ammonium hydroxide, and the *C. perfringens* colonies counted and recorded.

2.2.5 Stable Isotopes

All effluent samples were subjected to glass-fiber filtration (Whatman GF/F, nominal pore size 0.7 µm). After acidification to remove carbonate and desiccation in scintillation vials at 60°C, stable isotopes of particulate nitrogen (^{15}N) retained on the filters were analyzed by mass spectrometry. The samples were then flash-combusted at 1800°C in an evacuated gas manifold and the resulting gases were routed via a helium carrier flow to a cryogenic trap to separate the water, carbon dioxide, and nitrogen gases. The ^{15}N was analyzed using a Finnigan Delta-S mass spectrometer and the excess ^{15}N in each sample was detected by comparing the $^{15}N/^{14}N$ against an air reference.

Sulfur isotope (^{34}S) measurements were taken on a separate sample, which was dried and combusted in a sealed tube with potassium nitrate to oxidize sulfur species to sulfate salts. Sulfate salts were digested in an acid solution, which was filtered; 10% barium chloride solution was added to precipitate sulfate as barium sulfate. The barium sulfate was recovered by filtering the solution through ashless filters which were subsequently combusted in crucibles. Finally, the residual barium sulfate ash was treated with vanadium pentoxide and elemental copper, and transferred to a vacuum apparatus. Upon heating, sulfur dioxide was released, cryogenically trapped on the vacuum line, and analyzed for ^{34}S using a Finnigan MAT 251 isotope ratio mass spectrometer. The excess ^{34}S in each sample was determined by comparing the $^{34}S/^{32}S$ against a Canyon Diablo Triolite meteorite reference.

2.3 Data Treatment

2.3.1 Effluent Data

Effluent data were treated as described in Uhler *et al.* (1994). Individual sample concentrations, monthly mean contaminant and nutrient concentrations, and effluent flow were plotted as a function of sampling month to evaluate temporal trends. Monthly loadings from the Deer Island treatment plant were estimated by multiplying the mean monthly contaminant or nutrient concentration and the mean flow rate for the two sample collections each month. The calculated monthly inputs between January and December 1995 were used to estimate the annual loading of the various contaminants and nutrients from the Deer Island treatment plant.

The annual loading estimates were based on the following assumptions:

- The average of the two effluent flow measurements taken at the time of effluent sampling is representative of that entire month.
- The average concentration of contaminants measured in the effluent for a given month is representative of the entire month.

The annual loading for each contaminant of interest was calculated from the equation

$$L_i\ (\mathrm{Kg}) = [\Sigma\ (C_{i,m} \times F_m)]$$

where

L_i is the annual loading of contaminant in kilograms
$C_{i,m}$ is the average concentration of contaminant i in the effluent measured in month m in Kg/gal; m ranges from January to December

F_m is the effluent flow at Deer Island in millions of gallons per day (MGD), measured on the days that the effluent samples were collected for analysis in month m

This simple calculation allowed a first-order estimate of the inputs of anthropogenic contaminants to the Harbor and Bay, and provided a basis for comparison with contaminant loadings that have been estimated by other investigators.

Estimates of 1995 effluent loading to the Massachusetts Bay/Boston Harbor system were compared to previous estimates (Alber and Chan, 1994; Shea, 1993a; Hunt *et al.*, 1995) by assuming that effluent concentrations in the Nut Island effluent were the same as those at Deer Island. The effluent flow to the Boston Harbor/Massachusetts Bay system was then apportioned between the two treatment facilities based on the annual flow averages of 255 for Deer Island and 128 MGD for Nut Island reported by MWRA (MWRA NPDES NEWS, November 1994). Based on these assumptions, the Deer Island effluent loading estimates were increased by a factor of 1.5 to account for the total loading from both facilities.

2.3.2 Pilot Treatment Plant Data

Pilot treatment plant study results are reported as concentrations in the influent and primary and secondary effluents. Data treatment focused on estimating removal efficiencies for the various parameters during primary and secondary treatment, and on examining conversions among the various nutrient forms. Preliminary estimates of contaminants and nutrient loading to Massachusetts Bay, after the secondary treatment becomes operational, were also made, based on the 1995 loading estimates and the removal efficiencies of secondary treatment versus primary treatment.

The efficiency of the contaminant and nutrient removal process was examined using the following formula:

$$R_e = ((C_i-C_e)/C_i)*100$$

where

R_e is the removal efficiency
C_i is the influent concentration
C_e is the effluent concentration (either primary or secondary)
the constant 100 expresses the ratio as a percentage

The same formula was used to estimate removal efficiencies between the primary and secondary treatment trains of the pilot treatment plant.

2.3.3 Principal Components Analysis

Principal components analysis (PCA) is a multivariate data analysis tool for creating data matrices that distinguish similarities/differences in patterns (analyte distributions) between individual samples, and that determine the influence of each variable (analyte) or set of variables on a pattern. PCA is especially useful for uncovering underlying patterns that may not be obvious from a visual analysis of the data. This technique helps determine how samples may be related and which characteristics of the samples define their relationship. The Statmost software package was used to perform PCA analysis of the PAH and LAB data from the effluent samples. Initially, the effluent data (PAH) from 1995, as well data from analysis of several common fuel products, were explored with PCA. The PAH and LAB data from the pilot plant study were then included with the effluent data to emphasize any potential differences in the analyte distributions that may be attributed to the treatment processes.

3.0 RESULTS AND DISCUSSION

3.1 Effluent

There are several factors which may influence the ability to compare 1995 data with 1993/4 data (which comes from the 1995 Battelle report by Hunt *et al.*), as well as comparisons among different 1995 data sets. First, new laboratories were employed in 1995 for almost all of the analysis. Even though the same methods were used, slightly different results may have been obtained from lab to lab. In addition, a new treatment plant went online by the end of January of 1995, likely producing slightly better removal efficiencies than before. Finally, the use of grab versus composite sampling for certain parameters (in particular, nutrients) may add complications.

3.1.1 Flow

Flow data for the sampling periods (Figure 2) indicate that flows in the winter/spring period were slightly higher than in the summer/fall period. The ratio of the average flows for the sample collection dates from January through May 1995 plus December 1995 (comprising the winter/spring dates), and June through November 1995 (comprising the summer/fall dates) shows that the winter/spring flow was approximately 1.12 times the flow during the summer/fall period. This is a smaller variation than 1994, when the winter/spring flow was 1.3 to 1.4 times that of the summer/fall flow. This partially explains the lack of seasonality for some of the metals and nutrients and is further discussed in section 3.14.

3.1.2 Trace Organic Contaminants

The temporal variability of the organic compounds measured between January and December 1995 is considered in this section.

PAHs - There are two primary sources for PAH in the environment. Spills or chronic input of refined and unrefined petroleum are the source of the lighter-weight, more volatile 2- and 3-ring petrogenic PAHs products. These are the dominant PAH compounds in the Deer Island effluent. The heavier pyrogenic 4-, 5-, and 6-ring PAHs are derived from the combustion of fossil fuels and are present at significantly lower concentrations in the effluent. The total PAH concentrations (sum of all PAHs listed in Table 1) in the Deer Island effluent samples are presented in Figure 3.

Figure 2:Deer Island flow rates on the days that the effluent samples were collected.

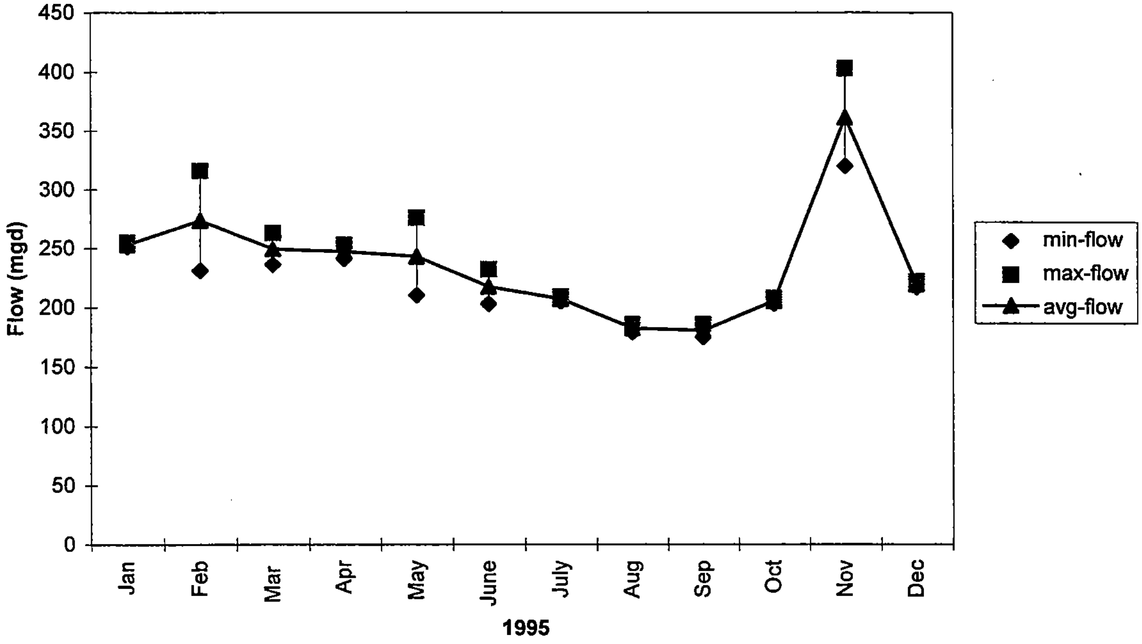
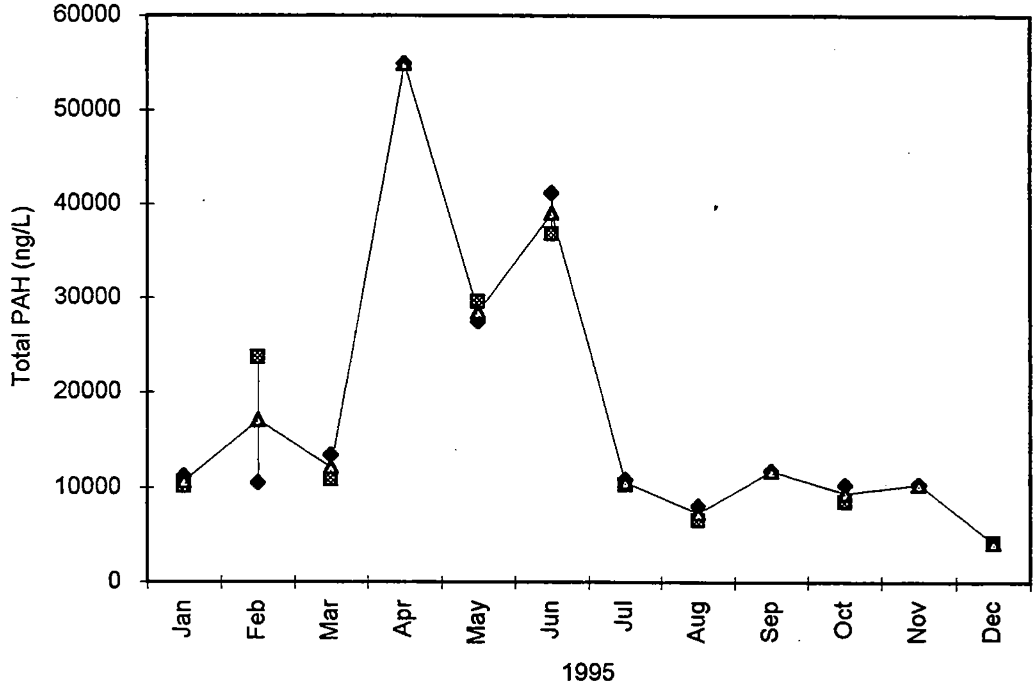


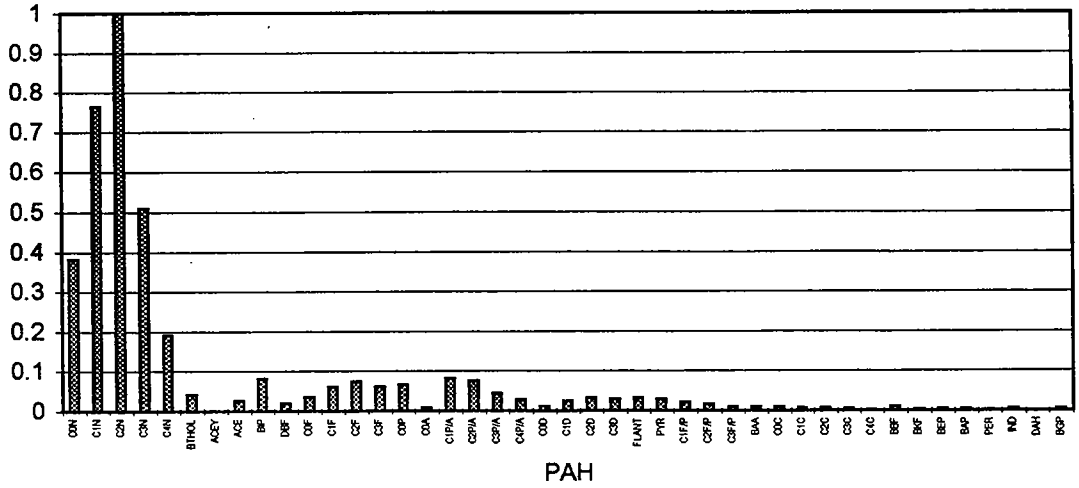
Figure 3: Temporal response in Total PAH for 1995



The highest total PAH concentrations were measured in April, May and June of 1995 (compared to January and February in 1994), averaging approximately 40,800 ng/L for these months (vs. ~30,000 ng/L in 1994). The other nine 1995 sampling events were more consistent, averaging approximately 10,400 ng/L. A low of 133 ng/L was measured on December 13 for regular Deer Island effluent, but another sample taken at the Pilot Treatment Plant for 1° effluent on the same day had a concentration of 4,111 ng/L. The December 15th sampling effort at Deer Island had concentrations of total PAH of 4,204 ng/L in the effluent, comparable to that of the Pilot Treatment Plant two days prior. This indicates that the December 13th data point for total PAH in Deer Island effluent was not representative of the sample set, and its value may skew the data to the lower end. For this report, the December 13th data point was not included in the analysis. Despite variabilities in concentration, the distribution of the individual PAH compounds was relatively consistent between samples (Figure 4). For this comparison, the samples with the second lowest and second highest total PAH were charted. In each case, the low-molecular-weight petrogenic PAHs dominate the distribution. The presence of - these compounds in the effluent is probably related to the input of refined fuel products. The major pyrogenic PAHs are also present in the effluent, but at lower concentrations. To evaluate differences in analyte distribution among the samples, PAH data was subjected to a principal components analysis (PCA) as was done in 1993/4. PAH data for kerosene, unleaded gas, bunker fuel oil #6 and fuel oil #2 was included with the effluent data to determine if the analyte distributions for the field samples resembled the distributions for common fuel products. For the PCA, a correlation matrix was used, all variables being scaled to unit variance and zero mean. For PCA analysis of PAHs, samples were separated into two distinct clusters (Figure 5). Some seasonal variability was detected in these analyses, including the separation of January-June samples into one cluster and July-December samples into a second cluster. Subtle differences in analyte distributions may have been caused by variations in input to the system which may be related to seasonal lifestyle changes. The petroleum products most closely related to the July-December cluster were unleaded gas and kerosene. None of the fuel products was close to the January-June data. In the 1994 data, the samples were closest to fuel oil #2 (as well as fuel oil and residual fuel oil, not analyzed in this report).

LABs - LABs are used in the production of linear alkylbenzene sulphonate surfactants (LAS), which are common in domestic detergents (Eganhouse *et al.*, 1983; Takada and Ishiwatari, 1990; Takada and Ishiwatari, 1991). LABs also remain in the detergent product as impurities. LASs are easily oxidized and, as a result, do not persist in the environment. LABs are more resistant to chemical breakdown, and as a result are often used as a tracer for domestic wastes. Total LAB concentrations are presented in Figure 6. For total LAB in 1995, the highest concentration was detected in March and April, compared to the 1994 high detected in November. After April 1995, concentrations steadily decreased

Figure 4
Relative PAH distributions for 2nd highest Total PAH (June 14, 1995). (Data is normalized to the compound of highest concentration.)



Relative PAH distributions for 2nd lowest Total PAH results (December 15, 1995). (Data is normalized to the compound of highest concentration.)

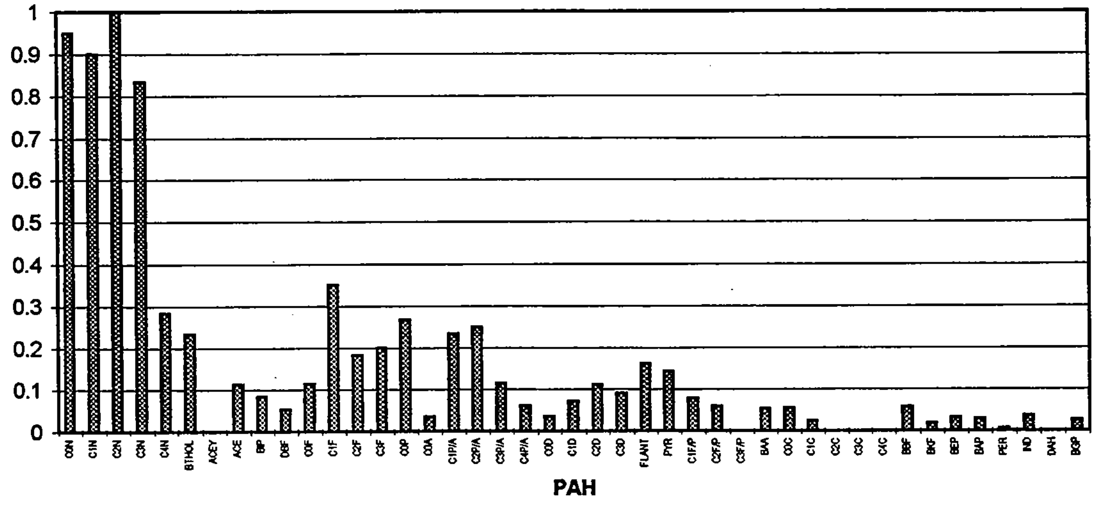


FIGURE 5: Principal Components Analysis of PAH's in Deer Island Effluent

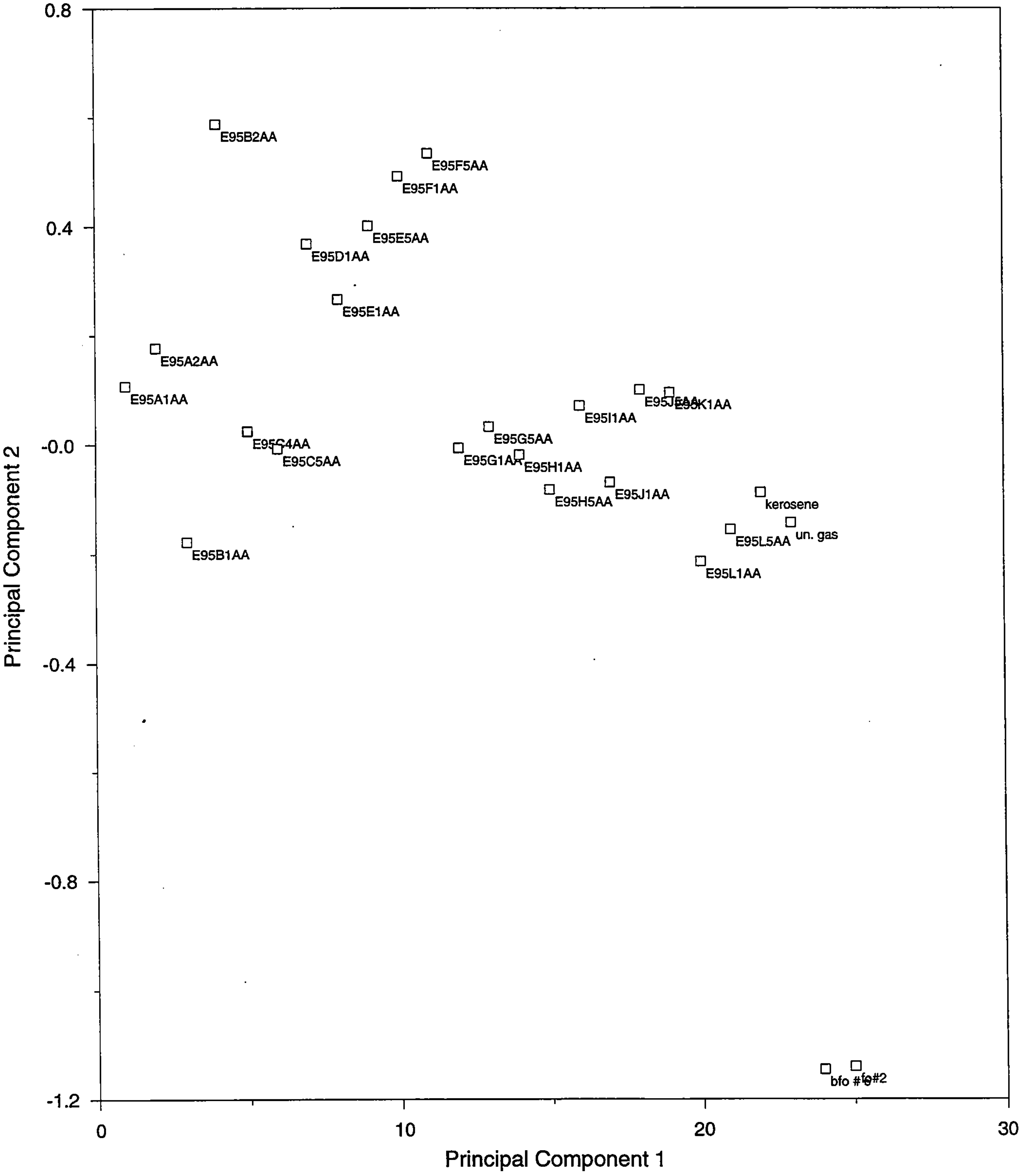
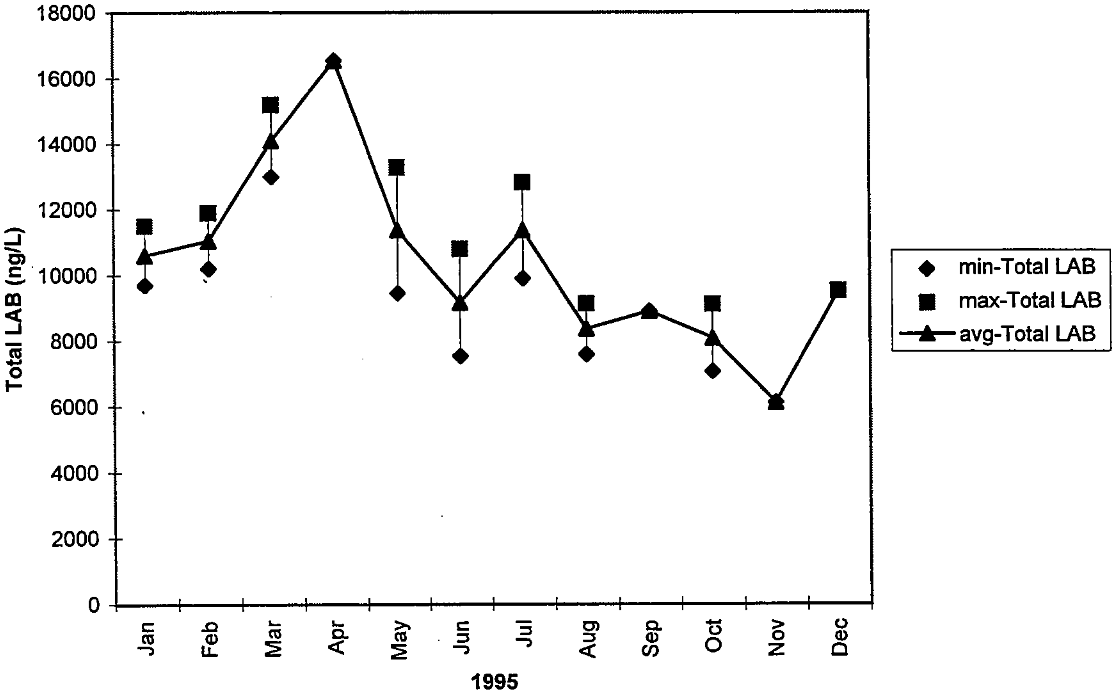


Figure 6: Temporal response inTotal LAB for 1995



until the end of the year. March and April total LAB concentrations averaged 15,320 ng/L while the other 10 months of 1995 averaged 9,451 ng/L. The importance of the individual LABs to total LAB remained consistent with the samples detecting the second lowest and second highest levels of total LAB (Figure 7). The 1995 data suggests that a lighter analyte, C11, was more prevalent. A heavier analyte, C12, was more prevalent in 1994.

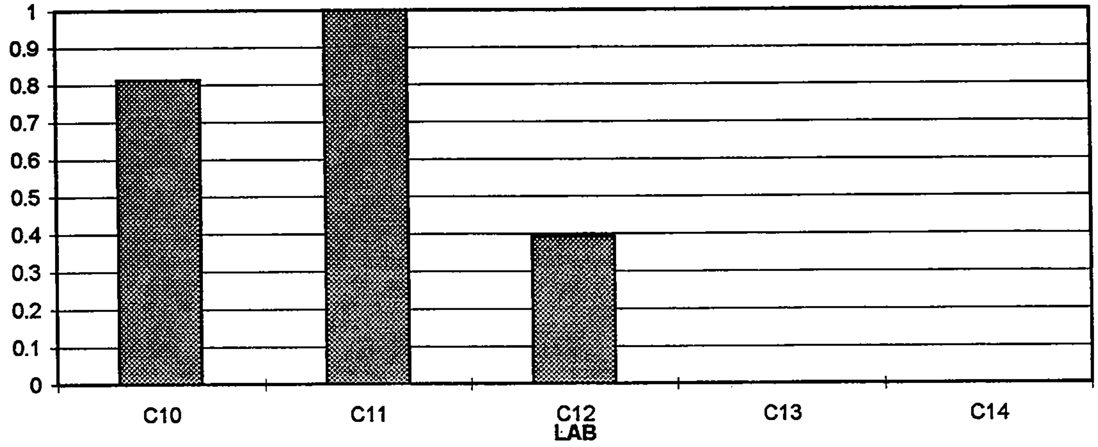
Chlorinated Pesticides - The target chlorinated pesticides are still persistent in the environment even though they have been banned in the United States. Figures 8, 9 and 10 show the concentrations of selected chlorinated pesticides in effluent during the sampling period. Except for the March 1995 sample, which averaged approximately 16.4 ng/L, concentrations of total chlordane (heptachlor + heptachlorepoxide + cis-chlordane + transnonachlor) were relatively constant (<12 ng/L) throughout the sampling period. Concentrations of total DDT (the sum of parent and all breakdown products) ranged from 0 ng/L to 30.8 ng/L (compared with 7 ng/L and 160 ng/L in 1994). The highest concentrations were detected in June and August of 1995. With the exception of a spike in the July 1995 sample, lindane concentrations were relatively constant, averaging 5-27 ng/L (compared with 10-15 ng/L in 1994). There were no detected levels of dieldrin in any of the 1995 samples.

PCBs - PCBs have a wide range of industrially desirable characteristics, including flame resistance, electrical properties, and chemical stability. Similar to the chlorinated pesticides discussed above, PCBs were banned in the U.S. but are still found in effluent streams. PCBs are made up of various combinations of 209 congeners, twenty of which were monitored in this effluent study (the same congeners that are monitored in the NOAA Status and Trends Program).

Total PCB concentrations (sum of 20 congeners) detected in the effluent samples are presented in Figure 11. Monthly average concentrations ranged from 7 to 225 ng/L, with the distributions varying throughout the samples. In samples with total PCB between 12 and 26, congeners 187, 118 and 153 were found most frequently, and samples with total PCB between 40 and 75 had congener 18 as the most consistently high analyte. In general, congeners 18 and 180 were most prevalent in the samples with total PCB greater than 95 (Figure 12). Recent investigations indicate that these maybe analytical artifacts and 180 maybe due to phthalate interference (Mitchell *et al.*, 1997). The highest concentrations of total PCBs were detected in June and July 1995 while the lowest concentrations occurred in April and May 1995.

Figure 7

Relative LAB distributions for 2nd highest Total LAB (March 14, 1995). (Data is normalized to the compound of highest concentration.)



Relative LAB distributions for 2nd lowest Total LAB (November 15, 1995). (Data is Normalized to the compound of highest concentration.)

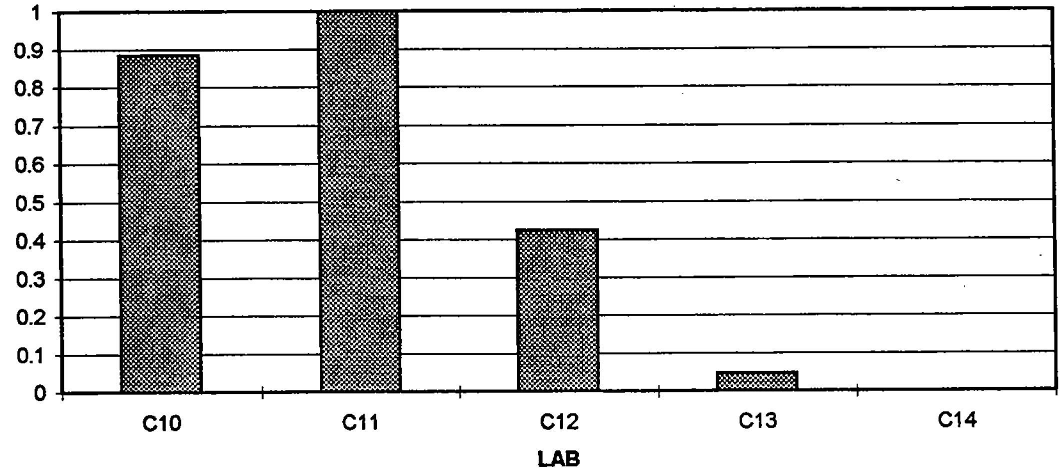


Figure 8: Temporal response in Total Chlordane for 1995

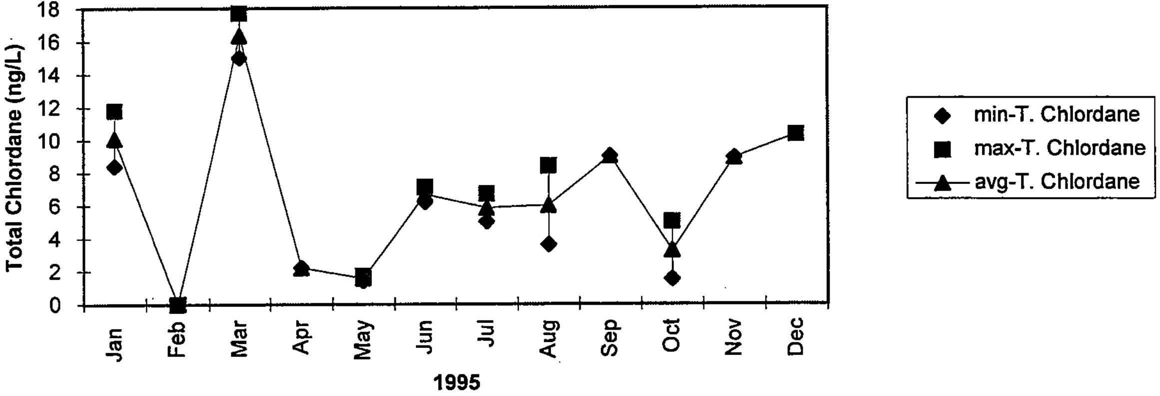


Figure 9: Temporal response in Total DDT and 4,4'-DDT for 1995

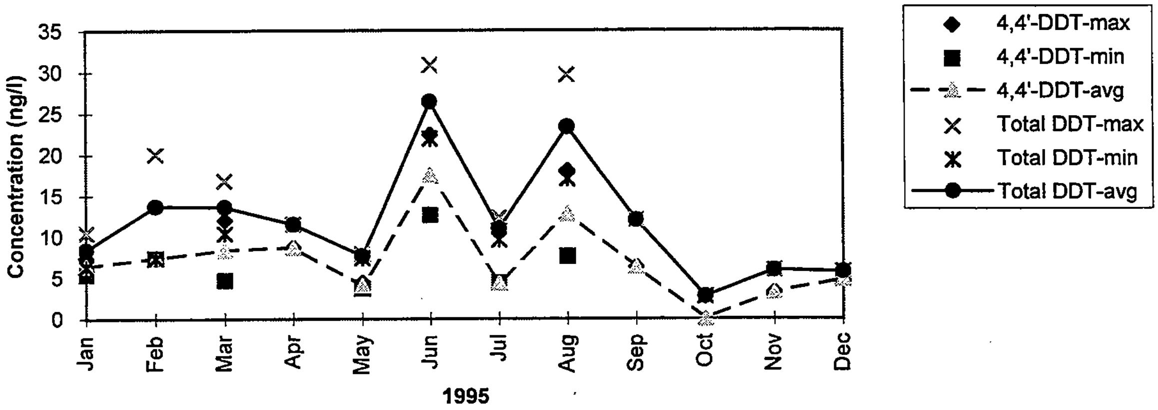


Figure 10: Temporal response in Lindane for 1995

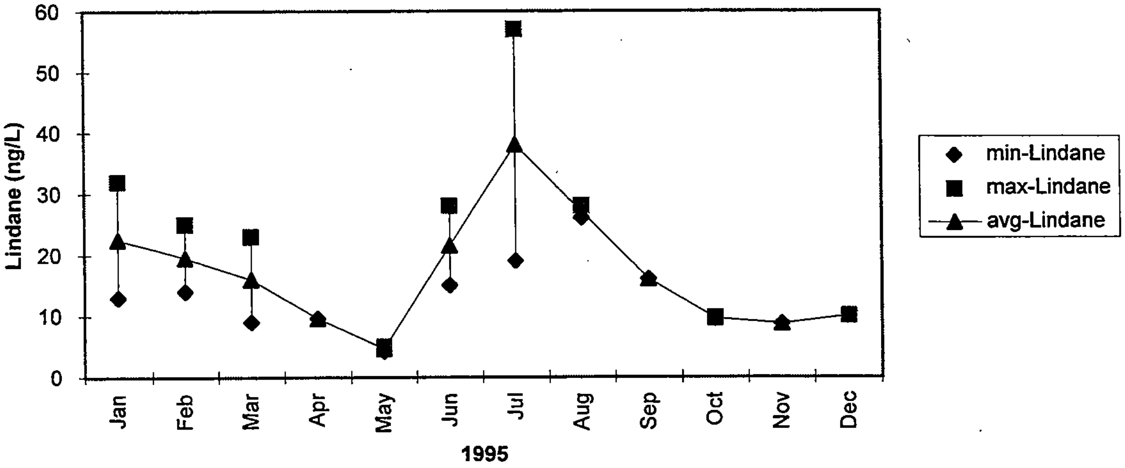


Figure 11: Temporal response in Total PCBs for 1995

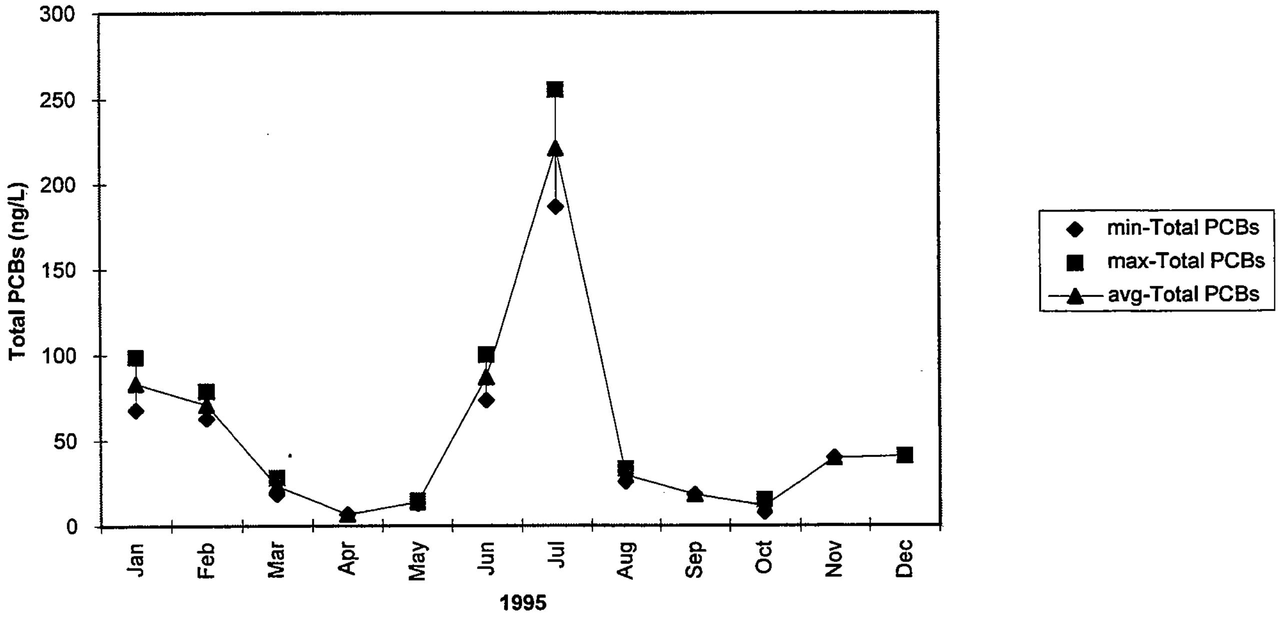
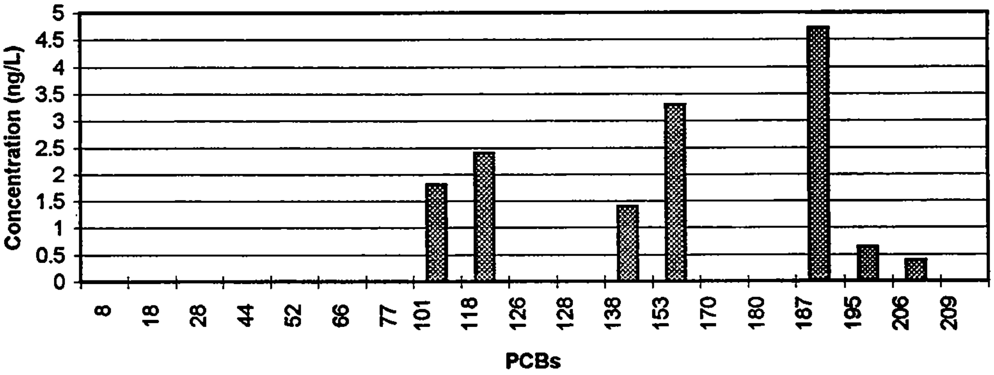
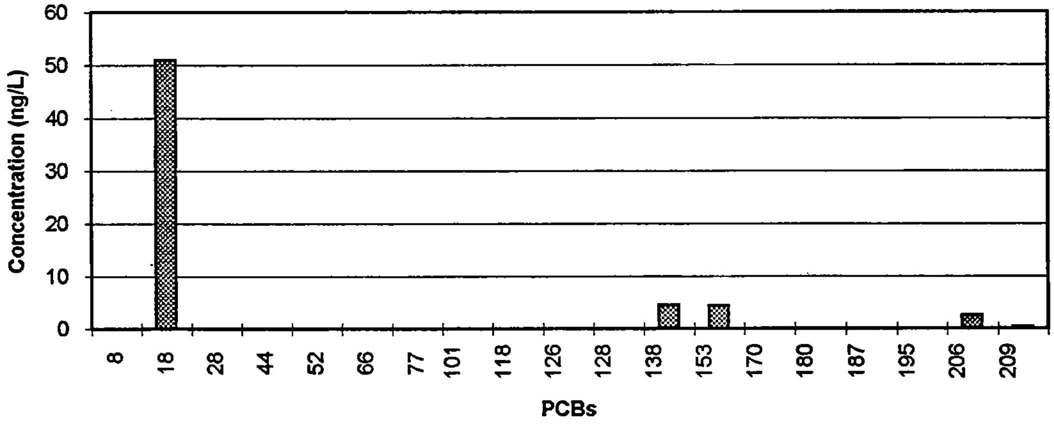


Figure 12

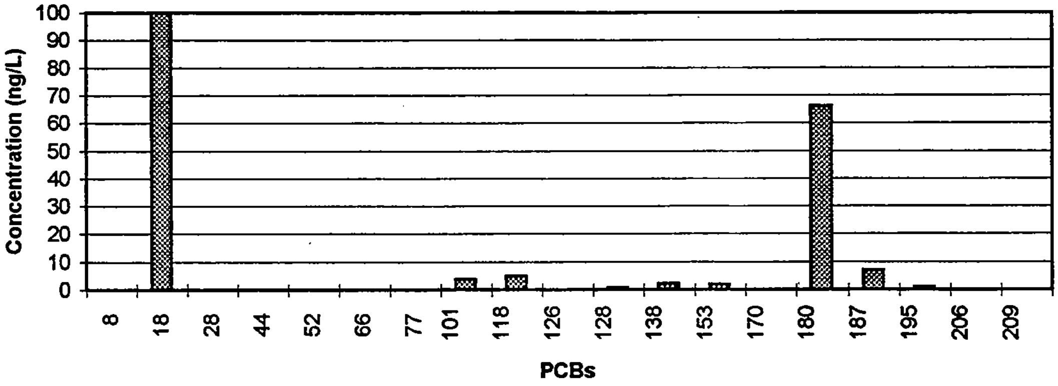
Sample E95E5AA Total PCB = 14.6 ng/L



Sample E95B2AA Total PCB = 62.7 ng/L



Sample E95G1AA Total PCB = 186.5 ng/L



3.1.3 Trace Metals

Concentrations of Ag, Cd, Cr, Cu, Hg, Mo, Ni, Pb, and Zn were measured in the Deer Island effluent because they reflect anthropogenic inputs and are metals of concern for the receiving waters. They also represent different potential natural, industrial, and municipal sources to the waste stream and may be used as relatively unique tracers of the effluent in the receiving waters (*e.g.*, Ag [Sanudo-Wllhelmy and Flegal, 1992; Bothner *et al.*, 1994]). Also, the U.S. EPA has established marine water quality criteria for some of these metals because of concern for potential ecological impacts.

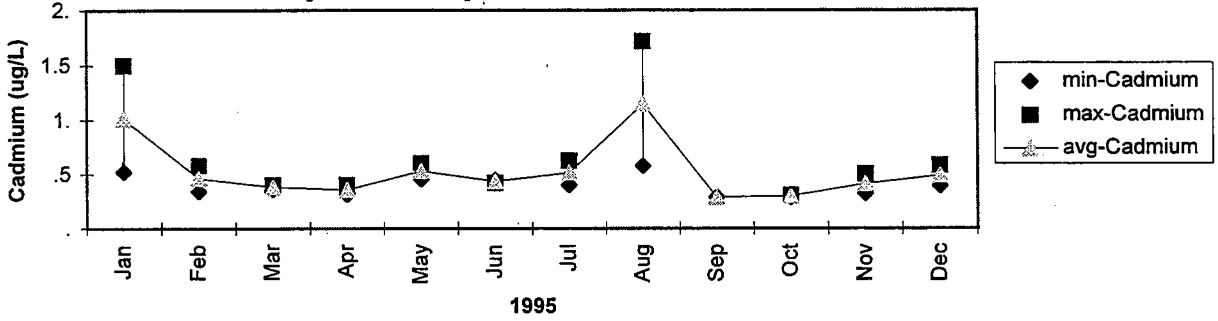
The concentrations of each trace metal in the effluent stream were relatively constant during 1995 (Figures 13a, 13b, and 13c). For each sampling month, the mean concentration for each two-day sampling event is depicted by the midpoint of the bar. The bar represents the range (high to low) between the two measurements. During the 1995 sampling period, the concentration ranges for each trace metal in the effluent were: 1.3 - 5.8 µg/L for Ag; 0.3 -1.7 µg/L for Cd; 3.1 - 185 µg/L for Cr; 46.7 - 103.0 µg/L for Cu; 0.03 - 0.3 µg/L for Hg; 9.2 -26.9 µg/L for Mo; 3.7 - 20.4 µg/L for Ni; 4.3-29.2 µg/L for Pb; and 49.4 - 136.4 µg/L for Zn.

No significant temporal trends were noted in the 1995 metal data. However, concentrations of Mo and Cu appeared to be slightly higher in the late spring and summer than in the fall and winter. Zn had higher concentrations in the spring except for a spike in November. Ni was fairly consistent throughout the year. Hg had low readings for the first three months of the year, but then increased to a level comparable to the 1994 data (Hunt *et al.*, 1995). Cr had two large spikes, in January and February, however the rest of the months showed little change. Upon further investigation by the laboratory and ENSR, the two Cr spikes could not be rejected and are considered valid sample results. The NPDES samples also showed Cr peaks.

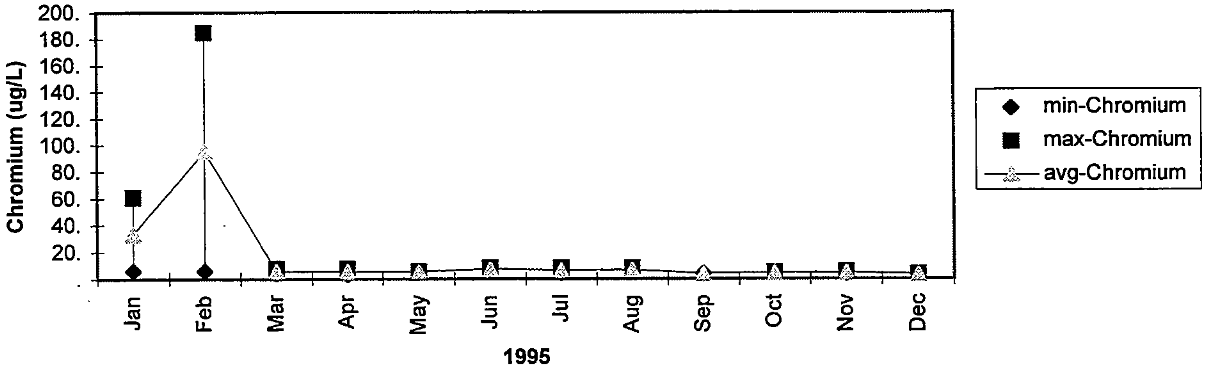
The concentrations of metals in the effluent were similar to concentrations measured in 23 effluents from the greater New York City area in 1992 (EPA, 1991) using comparable sampling methods, and "clean" processing and analysis procedures. The range of measured total recoverable values in that study are included for comparison as follows: 0.2 -16 µg/L for Ag; 0.1 - 2.6 µg/L for Cd; 10 - 100 µg/L for Cu; <0.004 - 0.15 µg/L for Hg; 1 - 14 µg/L for Pb; 2 - 70 µg/L for Ni; and 15 - 175 µg/L for Zn.

Figure 13a

Temporal response in Cadmium for 1995



Temporal response in Chromium for 1995



Temporal responses in Copper for 1995

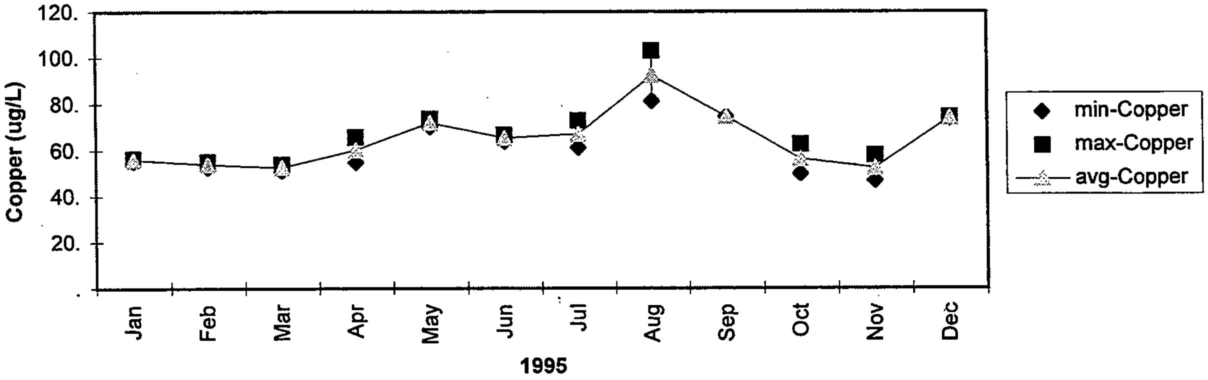
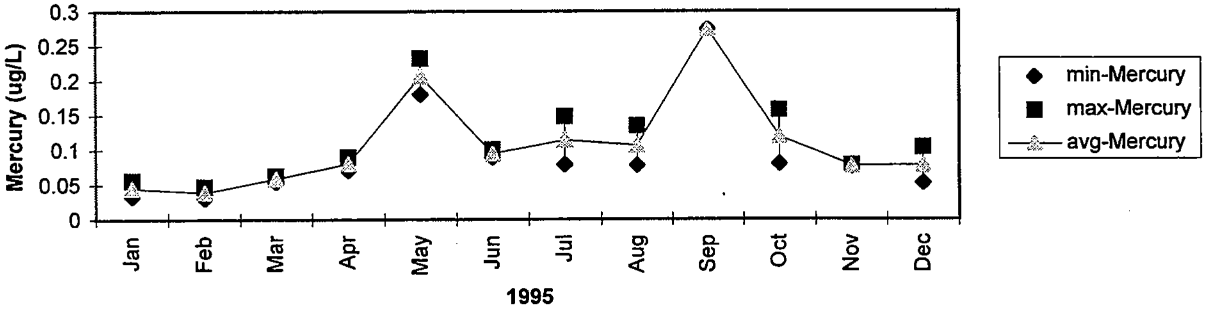
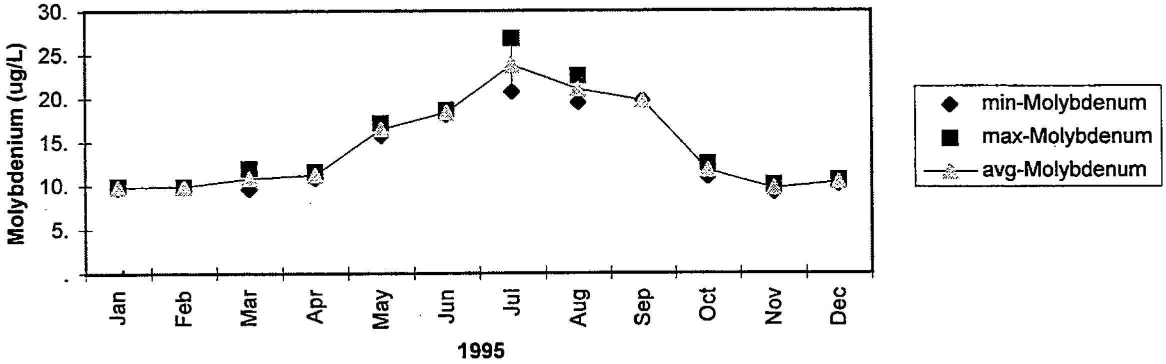


Figure 13b

Temporal response in Mercury for 1995



Temporal response in Molybdenum for 1995



Temporal response in Nickel for 1995

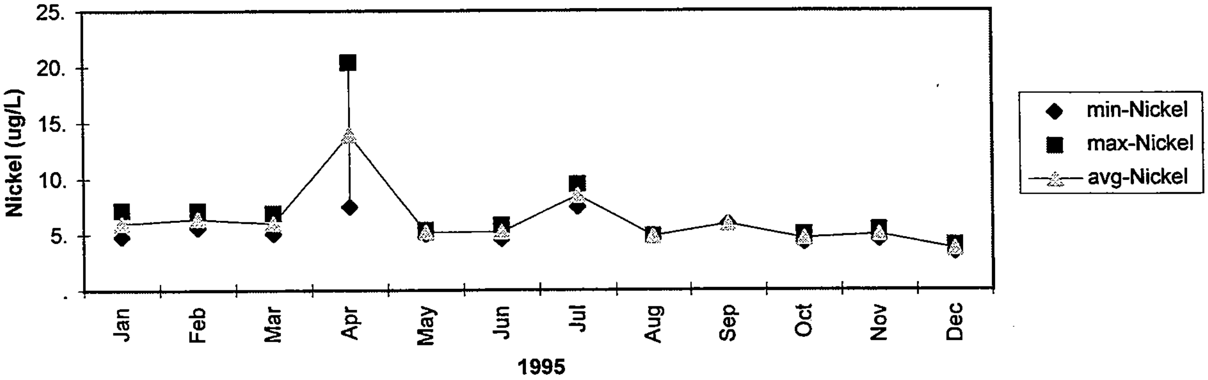
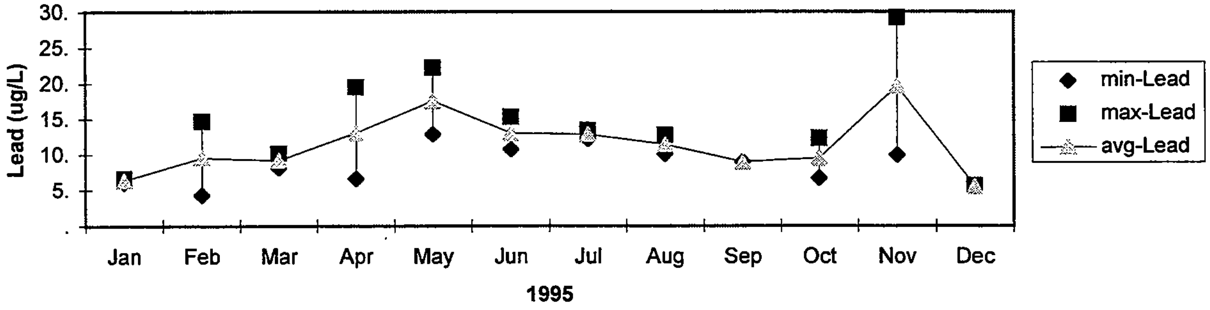
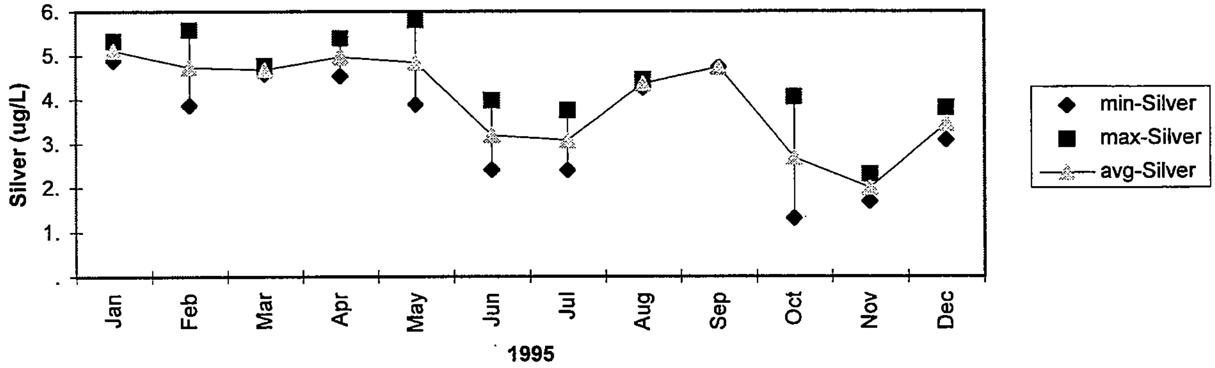


Figure 13c

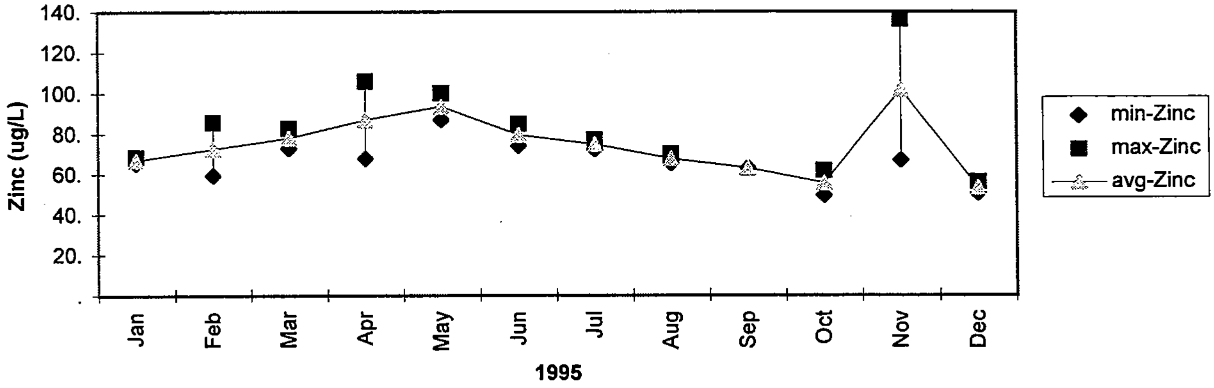
Temporal response in Lead for 1995



Temporal response in Silver for 1995



Temporal response in Zinc for 1995



3.1.4 Nutrients

Temporal trends of the various nutrient forms in the Deer Island primary effluent samples collected throughout 1995 are considered in this section. In comparing 1995 to 1994, it should be noted that grab samples were analyzed by NPDES methodology in 1995 and composite samples were analyzed by seawater methodology in 1994. Each major nutrient (nitrogen, phosphorus, silicate) as well as organic carbon is discussed separately.

Nitrogen - Total nitrogen (the sum of the particulate and total dissolved nitrogen) in the Deer Island primary effluent ranged between 516 and 2250 µM (vs. 830 and 1740 µM in 1994), see Figure 14. Concentrations of total nitrogen in the effluent did not show a clear seasonal response for 1995. The winter/spring (December-May) concentrations, averaging 1447 µM, were slightly lower than the summer/fall (June-November) concentrations which averaged 1635 µM. The average summer/fall concentration is 1.13 times the winter/spring concentration. This ratio is almost identical to the ratio of winter/spring flow over the summer/fall flow. This shows that the input of total nitrogen remained relatively constant through the year, and the seasonal variation is flow driven.

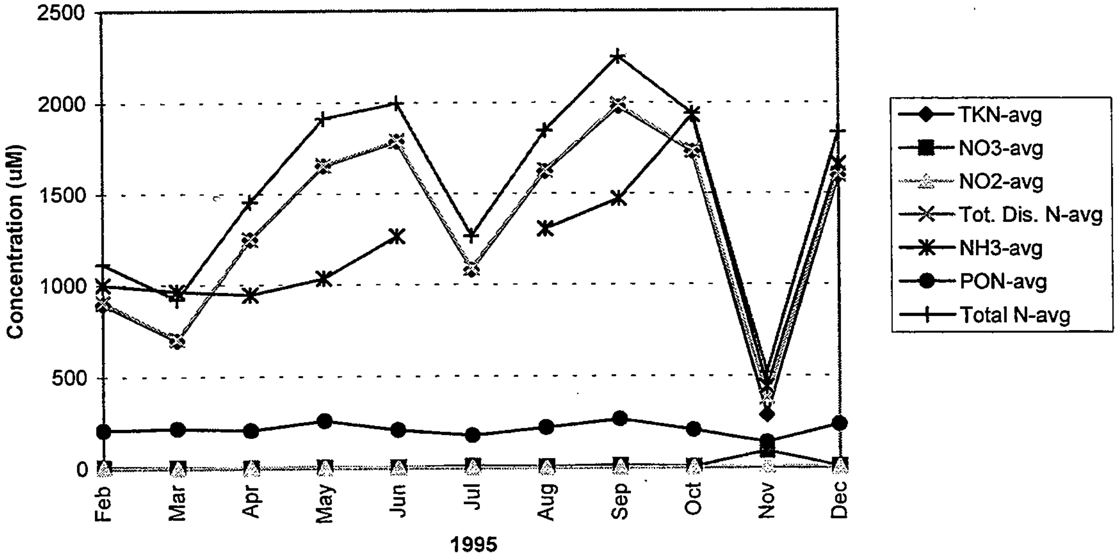
Evaluation of the nitrogen data concentration indicates that for 1995 an average of 69% of the nitrogen discharged was in the form of ammonia (Figure 14). Concentrations of ammonia in the effluent ranged between approximately 285 and 1975 µM (compared to ~300 and 1200 µM in 1994) . The seasonal variability of ammonia was similar to the range for total nitrogen. Ammonia comprised up to 91% of the annual total dissolved nitrogen and its temporal variability was similar to that for total dissolved nitrogen (Figure 14). Little seasonal difference was noted in the ammonia data; the average winter/spring (993.4 µM) were slightly lower than the average summer/fall concentrations (1073.8 µM). Several samples showed zero ammonia concentrations, they were not used for calculating loadings because it is unlikely that the actual ammonia concentration in effluent was zero.

Concentrations of particulate organic nitrogen in the Deer Island effluent ranged between 137 and 310 (Figure 14), similar to the 1994 range of 180 and 300 µM. Particulate organic nitrogen contributed 10-27% of the total nitrogen in the effluent.

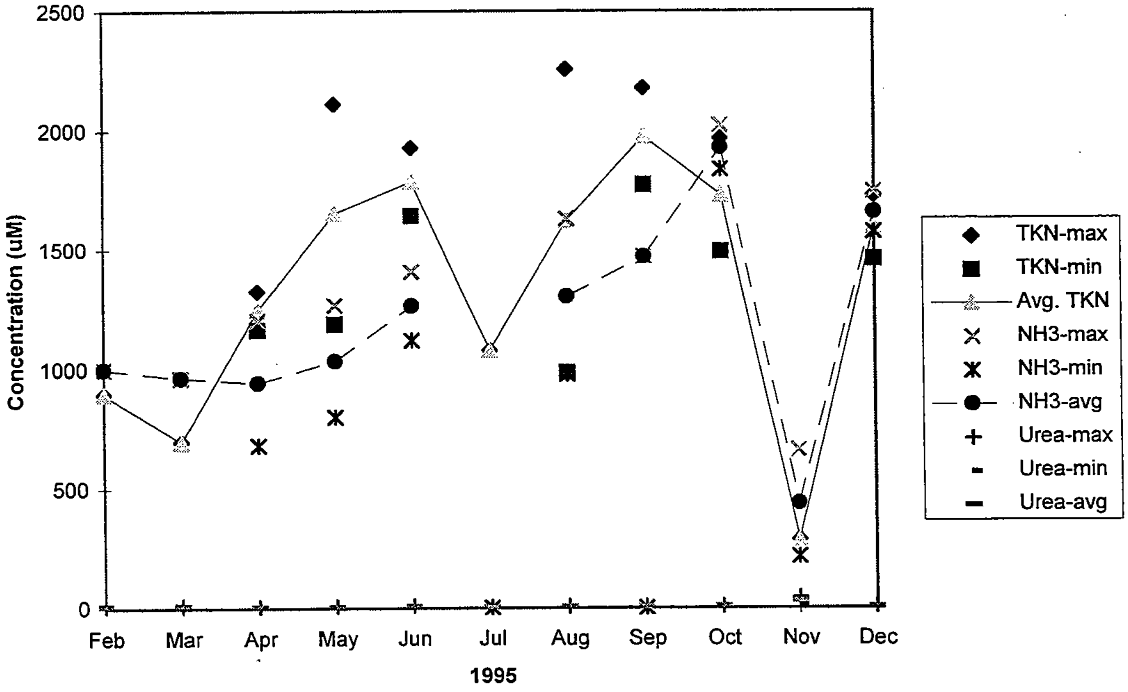
The concentration of nitrate and nitrite (Figure 14) in the effluent was low (<10 µM), except in November when nitrate contributed approximately 88.5 µM. The summer/fall nitrate + nitrite concentrations, consistently ranging between 3 and 10.3 µM, were lower than concentrations measured during the winter. The winter/spring concentrations averaged 5.9 µM, and the summer/fall

Figure 14

Temporal response to nitrogen for 1995



Temporal response in TKN, NH3 and Urea for 1995



concentrations averaged 21.7 µM. The high summer/fall nitrate + nitrite concentrations were primarily due to the November peak.

Phosphorus - Total phosphorus concentrations in the Deer Island effluent (Figure 15) showed a seasonal pattern, with higher concentrations in the summer/fall (124 µM) than in the winter/spring (79 µM). Note that a steady increase in the total and dissolved phosphorus concentrations characterized the second half of 1995, except for a steep drop in November, which is mainly related to flow. This steady increase in the second half of the year is consistent with the 1994 data.

Particulate phosphorus concentrations were consistent throughout the year. Therefore, the summer/fall increase in total phosphorus was entirely due to dissolved forms of this nutrient. Inorganic phosphate comprised approximately 25% of the total dissolved phosphorus. One of the few differences between the 1994 and 1995 data sets was the PO_4 comparisons. In 1995, PO_4 ranged from 0.4 to 31.6 µM, while the 1994 ranges for PO_4 were from 20 to 85 µM, (Hunt *et al.*, 1995).

Total phosphorus concentrations in the effluent ranged from 41 to 313 µM, slightly higher than the 1994 range of from 14 to 117 µM . In 1995, the average total phosphorus concentration was 104 µM, slightly higher than 86 µM in 1994. This compares well with the 1993 average concentration of 116 µM reported by Alber and Chan (1994). The average total phosphorus concentrations were 79 and 124 µM for the winter/spring and summer/fall periods, respectively, slightly higher than the 1994 averages of 54 and 118 µM for the winter/spring and summer/fall periods, respectively. In October, the total phosphorus concentration was significantly higher, corresponding to the higher total dissolved phosphorus concentrations that were also observed.

Silicate - Biologically available forms of silica including dissolved silica and biogenic particulate silica, were dominated by dissolved Si (91-97% of the total biologically available silicate). Concentrations of dissolved Si (Figure 16) in the effluent ranged from 258 to 494 µM over the course of the year. The average dissolved Si concentration was 372 µM, which was higher than the 1994 average of 151 µM. There was no apparent seasonality in the 1995 data. Biogenic silica ranged between 15 and 36 µM, with an annual average of 22.4 µM (higher than the 1994 average of 7.1 µM. Likewise, no seasonality was noted for biogenic Si for 1995.

Organic Carbon - Higher concentrations of dissolved, particulate, and total (sum of dissolved and particulate) organic carbon concentrations (Figure 17) were measured in winter/spring than in summer/fall. The ratio of winter/ spring to summer/fall concentrations was 1.11 for DOC, 1.25 for

Figure 15

Temporal response in total dissolved, particulate, and total phosphorus and ortho-phosphate concentrations for 1995

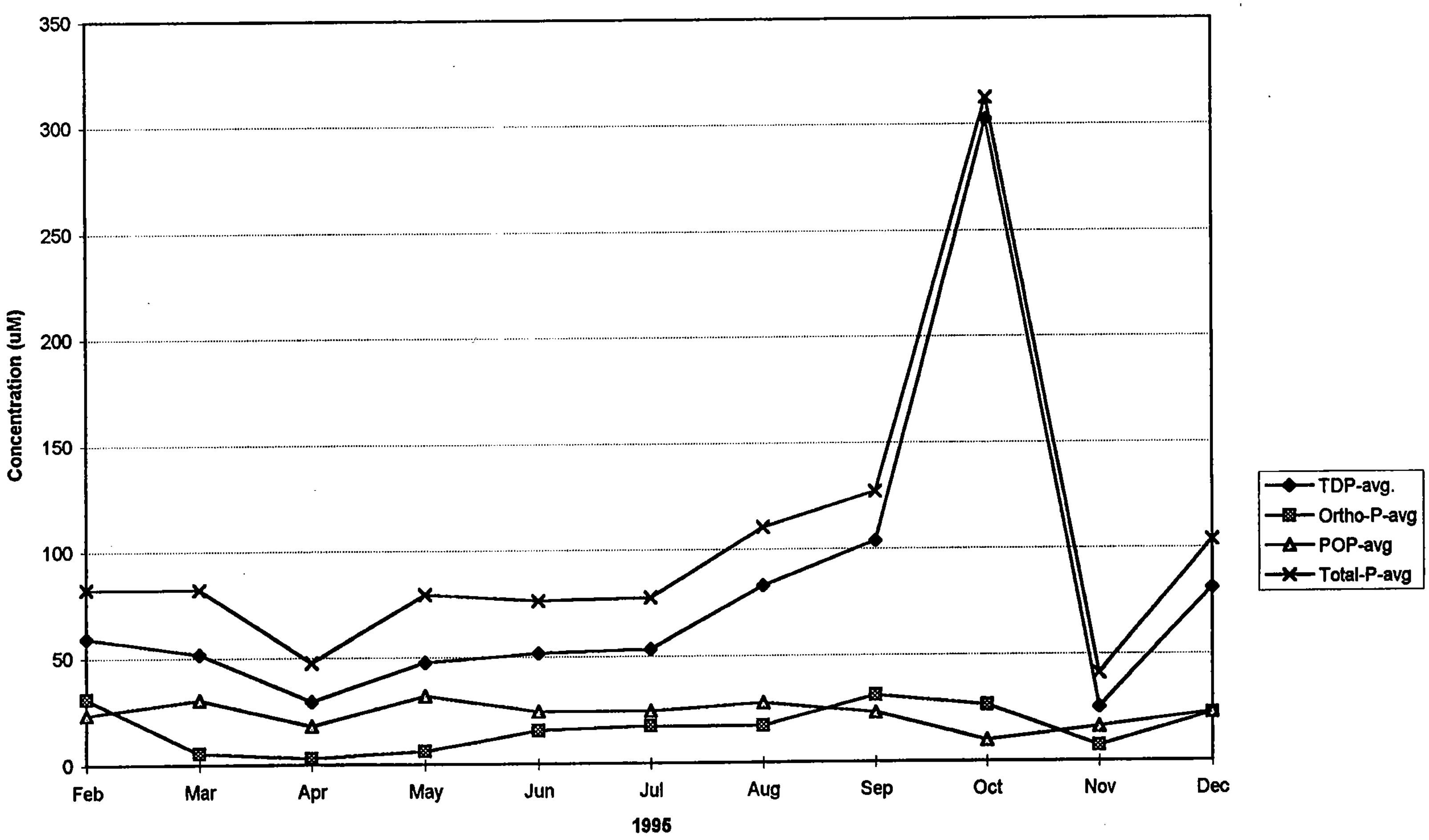


Figure 16
Temporal response in Biogenic Silica and Silicate for 1995

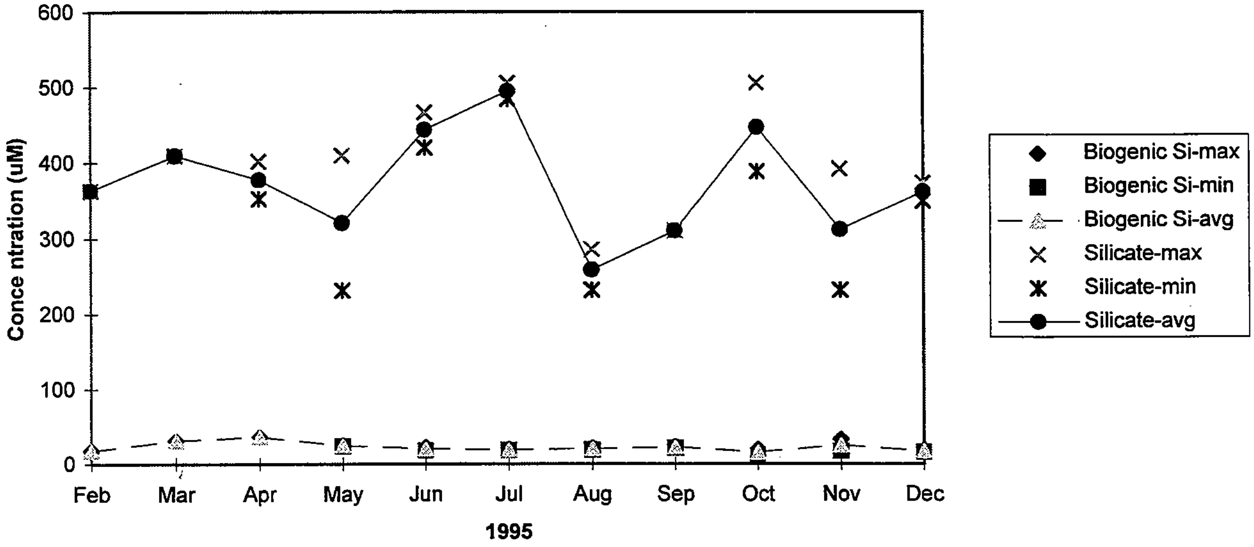
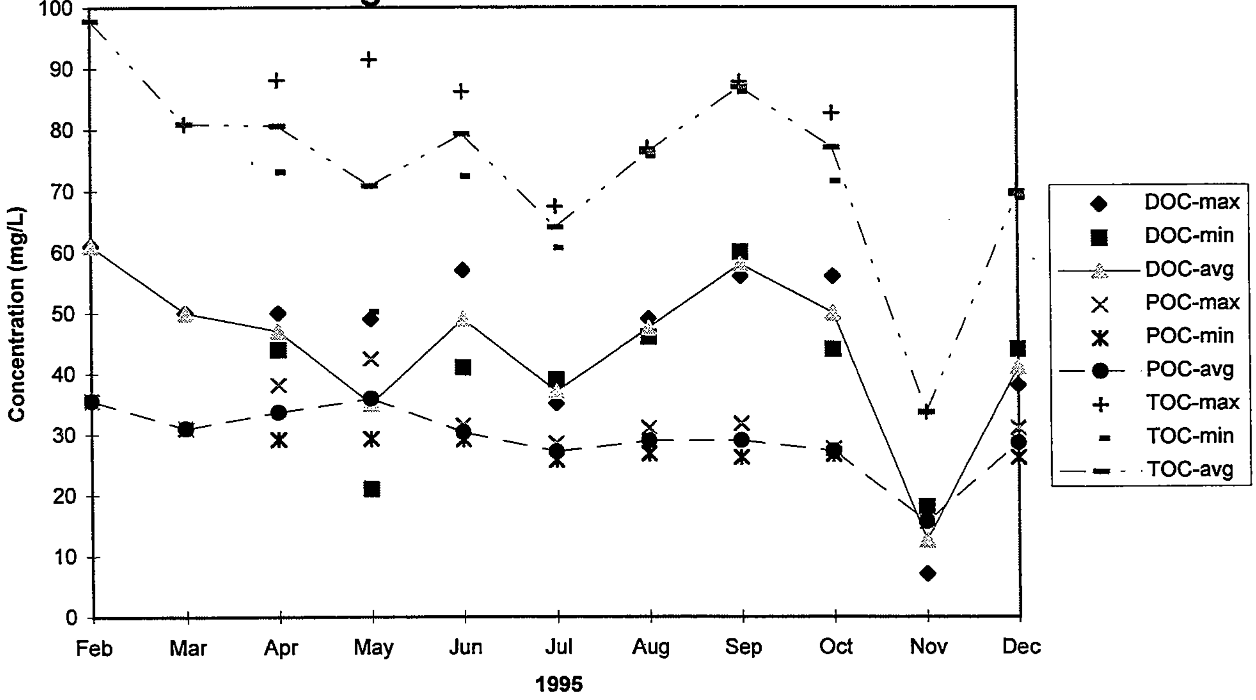


Figure 17
Temporal response in dissolved and particulate carbon organic concentrations for 1995



POC, and 1.15 for TOC (Table 5). Concentrations of total organic carbon in the effluent ranged between 33.5 and 97.8 mg/L, similar to the 1994 range of 35 and 80 mg/L. In 1995, concentrations of dissolved and particulate organic carbon averaged 44 and 29 mg/L, respectively, compared to 1994 averages of 57 and 24 mg/L, respectively. Seasonally, the particulate organic carbon averaged 32.9 (21.1 in 1994) in the winter/spring periods and 26.9 mg/L (27.2 mg/L in 1994) in the summer/fall periods, while the dissolved organic carbon averaged 46.8 mg/L (25.6 mg/L in 1994) in the winter/spring periods and 42 mg/L (39.6 mg/L in 1994) in the summer/fall periods. For both POC and DOC, the winter/spring average was considerably higher. The dissolved component of the total organic carbon concentrations was generally higher than the particulate fraction.

Urea - Urea in the Deer Island primary effluent ranged from 3.2 to 43 µM. The 43 µM occurred in November, which should have shown a decrease if loads were consistent and flow increased (as in November). The range was only 3.2 to 11 µM if the November concentration was dropped. The average urea (all data) concentration was 8.5 µM. No seasonal trend was evident.

Nutrient Ratios - The overall 1995 TN/TP and DIN/PO_4 ratios were higher than the 1994 ratios, mainly due to lower PO_4 concentrations in 1995. A high total nutrient ratio (TN/TP) was obtained for the April samples, and high dissolved phase ratio (DIN/PO_4) was calculated in March and April. Lower values were obtained for the summer/fall period. The lowest ratios were for the October 1995 TN/TP samples and for the July DIN/PO_4 samples. The DIN/PO_4 ratio in March and April (180 and 321.0, respectively) was much higher than in 1994 (21.2 and 15.5, respectively) due to low PO_4 results (Table 4).

Seasonal Changes in Sources to the MWRA Collection System - The 1995 winter/spring flow is only 1.13 times that of the summer/fall flow. Thus if contaminant loads are relatively constant throughout the year, then the winter/spring concentrations would be lower than the summer/fall concentrations by a reciprocal amount 1/1.13 = 0.88. Table 5 shows that the seasonal behavior for Cu, total N as well as NH_3 can be explained mainly by the flow variation. The average winter/spring over summer/fall concentration ratios for Cu was 0.90, for total N was 0.88 and for NH_3 was 0.93. These were very close to 0.88.

3.1.5 *Clostridium perfringens*

Clostridium perfringens is a bacterium commonly associated with sewage wastes because it inhabits the intestines of human beings and other mammals. It is often used as a sewage tracer because each

TABLE 4

Molar ratio of total nitrogen (TN) to total phosphorous (TP) and dissolved inorganic nitrogen (DIN) to phosphate (PO_4) in the Deer Island primary effulent.

Month	TN/TP	DIN/PO_4
February 1995	13.5	32.7
March 1995	11.2	180.5
April 1995	30.6	321.0
May 1995	24.1	65.8
June 1995	26.2	81.9
July 1995	16.3	2.6
August 1995	16.7	76.3
September 1995	17.7	47.8
October 1995	6.2	73.6
November 1995	12.5	72.8
December 1995	17.7	74.6

Table 5

Comparison of ratio of the average winter/spring and summer/fall contaminant concentrations in the Deer Island effluents for 1995 to the ratio of effluent flow.

Compound	WS/SF	SF/WS
Flow (Sample collection)	1.12	0.90
PAH	1.44	0.69
PCB	0.59	1.71
LAB	1.41	0.71
Chlorodanes	1.02	0.98
Lindane	0.68	1.47
DDT's	0.75	1.34
Ag	1.39	0.72
Cd	1.04	0.96
Cu	0.90	1.11
Cr	4.53	0.22
Hg	0.65	1.55
Mo	0.69	1.45
Ni	1.21	0.83
Pb	0.81	1.23
Zn	1.02	0.98
Total N	0.88	1.13
Total dissolved N	0.85	1.17
NH_3	0.93	1.08
$NO_2 + NO_3$	0.27	3.65
Particulate organic N	1.11	0.90
Total P	0.64	1.57
Particulate P	1.21	0.83
Phosphate	0.71	1.41
Silicate	1.07	0.93
DOC	1.11	0.90
POC	1.25	0.80
TOC	1.15	0.87

cell produces a metabolically stable endospore that is resistant to most wastewater chlorination procedures and can survive in aquatic environments for long periods (Bisson and Cabelli, 1980; Davis and Olivieri, 1984; Hirata *et al.*, 1991).

Concentrations of *Clostridium perfringens* spores were measured in 18 Deer Island effluent samples collected between February and December 1995. Concentrations of *C. perfringens* spores in the Deer Island effluent appeared seasonal, exhibiting lows in the summer/fall period (2615/100ml average) compared to the winter/spring months (8045/100 ml average) (Figure 18). This seasonal pattern is identical to the 1994 data which showed high concentrations from January to April, then consistently lower concentrations from May to October, followed by a jump in concentration levels in November and December (Hunt et al., 1995). The concentrations, however, were 3 to 4 times larger in 1994 for the winter/spring months (22,500/100ml) and ~150 times larger for the summer/fall months (9800/100ml). One possible explanation is that in early summer 1995 a higher amount of chlorination was released into the treatment plant, causing a higher level of biological kill. This is consistent with the steep drop in concentrations found in May, with levels staying low until October. The decrease in 1995 may also be explained by improved performance of the new primary plant. The removal efficiency for settling is expected to vary with effluent temperature and flow.

3.1.6 Stable Isotopes

Nitrogen - The stable nitrogen isotope ratio in the 22 samples of Deer Island effluent collected between February and December 1995 ranged between -0.90 and 3.6‰, compared with 0 to 1.9‰ in 1994. Clear seasonal trends were not evident in the data (Figure 19). The average monthly value, 0.24‰, is only slightly higher than the $\delta^{15}N$ ratio for terrestrial materials, which is generally near 0‰, the ratio for atmospheric nitrogen (Peterson and Fry, 1987). Eight samples in 1995 exhibited negative results. The negative result is better understood when examining the equation used to derive the ratio. If:

a = the measured isotope ration of $^{15}N/^{14}N$ in the sample
b = the measured isotope ration of $^{15}N/^{14}N$ in the standard,

$$\delta^{15}N = ((a-b)/b) * 1,000$$

Figure 18
Temporal responses in Clostridium perfringens concentrations for 1995

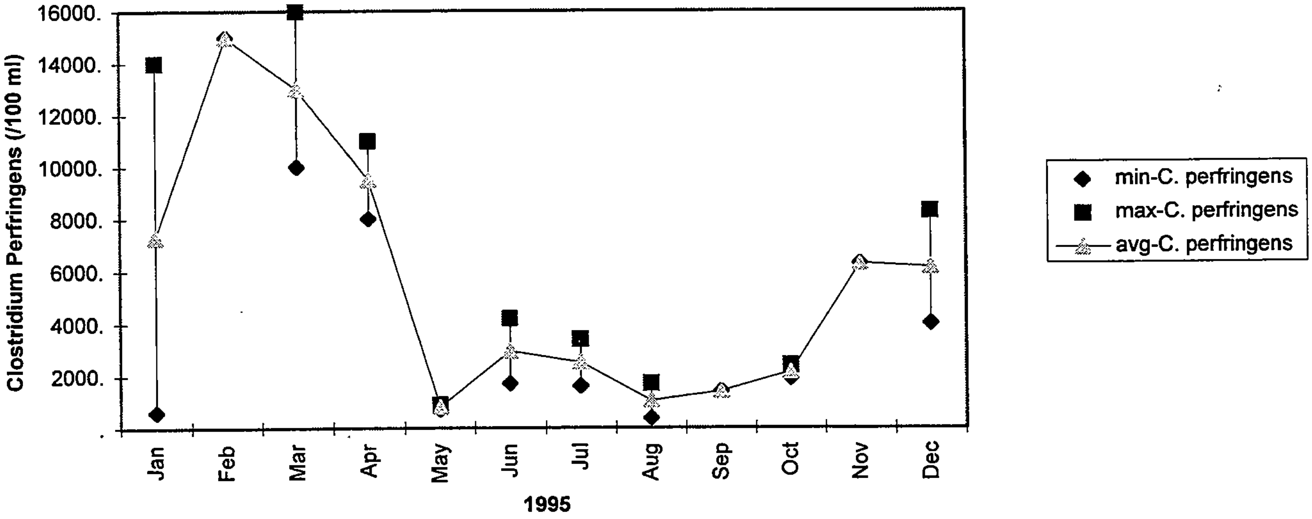
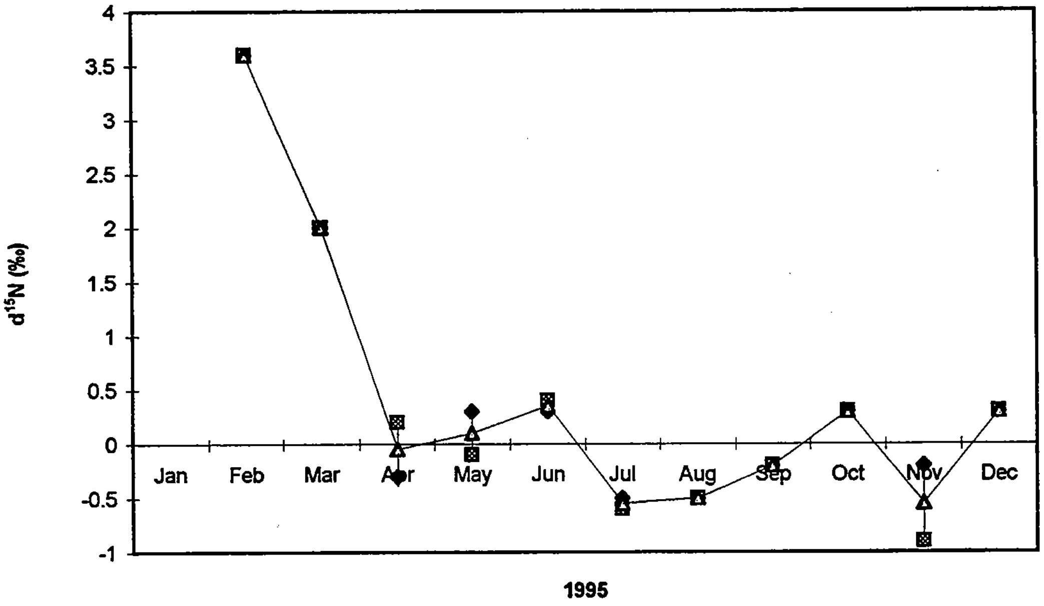
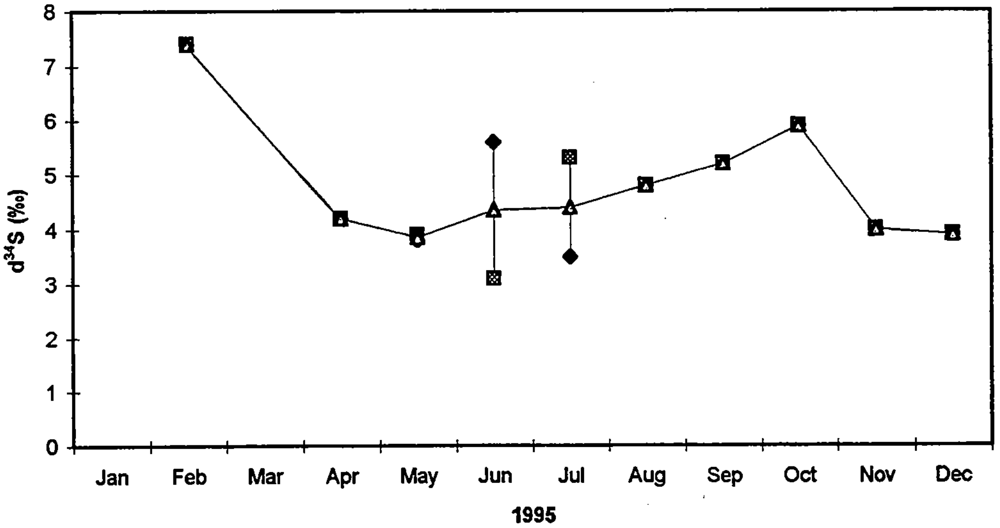


Figure 19
Temporal response in stable nitrogen isotope ratios for 1995



Temporal response in stable sulfur isotope ratios for 1995



The negative sample result indicates that the sample is ^{15}N deficient. However, the reason for so many negative results in 1995 versus 1994 (where the lowest value observed was 0/00 parts per thousand) is unclear, especially since the same laboratory and methods were used.

The nitrogen isotope ratios for 1995 Deer Island primary effluent samples were slightly less than those reported for particles in previous studies. In a previous study of effluent discharged off the coast of southern California (*e.g.* Sweeney *et al.*, 1980), nitrogen isotope ratios ranged from 2.0 to 3.0‰ and averaged 2.5‰. The nitrogen isotope ratio for the Deer Island effluent was approximately three times lower than a nitrogen isotope sludge sample ratio (3.3‰, Giblin *et al.*, 1992). The stable nitrogen isotope ratios for New York/New Jersey sludges sampled in 1991 ranged from 0.6 to 5.8‰ and averaged 3.4 ± 1.8‰ (Hunt *et al.*, 1993). Generally, it is expected that the nitrogen isotope ratios for primary treated sludge would be similar to the primary effluent ratio because of the lack of processes that can alter the ratios. Differences in treatment or regional signatures in the sewage source material may account for the lower effluent nitrogen isotope ratios as compared to sludge ratios in 1994 and 1995.

Sulfur - Of the 22 stable isotope samples collected from the Deer Island primary effluent in 1995, two (collected in March) had volume too small to provide useful data. Sulfur stable isotope ratios ranged from 3.1 to 7.4 ‰ (vs. 4.5 to 8.4‰ in 1994) and averaged 4.7‰ in 1995 (vs. 5.8‰ in 1994) (Figure 19). These values were consistent with the sulfur isotope ratios for terrestrial vegetation. The latter average between +2 and +6‰ and were distinct from ratios for marine plankton and algae which ranged between +17 and +21‰ (Peterson and Fry, 1987). As in 1994, the Deer Island primary effluent particles in 1995 remain slightly more enriched in $\delta^{34}S$ than in previous studies: southern California sludge particles measured in the early 1980s (four samples of primary treated sludge ranged between -0.2 and +0.1 [Sweeney and Kaplan, 1980]), and 1991 New York/New Jersey sludge samples in which sulfur stable isotope ratios ranged from 1.9 to 5.5‰, and averaged 3.2 ± 1.1‰ (Hunt *et al.*, 1993).

Because they are clearly separate from the marine ratios, the sulfur isotope ratios are a strong candidate for tracing the effluent discharge in Massachusetts Bay. The nitrogen isotope ratio is less attractive as a tracer of the effluent particles because it is subject to changes by primary productivity (Altabet, 1988) and, more significantly, to bacterial degradation processes (Saino and Hattori, 1980; 1985). However, the use of both N and S ratios provide useful information for tracing sewage effluent fate and it is recommended that both parameters be considered as potential tracers of the effluent particulate matter in sediments and organisms in Massachusetts Bay.

3.1.7 Contaminant Loading

In this section, estimates of contaminant and nutrient inputs to Massachusetts Bay are based on the 1995 Deer Island effluent data. Loading estimates for contaminants and nutrients, available from Alber and Chan (1994) and Shea (1993a), apply to the combined Deer and Nut Island effluent. To estimate the combined loading of Deer Island and Nut Island, the Deer Island loading estimates were multiplied by 1.5 (see Table 6, Footnote (1) for an explanation). The annual loading for selected organic contaminants from Deer Island and the combined discharge are presented in Table 6. These analytes (or analyte groups) were chosen according to their level of detection in the effluents. Total organic loadings for 1995 were all lower than 1993/4 except for individual compounds like benzo(a)pyrene and lindane). Total metal loadings for 1995 were all lower than 1993/4 except for Cr.

PAHs - The annual loading of total PAHs from Deer Island was calculated as 5915 Kg/year, slightly lower than the 1994 calculation of 6400 Kg/year. More than 63% (compared to 64% in 1994) of this loading was due to naphthalene and its alkyl homologues. Loading rates into Massachusetts Bay ranged from 107 Kg/month in December 1995 (sample collected on Dec. 13 considered an outlier and not used) to a high of 1533 Kg/month in April 1995. In June, petrogenic naphthalenes comprised 79% (vs. 74% in 1994) of the total PAHs. In February the contribution from petrogenic naphthalenes was 46%. Pyrene, a dominant pyrogenic PAH, contributed approximately 76 Kg/year. The highest loading rates occurred during April and November 1995. Benzo[a]pyrene loading was calculated at 17 Kg/year, compared to 15 Kg/year in 1994.

Pesticides and PCBs - The total annual DDT loading from Deer Island in 1995 was 3.7 Kg/year, considerably less than the 1994 calculation of 22 Kg/year. The parent compound, 4,4'-DDT, contributed 59% of the total loading in 1995, much more than the 1994 estimates of 18%. Total chlordane and lindane loadings were 2.1 and 5.3 Kg/year, respectively, for 1995 (compared to 4.6 and 4.9 Kg/year, respectively, for 1994). The heaviest loadings, however, were at different times of the year. Chlordane loading was highest in March and November, while lindane contributions were greatest in July. Dieldrin was not detected in any 1995 sample. The loading for PCBs was 17 Kg/year in both 1994 and 1995.

Trace Metals - The input of metals associated with the Deer Island effluent in 1995 is summarized in Table 7. Concentrations of all nine metals were measured quantitatively in each sample and were found to be well above the method detection limits. Therefore, the loading estimates were not biased

Table 6
Comparison of 1995 organic contaminant loading (kg/yr) from Deer Island to previous studies

	Deer Island				Deer Island Plus Nut Island [1]			
Organic Contaminant	**1995 This Study**	**1994 Battelle Study**	**1993 Uhler et al. (1994)**	**1993 Alber and Chan (1994)**	**1995 This Study**	**1994 Battelle Study**	**1993 Alber and Chan (1994)**	**1993 Shea (1993a)**
Total PAH [3]	5,915	7,270	5,414	NA	8,873	10,900	NA	4,700
Total Naphthalenes	3,694	4,080	3,692	NA [2]	5,541	6,100	NA	NA
Pyrene	76	78		49	114	117	59	NA
Benzo(a)pyrene	17	15	8	4	26	23	6.3	NA
Total LAB [4]	3402	5,340	NA	NA	5,103	8,000	NA	NA
Total DDT	3.7	21.6	NA	NA	5.6	32	NA	NA
4',4'-DDT	2.2	4.0	2.0	NA	3.3	6	NA	NA
Total Chlordane	2.1	4.6	NA	NA	3.1	7	NA	NA
Lindane	5.3	4.9	4	NA	7.9	7	NA	NA
Dieldrin	ND	0.77	NA	NA	ND	1.2	NA	NA
Total PCB [5]	17	17	18	NA	25	26	NA	36

[1] Estimated by assuming the contamminant concentrations in the Nut Island effluent are the same as the Deer Island effluent and flow proportioning the loading based on the December 1993 to November 1994 flows (Deer Island 253; Nut Island 128 MGD), Deer Island loading estimate was multiplied by 1.5 to get the loading from both treatment plants.

[2] 2-methylnaphthalene estimated at 1,473 Kg/yr.

[3] Sample E95C5AA had a matrix interferant. For samples E95F1AA and E95F5AA, the calibration level was exceeded. For E95J1AA, analytical concentration reported from standard.

[4] Samples E95A1AA, E95A2AA, E95B1AA and E95B2AA had an interferant from standard in at least one compound.

[5] All January, February, June, July and November samples contained at least one compound with a matrix interferant.

Table 7

Comparison of 1995 metals contaminant loading (kg/yr) from Deer Island to previous studies

	Deer Island				Deer Island Plus Nut Island [1]			
Metals Contaminant	**1995 This Study**	**1994 Battelle Study**	**1993 Uhler et al. (1994)**	**1993 Alber and Chan (1994)**	**1995 This Study**	**1994 Battelle Study**	**1993 Alber and Chan (1994)**	**1993 Shea (1993a)**
Ag	1,286	1,730	1,129	NA	1,929	2,600	NA	2,030
Cd	170	250	150	NA	255	370	NA	430
Cr	5,241	1,420	931	NA	7,861	2,100	NA	2,450
Cu	20,685	25,456	19,626	21,500	31,028	38,200	3,140	30,780
Hg	33	51	42	164	50	75	215	140
Mo	4,521	4,875	1,642	NA	6,782	7,300	NA	NA
Ni	2,052	2,220	1,642.0	NA	3,079	3,300	NA	4,800
Pb	3,839	3,900	3,198	4,320	5,758	6,000	6,100	5,670
Zn	24,944	29,610	23,645	31,460	37,415	44,400	43,800	37,630

[1] Estimated by assuming the contamminant concentrations in the Nut Island effluent are the same as the Deer Island effluent and flow proportioning the loading based on the December 1993 to November 1994 flows (Deer Island 253; Nut Island 128 MGD), Deer Island loading estimate was multiplied by 1.5 to get the loading from both treatment plants.

by nondetectable results and are considered to be an accurate representation of the actual metals loading.

In 1995, the input of metals from Deer Island to Massachusetts Bay ranged from 24,944 Kg/year for Zn to 33 Kg/year for Hg (vs. 29,610 Kg/year for Zn to 51 Kg/year for Hg in 1994). Estimated 1995 inputs of Cu, Pb, and Zn from Deer Island are in reasonable agreement with those developed by Alber and Chan (1994) for 1993 and Hunt *et al.* (1995) for 1994

The monthly loading rate results (see the appendix for graphs) indicate that seasonal changes in flow rates affected the loading rates. For example, monthly Zn loading over the sampling period paralleled the effluent flow rate; the highest loading occurred in the winter/spring. Most of the other metals (Ag, Cd, Cr, Hg, Ni, Pb) behaved similarly.

In contrast to the loading of these metals, Mo loading rates were lower in the spring when flows were highest (~300 Kg/month from December through April and ~450 Kg/month through November). Mo concentrations were lowest in December. This probably reflects the seasonal use of Mo in cooling towers.

Little seasonal influence on the loading of Cu was observed. Over the 12-month study period in 1995, Cu loading was consistently around 1725 Kg/month. The major source of Cu is from corrosion of copper plumbing in the service area.

Estimates of the total effluent output of Cd, Ag, Cu, Zn and Pb from the Deer Island and Nut Island treatment facilities were similar to those reported by Shea (1993a) and Hunt *et.al.* (1995). However, Cr was three times the 1993 Shea estimate, due to spikes in the January and February data points. Hg and Ni levels were lower than those reported by Shea. Reasonably good agreement was found for two (Pb and Zn) of the four metals common to Alber and Chan's study. The Cu loadings were higher in 1995, while Hg loading was about four times lower than the Alber and Chan (1994) data.

Nutrients - Nutrients contributed the largest mass loading to Massachusetts Bay from the sewage treatment plants. Unlike toxic contaminant loadings on the order of Kg/year, nutrients were loaded to the system in hundreds to thousands of metric tons (mtons/year) (Table 8). In 1995, total organic carbon constituted the largest loading of eutrophication-related nutrients from the Deer Island treatment plant (23,500 mtons/year vs. 18,300 mtons/year in 1994). Fifty-nine percent was contributed as dissolved organic carbon. The loading of other nutrient forms from Deer Island ranged from

Table 8

Comparison of 1995 nutrient loading (metric tons/yr) from Deer Island to previous studies

	Deer Island			Deer Island Plus Nut Island [1]		
Nutrient Form	**1995 This Study**	**1994 Battelle Study**	**1993 Alber and Chan (1994)**	**1995 This Study**	**1994 Battelle Study**	**1993 Alber and Chan (1994)**
Ammonia	4,483	3,710	4,430	6,725	5,570	6,240
Nitrite	9	21	53	13	32	95
Nitrate	75	125	274	113	190	425
Particulate Nitrogen	944	92	NA	1,416	140	NA
Total Dissolved Nitrogen	5,725	4,560	NA	8,587	6,840	NA
Total Nitrogen	6,669	5,480	8,760 (2)	10,003	8,220	11,470
Phosphate	157	539	806	236	810	953
Particulate Phosphorous	228.3	195.0	NA	343	290	NA
Total Dissolved Phosphorous	755.4	632.0	NA	1,133	950	NA
Total Phosphorous	984	823	1,450	1,476	1,230.0	1,870
Dissolved Silicate	3,392	1,500	NA	5,087	2,250	NA
Biogenic Silicate	209	66	NA	313	100	NA
Particulate Organic Carbon	9,355	7,910	NA	14,033	11,900	NA
Dissolved Organic Carbon	13,856	10,300	NA	20,784	15,500	NA
Total Organic Carbon	23,501	18,300	NA	35,251	27,500	NA

[1] Estimated by assuming the contamminant concentrations in the Nut Island effluent are the same as the Deer Island effluent and flow proportioning the loading based on the December 1993 to November 1994 flows (Deer Island 253; Nut Island 128 MGD), Deer Island loading estimate was multiplied by 1.5 to get the loading from both treatment plants.

[2] As total Keldjhal nitrogen

approximately 9 mtons/year for nitrite to 6669 mtons of total nitrogen/year. Ammonia contributed the largest fraction (69%) of the total nitrogen discharged from this treatment plant. Total phosphorus (77% as total dissolved phosphorus) was added at 984 mtons/year. About 3600 mtons/year of silica (94% dissolved) was discharged from Deer Island.

The 1995 Deer Island nutrient loading estimates were generally lower than the values estimated by Alber and Chan (1994) but higher than the 1994 values presented by Hunt *et al.* (1995). The 1995 total nitrogen loading was approximately 76% while nitrite was approximately 17% of the 1993 estimates. Total nitrogen loading was 122% of the 1994 data, while nitrite was 60%. Total phosphorus and phosphate loadings were about 68% and 19%, respectively, in 1993, and 120% and 29%, respectively, for 1994.

Dissolved organic carbon concentrations showed no clear seasonal loading trends. It appears that TOC declined steadily from February to July, slightly increased over the summer/early fall, and then leveled out. Likewise, no seasonal patterns were seen in total dissolved nitrogen, ammonia, total nitrogen, or dissolved Si. Biogenic Si showed signs of seasonality, with summer concentrations less than during the rest of the year. Total dissolved nitrogen, nitrate, and nitrite were highly variable. Total dissolved phosphorus and phosphate loadings generally increased in the summer compared to early in the year.

Loading Summary - Generally, 1995 loading estimates for organics and metals were lower than for 1994 and slightly higher than for 1993, although the Hg input was decidedly lower in 1995. Nutrient loading appeared to be lower in 1995 than 1993, but higher than 1994 except for phosphate. However, differences in the various estimation methods preclude drawing specific conclusions. Seasonal loading of some organic and metal contaminants was apparent; the winter/spring high flow periods carried more contaminants than reduced flows in the summer and fall. The opposite pattern was seen for certain pesticides (*e.g.* high lindane loading in the summer) and Mo. Their loadings were generally higher in the low summer flow.

Nutrient loading appeared relatively constant, although Si loading decreased in the summer. The only noticeable difference in loadings between 1995 and 1994 was for PO_4. In 1995, the calculated PO_4 annual loading was 157 mtons/year, considerably below the 1994 calculation of 539 mtons/year (Hunt *et al.*, 1995).

3.1.8 Comparison to Water Quality Criteria

This section compares the effluent data to existing EPA aquatic life criteria. The marine acute and chronic aquatic life criteria, the mean Deer Island effluent concentration over the 1995 sampling period, and the occasions when effluent concentrations were higher than either water quality criteria (assuming zero dilution) are shown in Tables 9 (organics) and 10 (metals).

Trace Organics Compounds - None of the organic compounds in the 21 undiluted effluent samples analyzed in 1995 exceeded acute aquatic life water quality criteria (Table 9). However, contaminant concentrations in the effluent were higher than the chronic aquatic life criteria for p,p' - DDT and heptachlor on one or more occasions. Of the toxic organic compounds, the p,p' - DDT chronic criterion was exceeded most often (17 of 20 samples in 1995 versus 34 of 35 samples in 1994). The average effluent concentration of p,p' - DDT was about seven times the chronic criterion. Heptachlor occasionally exceeded the chronic criterion (5 of 20 samples), but the annual average, 2.5 ng/L, was below the chronic criterion.

Trace Metals - Hg concentrations in undiluted effluent exceeded the marine chronic water quality criterion in all 23 samples, with Hg concentrations approximately four times higher. The Pb concentrations in undiluted effluent generally were higher (by 74%) than marine chronic water quality criterion for many 1995 samples (15 of 23) (Table 10). Zn concentrations were higher than the criterion in 4 of 23 samples, although the mean effluent Zn concentration (74.9 µg/L) was lower than the chronic criterion (86 µg/L).

Cu concentrations exceeded the marine acute aquatic life criterion in all 23 samples; the mean effluent concentration of Cu (64.2 µg/L) was 22 times higher than the criterion. The Ag concentrations in the effluent exceeded the acute aquatic life criterion in 20 out of the 23 samples, although the mean effluent concentrations were only a factor of two higher than the criterion. Finally, Zn concentrations were higher than the acute criterion in 3 of the 23 sampling events. All other metals were below the acute criterion in the effluent samples.

Summary Remarks on the Aquatic Life Criteria - Some metal and organic contaminants in Deer Island effluent were occasionally found at concentrations higher than established acute and/or chronic aquatic life criteria. Of the metals, Cu effluent concentrations showed the greatest divergence (a factor of about 22 higher) from the aquatic life criterion. Of the organic compounds, p,p'- DDT exceeded

Table 9

Organic contaminant EPA aquatic life criteria (ng/L) and number of occurrences where samples exceeded criteria in undiluted effluent.

Parameter	Marine * Acute Criteria	Marine * Chronic Criteria	Mean Effluent Concentration	Number(1) of Exceedances of Marine Acute	Number (1) of Exceedances of Marine Chronic
Pesticides					
Aldrin	1,300	NC	ND	0	NC
p,p'-DDT	130	1	7.0	0	17
Dieldrin	710	1.9	ND	0	0
Endrin	37	2.3	ND	0	0
Heptachlor	53	3.6	2.5	0	5
Heptachlor Epoxide	53	3.6	ND	0	0
Lindane	160	NC	17.5	0	NC
PAH					
Acenaphthene	970	710	93	0	0
Fluoranthene	40,000	16,000	232	0	0
Naphthalene	2,350,000	NC	1,569	0	NC
Total PAH	300,000	NC	16,887	0	NC

(1) Number of exceedances out of 20 samples.

NC = No established criterion.

* From Battelle , March 1995.

Table 10

Metals EPA aquatic life criteria (ug/L) and number of occurrences where samples exceeded criteria in undiluted effluent.

Parameter	Marine Acute Criteria	Marine Chronic Criteria	Mean Effluent Concentration	Number(1) of Exceedances of Marine Acute	Number(1) of Exceedances of Marine Chronic
Silver	2.3	NC	3.95	20	NC
Cadmium	43	9.3	0.54	0	0
Chromium	1,100	50	15.56	0	2
Copper	2.9	NC	64.2	23	NC
Mercury	2.1	0.025	0.1	0	23
Nickel	75	8.3	6.28	0	2
Lead	220	8.5	11.46	0	15
Zinc	95	86	74.9	3	4

(1) Number of exceedances out of 23 samples.
NC = No established criterion.

the chronic aquatic life criterion by a factor of 7. The other metals and organic contaminants either met the criteria or had minor criteria exceedances.

When considering environmental impacts, the important issue is not contaminant concentrations in the undiluted effluent. Rather, aquatic life criteria should be measured against concentrations in the receiving environment only after dilution with receiving water. Assuming that metal and organic contaminant concentrations in the effluent remain essentially constant, the expected 50- to 100-fold dilution of the effluent within a few tens to hundreds of meters of the diffuser (Shea, 1993a) will ensure dilution of all metals and organic contaminants to concentrations below established acute or chronic aquatic life criteria. Consequently, in terms of the aquatic life criteria, these contaminants will pose little threat to organisms in the receiving waters. Also, as described in Uhler *et al.* (1994), many effluent contaminants may be expected to behave in a nonconservative manner (due to volatilization and settling) as the effluent mixes with seawater. This behavior further reduces contaminant concentrations in receiving waters. Once the outfall diffuser is operational, dilution and chemical-physical transformation of biologically available forms of metals and organics will bring contaminant concentrations well below any applicable aquatic life criteria.

Comparisons between effluent concentrations and marine aquatic life criteria presented in this section were based on the current level of primary treatment and contaminant concentrations in the discharge. Continuation of source-point reduction, improvements to the primary treatment plant, and start up of secondary treatment will result in further reductions in toxic effluent concentrations. The result will be lower contaminant loadings to the system and reduced potential for exceeding applicable aquatic life criteria. The following section discusses the potential for secondary treatment to reduce existing inputs of metals, organic contaminants, and nutrients.

3.2 Pilot Treatment Plant

The Pilot Treatment Plant study in 1993/4 was limited to only 5 sampling episodes. The efficacy of Chemically Enhanced Primary Treatment (CEPT) was tested against primary treatment in December of 1993. Primary treatment versus secondary biological treatment was tested 4 times, twice in June and twice in July of 1994. 10 sampling episodes were included in this study from January to December of 1995. Only February and April were not sampled, and sampling of nutrients did not take place in March.

3.2.1 Trace/Toxic Organic Contaminants

The concentrations of organic contaminants (total PAH, total PCB, total chlordane, total DDT, lindane, and total LAB) in the influent and primary effluent of the pilot treatment plant sampling events were generally similar (Table 11). The implication was that little removal of organic contaminants occurred during primary treatment. Some compounds were more effectively removed by the treatment plant than others. In several cases, effluent concentrations were higher than the influent concentrations. Analytical variability associated with the laboratory measurements is a possible cause. The concentrations in the samples were usually very low, and measurement variability can be high for low-level organic contaminant analysis. Another possible cause is the use of grab sampling, i.e. the samples analyzed did not come from the same parcel of water. Also, both the pilot plant and the new primary plant were operated under severe conditions in January (start-up), and may have induced recirculation, adding complications to obtaining a representative sample. Increases in contaminant concentrations during the treatment process should not occur because contaminants are not added during the standard secondary treatment processes.

In general, organic compounds with a strong tendency to adsorb on organic particles may be removed to some degree during primary settling. Volatile compounds, compounds susceptible to microbiological degradation as well as adsorption to particulates are more efficiently removed in secondary biological treatment. The average removal efficiencies during primary treatment observed in this study varied from negative (lindane and total LAB), to low (total PAH with a 5% removal efficiency), to medium (total PCB, total chlordane and total DDT removed at efficiencies of 16, 20 and 26% respectively). The average removal efficiencies during secondary biological treatment were all higher than that of primary treatment. The lowest removal was for lindane at 40% and can be as high as 93% for total PAH. There was no obvious seasonal trend with the removal efficiencies except for lower removals in January and March, chlordane and LABs also seemed to have lower removals in June and July.

The following discussion will focus on the effects of secondary biological treatment:

High variability was observed in the total PAH concentration in the influent, ranging from 10,019 to 66,201 ng/L. Secondary biological treatment consistently removed up to 99% of the total PAH (annual average of 93% removal). The lowest observed removal efficiencies were in January and March (64 and 83%). Secondary treatment will significantly reduce PAH loading to Massachusetts Bay.

Table 11

Removal efficiency of organic contaminants during the pilot treatment plant studies. Concentration units are in ng/L; efficiencies are in percent.

Event Date	Data Type	Analytical results and removal efficiencies					
		PAH[1]	PCB[3]	Chlordanes	DDTs	Lindane	LAB[2]
1/25/95	Influent	2653.5	21.26	12.6	0	4.4	1860
	1° Effluent	5995.6	59.37	0	0	14	6460
	2° Effluent	960	51.36	1.3	3.4	4.4	1390
	1° Efficiency (%)	-126	-179	100	CC	-218	-247
	2° Efficiency (%)	64	-142	90	CC	0	25
	2 vs 1	84	13	CC	CC	69	78
3/1/95	Influent	19639	27.3	15.7	14.3	0	7800
	1° Effluent	17360	14.9	16.2	10	0	7900
	2° Effluent	3250	12.1	5.7	0	3.3	2020
	1° Efficiency (%)	12	45	-3	30	CC	-1
	2° Efficiency (%)	83	56	64	100	CC	74
	2 vs 1	81	19	65	100	CC	74
5/10/95	Influent	37343	45.89	1.5	8.79	4.3	14660
	1° Effluent	29731.8	15.35	2.7	8.7	4	14090
	2° Effluent	315.71	0.88	0	0	5	890
	1° Efficiency (%)	20	67	-80	1	7	4
	2° Efficiency (%)	99	98	100	100	-16	94
	2 vs 1	99	94	100	100	-25	94
6/14/95	Influent	66491	132.22785	7.47	54.68	29	8740
	1° Effluent	46372.4	97.848101	5.95	24.05	24	7820
	2° Effluent	412.3	5.8333333	2.69	0.67	12	2696
	1° Efficiency (%)	30	26	20	56	17	11
	2° Efficiency (%)	99	96	64	99	59	69
	2 vs 1	99	94	55	97	50	66
7/12/95	Influent	10075	280.44	12.3	12.9	51	9580
	1° Effluent	11316.6	293.9	6.2	11.8	41	11880
	2° Effluent	203.5	15.9	0	1.99	11	730
	1° Efficiency (%)	-12	-5	50	9	20	-24
	2° Efficiency (%)	98	94	100	85	78	92
	2 vs 1	98	95	100	83	73	94
8/16/95	Influent	12693	25.9	2.7	16.6	17	12850
	1° Effluent	8565.3	11.4	1.8	12.8	17	8560
	2° Effluent	245	0.63	0	0	7.1	670
	1° Efficiency (%)	33	56	33	23	0	33
	2° Efficiency (%)	98	98	100	100	58	95
	2 vs 1	97	94	100	100	58	92

Event Date	Data Type	Analytical results and removal efficiencies					
		PAH[1]	PCB[3]	Chlordanes	DDTs	Lindane	LAB[2]
9/13/95	Influent	18267	25.79	10.3	23.7	24	11100
	1° Effluent	12063.8	21.1	8.1	17.5	18	8800
	2° Effluent	58.8	1.3	0	0	8.7	720
	1° Efficiency (%)	34	18	21	26	25	21
	2° Efficiency (%)	100	95	100	100	64	94
	2 vs 1	100	94	100	100	52	92
10/12/95	Influent	11819.9	14.07	1.9	4.3	11	10150
	1° Effluent	10335.5	5.88	1.7	3.1	9.5	8170
	2° Effluent	372.9	6.82	0	0	3.8	710
	1° Efficiency (%)	13	58	11	28	14	20
	2° Efficiency (%)	97	52	100	100	65	93
	2 vs 1	96	-16	100	100	60	91
11/15/95	Influent	13326	68.58	6.8	11.3	6.4	16274
	1° Effluent	10376	39.39	5.1	6	9.9	6240
	2° Effluent	151.6	4.2	0	0	5.7	1270
	1° Efficiency (%)	22	43	25	47	-55	62
	2° Efficiency (%)	99	94	100	100	11	92
	2 vs 1	99	89	100	100	42	80
12/13/95	Influent	5234.4	28.3	4	7.6	11	10240
	1° Effluent	4143.2	19.42	3.2	6.6	10	8780
	2° Effluent	124.7	5.4	0	0	6.2	1220
	1° Efficiency (%)	21	31	20	13	9	14
	2° Efficiency (%)	98	81	100	100	44	88
	2 vs 1	97	72	100	100	38	86
Average (%) 2 vs 1		95	65	85	91	46	98

CC = Cannot calculate (cannot divide by 0)

(1) Influent and 1° effluent samples taken on 6/14/95 contained at least one compound whose concentration exceeded calibration levels.

(2) All samples taken on 1/25/95 and 2° effluent taken 3/1/95 contained at least one compound which had an interferant from standard.

(3) 1° and 2° effluent samples taken 1/25/96 and influent and 1° effluent taken 6/14/95 and 7/12/95 contained at least one compound with a matrix interferant.

The chlordane and DDT pesticides were also efficiently removed by secondary treatment with annual average efficiencies of 92 and 98%, respectively. Removal for chlordane seemed to be lower in June and July. The removal for DDT was more consistent in 1995, with only a low of 85% in July. Secondary treatment was almost four times more efficient than primary treatment in the removal of DDT from the effluent.

In contrast, lindane removal is non-existent by primary treatment (average of -20%) and is only moderately removed by secondary treatment (40% annual average). Lindane in the influent was both low and highly variable from 0 to 41 ng/L.

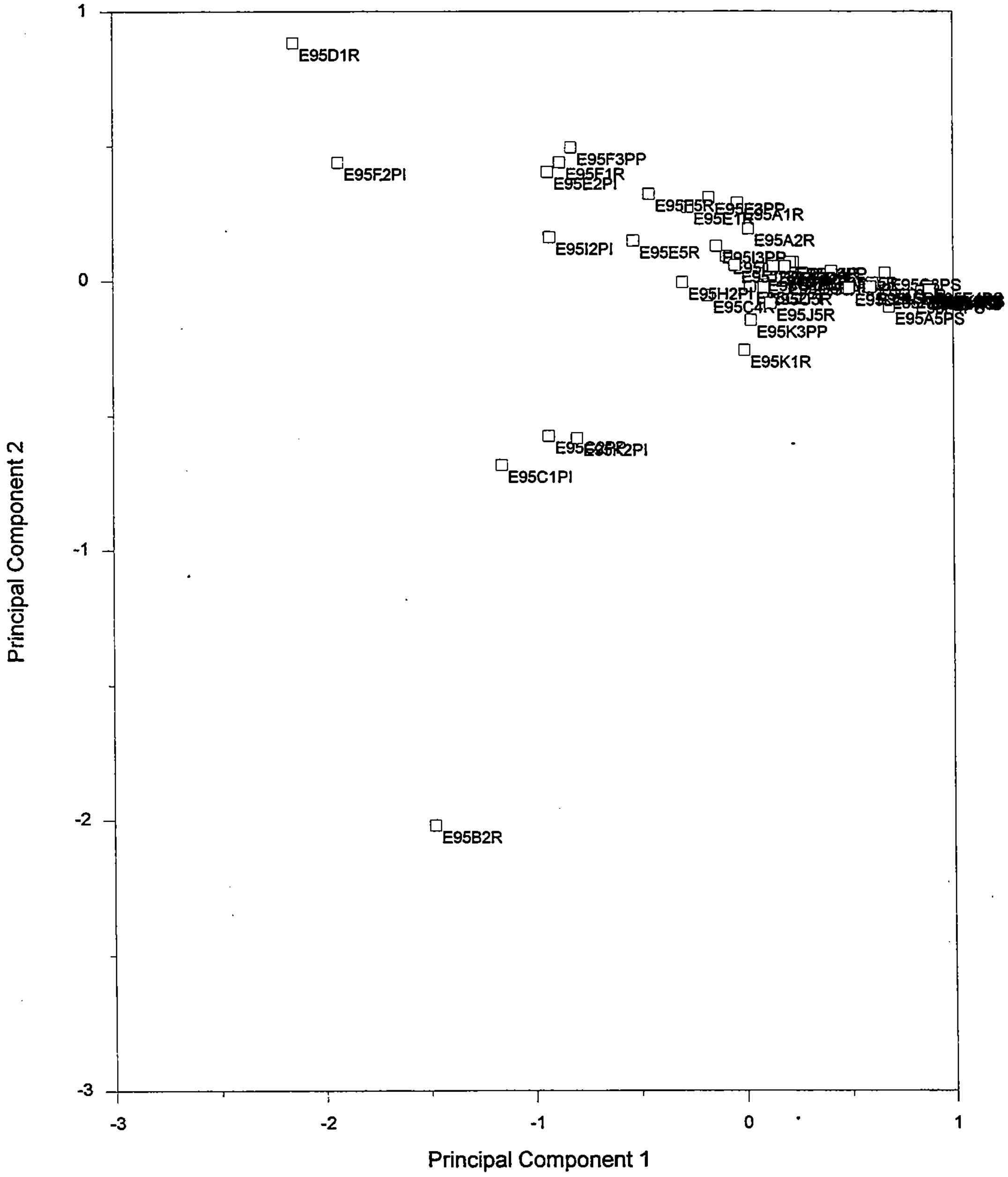
The annual average removal for total PCB was 62%. This value was greatly skewed by the January removal efficiency of -142%. The recalculated annual removal by secondary treatment without this apparent outlier was 72% for total PCB.

LAB concentrations in the influent to the pilot treatment plant ranged from 7800 (the Jan sample is considered to be an outlier) to 16,274 ng/L. LAB removal by secondary treatment was effective (82% annual average), especially when compared to the removal efficiency of primary treatment (-11%). As suggested for PAHs, data from this limited set of tests suggest that secondary treatment will substantially decrease the LAB loading to Massachusetts Bay.

PAH and LAB Principal Component Analysis - Samples from the pilot treatment plant, including influent (samples ending in PI), primary (samples ending in PP) and secondary (samples ending in PS) effluents were subjected to PCA to determine if the level of sewage treatment affected the PAH and LAB analyte distributions, and to determine if a different source signal may be expected when the secondary treatment plant becomes operational. Included in this comparison were the results from the Deer Island primary treated effluents (samples ending in R) sampled in 1995.

Comparison of the two treatment plants appears inconclusive since most of the samples were clustered together. Samples outside of the cluster were mostly influent from the primary treatment plant and effluent from Deer Island. Almost all of the 1° and 2° effluent samples were inside the tight cluster (Figure 20). This indicates that secondary treatment did not substantially alter the signature of the 1° effluent. However, the PAH distributions from the influent may have been changed by 1° treatment, since some of the outliers in Figure 20 were influent samples. The 1994 data suggested that the 1° treatment did not alter the influent, but that secondary treatment did. But the 1994 pilot treatment data were limited to June and July only.

FIGURE 20: Principal Components Analysis of PAH distributions



PCA analysis of the LAB data generally did not identify a distinct separation of pilot treatment plant influent from primary effluent from the Deer Island effluent. The pilot plant influent samples also generally fell within the grouping observed for the Deer Island primary effluent. The influent and primary effluent from the pilot treatment plant were generally grouped together with Deer Island effluent, while secondary effluent samples were grouped together. This indicates that secondary treatment might change LAB distributions (Figure 21).

The results of the 1995 pilot plant tests verify the 1994 findings that suggested that the secondary treatment process will likely alter the LAB but maybe not PAH source characteristics for current primary discharges and, by extension, past sludge discharges. If validation continues in future tests, the altered source characteristics could be used to trace the MWRA post-secondary treatment inputs to Massachusetts Bay. Such changes, if not properly characterized, could confound future data interpretation of chemical input to the sediments and the historical signatures recorded by the sediments. The evaluations should be continued until an adequate database is developed to describe variability across seasons and operational conditions.

Comparison to Water Quality Criteria and Receiving Water Concentrations - Table 12 compares organic contaminant concentrations in the pilot treatment plant primary effluent to the 1995 Deer Island effluent results, the ambient water column concentrations in Massachusetts Bay, and the EPA human health criteria. The pilot plant primary effluent concentrations are generally within the range of values measured in 1995 in the Deer Island primary effluent.

Considering the high expected dilution from the diffuser, the secondary treatment data suggest that effluent concentrations will be diluted to ambient levels in the immediate vicinity of the outfall. The compound that is of some concern is the PCBs. Human health criteria is based on aroclor analysis and risk assessment. This program analyzed for total PCBs and total PCB is not equivalent to aroclor analysis. The comparability of the two remains an issue to be worked out amongst the regulatory agencies.

3.2.2 Trace Metals

Trace metal concentration sample results from the pilot plant tests were relatively consistent (Table 13). Results suggest that the secondary treatment process achieves high removal efficiencies (>75% from the influent) for Ag, Cu, and Pb. Sample bottle identifications for July were likely in error, so they are not used in this analysis. Were the July samples included, the primary and

FIGURE 21: Principal Components Analysis of LAB distributions

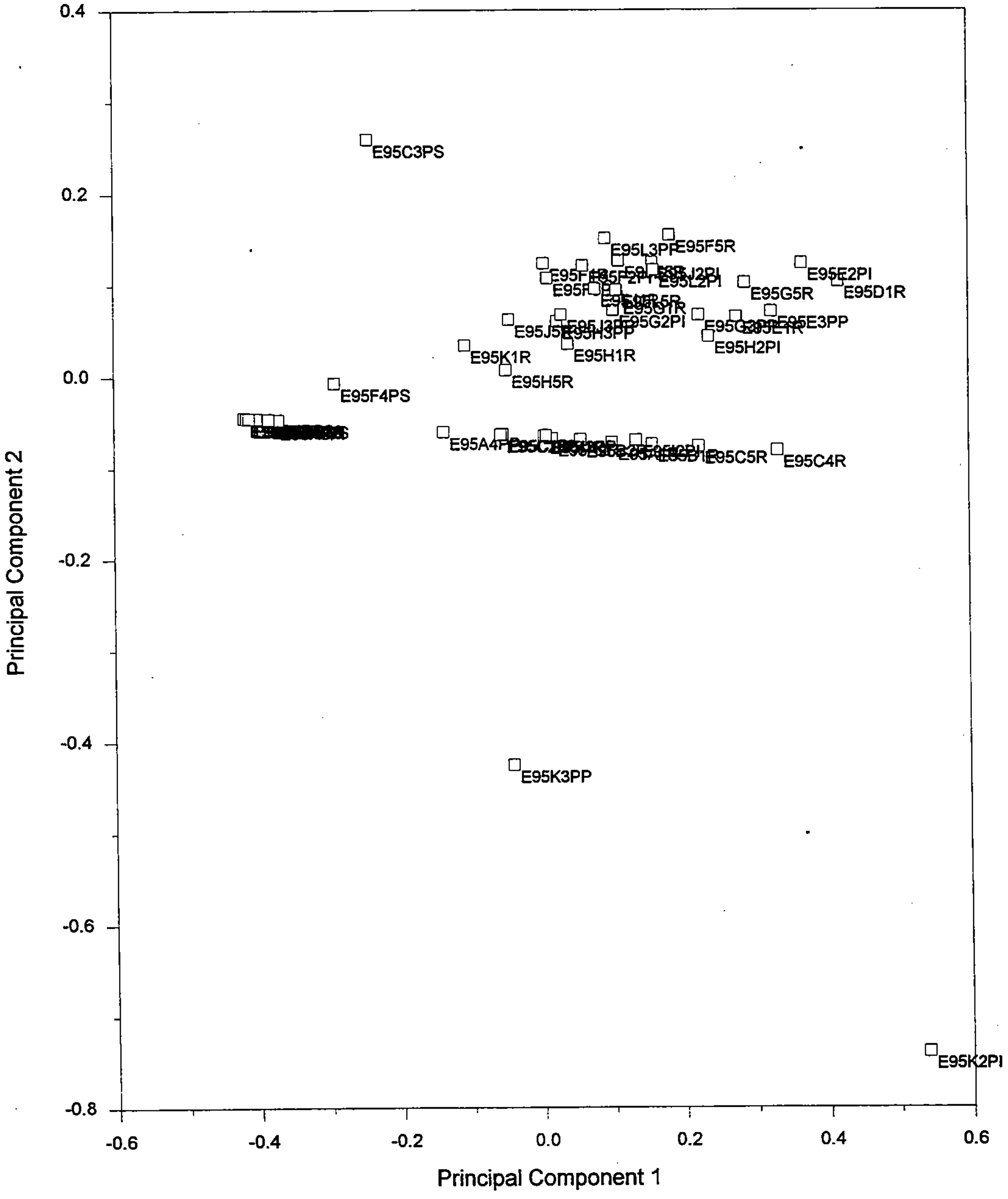


Table 12

Comparison of organic compound concentrations in the Pilot Treatment Plant effluent with concentrations measured in the Deer Island effluent in 1995, ambient concentrations in Massachusetts Bay near the future outfall, and human health criteria.

Element	1995 Deer Island Concentration Range (ng/L)	Pilot Plant Effluent Concentration (ng/L) 1°	2°	Ambient Water Concentrations in Massachusetts Bay near the future outfall (ng/L)[1]	Human Health Criteria (ng/L)
PAH	4,204 - 54,932	4,143 - 46,372	59 - 3250	6.5	a
PCB	7 - 255	6 - 293	1 - 51	0.27	b
Chlordanes	0 - 18	0 - 16	0 - 6	0.028	0.59
DDTs	3 - 31	0 - 24	0 - 3	0.053	2.02, c
Lindane	4 - 57	0 - 41	3 - 12	0.062	63
LAB	6,120 - 16,540	6,240 - 14,090	670 - 2,696	NA	d
Endrin	ND	ND	ND	< 0.0002	810

[1] Shea (1996) under review to be published

a. No established criteria for Total PAH, fluoranthene = 42,000 ng/L

b. Human Health Criteria for PCB based on Aroclor analysis = 0.045 ng/L. Not directly comparable to the total PCBs analysed in this study

c. Sum of the three 4,4'-DDT, DDE, and DDD compounds

d. No established criteria

Table 13

Removal efficiency of metals during the pilot treatment plant studies. Concentration units are in ug/L; efficiencies are in percent.

Event Date	Data Type	Analytical results and removal efficiencies								
		Ag	Cd	Cu	Cr	Hg	Mo	Ni	Pb	Zn
1/25/95	Influent	4.16	0.39	54.7	3.98	0.045	12.20	5.24	6.82	69.4
	1° Effluent	3.37	0.29	47.2	3.12	0.044	10.70	4.79	5.74	61.5
	2° Effluent	1.30	0.13	21.1	1.38	0.017	9.58	4.18	3.27	38.8
	1° Efficiency (%)	19	26	14	22	2	12	9	16	11
	2° Efficiency (%)	69	67	61	65	62	21	20	52	44
	2 vs 1	61	55	55	56	61	10	13	43	37
3/1/95	Influent	4.77	1.30	86.5	29.70	0.074	8.87	11.30	45.80	181.0
	1° Effluent	3.36	0.82	69.0	5.29	0.098	7.69	10.00	31.80	128.0
	2° Effluent	0.57	0.27	18.5	1.56	0.010	7.10	7.17	2.36	58.4
	1° Efficiency (%)	30	37	20	82	CC	13	12	31	29
	2° Efficiency (%)	88	79	79	95	CC	20	37	95	68
	2 vs 1	83	67	73	71	CC	8	28	93	54
5/10/95	Influent	6.95	0.44	77.6	6.39	0.080	20.22	5.12	16.71	99.2
	1° Effluent	5.86	0.36	63.8	5.84	0.087	20.34	4.85	11.26	79.2
	2° Effluent	0.37	0.13	16.1	2.70	0.060	12.72	3.30	0.81	26.8
	1° Efficiency (%)	16	19	18	9	-9	-1	5	33	20
	2° Efficiency (%)	95	70	79	58	25	37	36	95	73
	2 vs 1	94	63	75	54	31	37	32	93	66
6/14/95	Influent	2.42	0.44	74.2	7.62	0.084	14.64	5.08	25.34	109.1
	1° Effluent	4.64	0.37	61.6	7.46	0.072	18.83	4.43	14.62	80.2
	2° Effluent	1.29	0.20	21.6	11.79	0.071	16.15	4.35	3.66	50.9
	1° Efficiency (%)	-91	15	17	2	14	-29	13	42	26
	2° Efficiency (%)	47	54	71	-55	15	-10	14	86	53
	2 vs 1	72	46	65	-58	1	14	2	75	37
7/12/1995 *	Influent	0.05	0.08	2.8	1.60	0.075	1.28	1.42	2.69	41.3
	1° Effluent	2.59	0.35	36.3	4.47	0.050	20.98	7.07	14.23	99.4
	2° Effluent	0.61	0.13	16.6	2.91	0.062	27.78	6.08	1.73	27.0
	1° Efficiency (%)	-4700	-346	-1193	-180	33	-1543	-398	-430	-141
	2° Efficiency (%)	-1024	-65	-493	-83	17	-2075	-329	35	34
	2 vs 1	77	63	54	35	-24	-32	14	88	73
8/16/95	Influent	4.93	0.49	57.2	17.36	0.072	16.54	6.55	22.12	121.0
	1° Effluent	5.67	0.32	61.5	8.74	0.080	20.54	4.78	12.26	112.2
	2° Effluent	0.50	0.07	11.9	2.94	0.074	13.86	4.09	1.29	19.8
	1° Efficiency (%)	-15	35	-8	50	-11	-24	27	45	7
	2° Efficiency (%)	90	86	79	83	-3	16	38	94	84
	2 vs 1	91	78	81	66	8	33	15	89	82

Event Date	Data Type	Analytical results and removal efficiencies								
		Ag	Cd	Cu	Cr	Hg	Mo	Ni	Pb	Zn
9/13/95	Influent	5.57	0.37	62.8	5.46	0.402	12.55	5.39	9.39	64.2
	1° Effluent	5.61	0.29	64.6	5.81	0.256	19.49	6.05	12.74	63.0
	2° Effluent	0.59	0.13	9.3	2.25	0.008	14.21	5.01	1.30	13.4
	1° Efficiency (%)	-1	21	-3	-7	36	-55	-12	-36	2
	2° Efficiency (%)	89	64	85	59	98	-13	7	86	79
	2 vs 1	89	55	86	61	97	27	17	90	79
10/12/95	Influent	5.60	0.33	63.0	5.54	0.184	12.74	5.51	9.08	64.3
	1° Effluent	4.59	0.29	54.7	5.09	0.192	12.68	5.28	7.69	69.7
	2° Effluent	0.41	0.13	8.0	1.99	0.140	10.00	4.36	2.07	26.1
	1° Efficiency (%)	18	12	13	8	-4	1	4	15	-8
	2° Efficiency (%)	93	60	87	64	24	22	21	77	59
	2 vs 1	91	55	85	61	27	21	18	73	63
11/15/95	Influent	1.43	0.80	64.6	4.99	0.100	8.25	5.76	72.19	254.7
	1° Effluent	2.84	0.49	43.8	4.14	0.081	12.64	4.85	30.59	151.0
	2° Effluent	0.34	0.23	13.2	1.47	0.018	11.08	3.96	1.26	25.9
	1° Efficiency (%)	-98	39	32	17	19	-53	16	58	41
	2° Efficiency (%)	76	71	80	71	82	-34	31	98	90
	2 vs 1	88	53	70	64	78	12	18	96	83
12/13/95	Influent	4.92	0.30	69.0	5.47	0.120	9.41	3.76	9.00	76.5
	1° Effluent	4.77	0.30	59.8	4.75	0.054	10.70	3.74	7.11	62.4
	2° Effluent	0.71	0.14	16.2	1.74	0.016	8.84	3.36	1.38	24.0
	1° Efficiency (%)	3	2	13	13	55	-14	0	21	18
	2° Efficiency (%)	86	54	77	68	87	6	11	85	69
	2 vs 1	85	53	73	63	70	17	10	81	62
Average (%) 2 vs 1		84	58	74	49	51	20	17	81	62

CC = Cannot calculate (cannot divide by 0)

* = It is likely that bottle IDs were in error for the July metals results. They are nevertheless presented here as reported, however these data will not be used in calculating average removal efficiencies.

secondary removal efficiency would have been underestimated. Intermediate removal efficiencies were noted for Cr, Ni, Cd, Hg and Zn, while low removal efficiency was suggested for Mo.

Removal efficiency of the primary treatment process compared to pilot treatment plant results indicated high variability among the metals. These tests suggest that the new primary treatment process will be effective in removing a certain fraction of the metals entering the treatment plant. Although substantial variability exists in the removal efficiencies, tests indicated that primary treatment alone will remove an important amount (~8 to ~25%) of the Cd, Cu, Cr, Hg, Ni, Pb and Zn. Metal concentrations in the pilot plant primary effluent and the Deer Island treatment plant effluent were generally within the range measured in 1995 (Table 14).

Several observations can be made about expected improvements in metals loading to Massachusetts Bay once the secondary treatment process is on-line. The data from the tests conducted in 1995 demonstrated that secondary treatment was consistently effective in removing Ag, Cu and Pb. Annual average removal efficiencies for Ag, Cu and Pb were 81, 78 and 85%, respectively. Similar patterns were noted in removal efficiencies for Cd, Pb and Zn. Removal efficiencies were more variable and lower for Cr, Mo, and Ni. As shown in Table 13, secondary treatment can be expected to substantially lower most metals concentrations in the Deer Island effluent, reducing effluent loading.

This study indicated that metal concentrations in the secondary treatment effluent should be well below any applicable marine water quality criteria (Table 14). Cu alone would exceed the EPA water quality criterion, and only by a factor of 3-7. Considering the predicted effluent dilutions, it is unlikely that any exceedance will occur. In fact, if the effluent concentrations measured in the pilot plant secondary effluent are achieved, it would be difficult to detect increases in the ambient Massachusetts Bay metal concentrations.

3.2.3 Nutrients

Nine sets of nutrient samples were collected in 1995. Analytical results and removal efficiencies from these tests are reported in Tables 15 and 16. DON was calculated by subtracting NH_3 from TKN and not measured directly. This was done for each sample, then the mean concentrations calculated. DOP was calculated by subtracting PO_4 from TDP. Note that for several parameters calculated concentrations are negative. This is due in part to the use of grab sampling, analytical variability and start-up conditions in January.

Table 14

Comparison of metal concentrations in the Pilot Treatment Plant effluent with concentrations measured in the Deer Island effluent in 1995, ambient concentrations in Massachusetts Bay, and EPA chronic water quality criteria.

Element	1995 Deer Island Concentration Range (ug/L)	Pilot Plant Effluent Concentration (ug/L)		Ambient Water Concentrations in Massachusetts Bay (ug/L)	EPA Chronic Water Quality Criteria
		1°	2°		
Ag	1.30 - 5.801	2.59 - 5.86	.34 - 1.29	NA	2.3 (1)
Cd	0.28 - 1.72	0.29 - 0.82	0.07 - 0.27	0.02 - 0.03 (2) 0.02 - 0.3 (3)	9.3
Cr	3.07 - 185.00	3.12 - 8.74	1.38 - 11.79	0.10 - 0.18 (2)	50
Cu	46.7 - 103.0	36.26 - 69.00	7.96 - 21.62	0.1 - 0.3 (2) ~ 0.3 (3)	2.9 (1)
Hg	0.0 - .3	0.0 - .3	0.0 - 0.1	0.0005 - 0.0014 (2) ~ 0.003 (3)	0.025
Mo	8.87 - 26.87	7.69 - 20.98	7.10 - 27.78	NA	NA
Ni	3.36 - 20.40	3.74 - 10.00	3.30 - 7.17	0.26 - 1.6 (2) ~ 1.5 (3)	8.3
Pb	4.30 - 29.18	5.74 - 31.80	0.81 - 3.27	0.03 - 0.19 (2) ~ 0.2 (3)	8.5
Zn	49.42 - 136.38	61.50 - 151.01	13.44 - 58.40	0.08 - 0.57 (2) ~ 0.6 (3)	86

(1) Chronic criteria are not available; value is the acute water quality criteria
(2) Battelle (1992) as cited in Batelle 1995
(3) Wade et al., (1987) as cited in Batelle 1995

Table 15

Estimated removal efficiency for nitrogen forms during the pilot treatment plant studies. Concentration units are in uM; removal efficiencies are in percent.

Event Date	Data Type	Analytical results and removal efficiencies							
		NH_3	NO_2	NO_3	$NO_2 + NO_3$	DON	TDN	PON	TN
1/25/95	Influent	827	1.4	0	1.4	30	859	397	1255
	1° Effluent	891	0.0	0	0.0	87	979	252	1231
	2° Effluent	976	0.7	0	0.7	74	1051	164	1214
	1° Efficiency (%)	-8	100	CC	100	-190	-14	36	2
	2° Efficiency (%)	-18	47	CC	47	-148	-22	59	3
	2 vs 1	-9	CC	CC	CC	15	-7	35	1
5/10/95	Influent	1468	0.3	2.1	2.4	825	2295	490	2785
	1° Effluent	1275	0.2	1.4	1.6	339	1616	377	1993
	2° Effluent	1134	1.6	2.9	4.4	1138	2276	39	2315
	1° Efficiency (%)	13	25	33	32	59	30	23	28
	2° Efficiency (%)	23	-450	-33	-82	-38	1	92	17
	2 vs 1	11	-633	-100	-170	-235	-41	90	-16
6/14/95	Influent	879	0.0	0.0	0.0	414	1293	282	1575
	1° Effluent	1179	0.2	0.0	0.2	536	1715	271	1986
	2° Effluent	1221	2.4	1.6	4.0	314	1540	57	1597
	1° Efficiency (%)	-34	CC	CC	CC	-29	-33	4	-26
	2° Efficiency (%)	-39	CC	CC	CC	24	-19	80	-1
	2 vs 1	-4	-1033	CC	-1767	41	10	79	20
7/12/95	Influent	801	0.1	0.0	0.1	326	1127	286	1413
	1° Effluent	1159	0.0	0.0	0.0	-25	1134	212	1345
	2° Effluent	941	3.6	2.9	6.4	106	1054	35	1088
	1° Efficiency (%)	-45	100	CC	100	108	-1	26	5
	2° Efficiency (%)	-17	-2400	CC	-4400	68	7	88	23
	2 vs 1	19	CC	CC	CC	523	7	84	19
8/16/95	Influent	1079	0.4	0.0	0.4	484	1563	307	1869
	1° Effluent	1514	0.4	0.0	0.4	408	1923	216	2138
	2° Effluent	1644	3.4	9.3	12.6	464	2121	43	2164
	1° Efficiency (%)	-40	17	CC	17	16	-23	30	-14
	2° Efficiency (%)	-52	-683	CC	-2850	4	-36	86	-16
	2 vs 1	-9	-840	CC	-3440	-14	-10	80	-1
9/13/95	Influent	1729	0.3	0.0	0.3	89	1817	448	2266
	1° Effluent	1693	0.4	0.0	0.4	42	1735	254	1990
	2° Effluent	1671	0.5	0.0	0.5	176	1848	158	2006
	1° Efficiency (%)	2	-50	CC	-50	52	5	43	12
	2° Efficiency (%)	3	-75	CC	-75	-99	-2	65	11
	2 vs 1	1	-17	CC	-17	-319	-7	38	-1

Event Date	Data Type	Analytical results and removal efficiencies							
		NH_3	NO_2	NO_3	NO_2 + NO_3	DON	TDN	PON	TN
10/12/95	Influent	2344	0.6	4.1	4.7	-630	1718	353	2071
	1° Effluent	2443	0.9	4.1	5.0	-520	1928	261	2189
	2° Effluent	2132	5.4	6.6	12.1	-640	1504	29	1534
	1° Efficiency (%)	-4	-50	0	-6	17	-12	26	-6
	2° Efficiency (%)	9	-850	-60	-156	-2	12	92	26
	2 vs 1	13	-533	-60	-141	-23	22	89	30
11/15/95	Influent	447	1.1	109.3	110.4	155	713	154	867
	1° Effluent	636	1.1	0.0	1.1	101	738	176	914
	2° Effluent	711	2.4	17.9	20.3	12	743	2	745
	1° Efficiency (%)	-42	-7	100	99	35	-4	-14	-6
	2° Efficiency (%)	-59	-127	84	82	92	-4	99	14
	2 vs 1	-12	-113	CC	-1675	88	-1	99	19
12/13/95	Influent	1655	0.2	2.1	2.4	-106	1551	495	2045
	1° Effluent	1765	0.2	1.4	1.6	-195	1572	292	1863
	2° Effluent	1721	0.3	6.4	6.7	-331	1396	17	1413
	1° Efficiency (%)	-7	0	33	30	-83	-1	41	9
	2° Efficiency (%)	-4	-33	-200	-185	-211	10	97	31
	2 vs 1	3	-33	-350	-309	-70	11	94	24
Average (%) 2 vs 1		1	-458	-170	-1250	1	-2	76	10

CC = Cannot calculate (cannot divide by 0)

Table 16

Removal efficiencies of phosphorous, silica, and organic carbon forms during the pilot treatment plant studies. Concentration units are in uM except for DOC and POC which are in mg/L; removal efficiencies are in percent.

Event Date	Data Type	Analytical results and removal efficiencies										
		PO_4	DOP	TDP	POP	TP	Si	Bio Si	T Si	DOC	POC	TC
1/25/95	Influent	17.0	24.7	41.7	18.60	60.3	360	12.3	372	18	52	70
	1° Effluent	19.6	22.4	42.0	20.90	62.9	377	10.9	388	18	34	52
	2° Effluent	9.3	14.0	23.2	21.18	44.4	363	5.4	369	9	14	23
	1° Efficiency (%)	-16	9	-1	-12	-4	-5	12	-4	0	34	26
	2° Efficiency (%)	45	43	44	-14	26	-1	56	1	50	73	67
	2 vs 1	53	38	45	-1	29	4	50	5	50	59	56
5/10/95	Influent	17.7	40.1	57.8	35.84	93.6	456	45.9	502	38	79	117
	1° Effluent	18.1	40.3	58.4	31.22	89.7	477	26.3	503	40	54	94
	2° Effluent	10.2	27.6	37.8	4.71	42.5	313	1.0	314	11	3	14
	1° Efficiency (%)	-2	-1	-1	13	4	-5	43	0	-5	31	19
	2° Efficiency (%)	42	31	35	87	55	31	98	37	71	96	88
	2 vs 1	44	32	35	85	53	34	96	38	73	94	85
6/14/95	Influent	19.4	26.8	46.2	30.42	76.6	438	23.9	462	22	49	71
	1° Effluent	24.6	27.7	52.3	26.22	78.5	562	20.4	583	33	33	66
	2° Effluent	16.2	27.1	43.3	13.56	56.8	292	10.8	303	10	5	15
	1° Efficiency (%)	-27	-3	-13	14	-3	-28	15	-26	-50	33	7
	2° Efficiency (%)	16	-1	6	55	26	33	55	34	55	89	78
	2 vs 1	34	2	17	48	28	48	47	48	70	83	76
7/12/95	Influent	15.9	30.9	46.8	44.88	91.7	431	27.4	458	22	47	69
	1° Effluent	17.9	35.7	53.6	11.53	65.1	562	22.3	585	29	26	55
	2° Effluent	6.6	19.8	26.5	2.10	28.6	285	3.8	289	9	3	12
	1° Efficiency (%)	-13	-15	-14	74	29	-31	19	-28	-32	46	21
	2° Efficiency (%)	58	36	43	95	69	34	86	37	59	94	83
	2 vs 1	63	44	51	82	56	49	83	51	69	90	79
8/16/95	Influent	16.8	66.8	83.6	26.25	109.9	466	28.7	495	38	49	87
	1° Effluent	17.7	81.4	99.1	23.44	122.6	466	19.9	486	51	24	75
	2° Effluent	11.9	33.3	45.2	5.36	50.6	260	4.4	264	11	3	14
	1° Efficiency (%)	-5	-22	-19	11	-12	0	31	2	-34	50	14

Event Date	Data Type	Analytical results and removal efficiencies										
		PO_4	DOP	TDP	POP	TP	Si	Bio Si	T Si	DOC	POC	TC
	2° Efficiency (%)	29	50	46	80	54	44	85	47	71	94	84
	2 vs 1	33	59	54	77	59	44	78	46	78	88	81
9/13/95	Influent	37.9	85.4	123.3	33.58	156.9	352	34.7	387	58	72	130
	1° Effluent	33.7	81.3	114.9	20.15	135.1	349	24.2	373	72	31	103
	2° Effluent	34.7	77.9	112.7	12.08	124.8	274	4.9	279	14	11	25
	1° Efficiency (%)	11	5	7	40	14	1	30	4	-24	56	20
	2° Efficiency (%)	8	9	9	64	20	22	86	28	76	85	81
	2 vs 1	-3	4	2	40	8	21	80	25	81	66	76
10/12/95	Influent	29.6	315.3	344.8	34.55	379.4	363	29.0	392	NA (1)	51	NA
	1° Effluent	31.4	337.4	368.7	25.51	394.3	445	19.6	465	61	28	89
	2° Effluent	18.3	195.4	213.8	11.30	225.1	295	1.7	297	8	2	10
	1° Efficiency (%)	-6	-7	-7	26	-4	-23	32	-18	CC	46	CC
	2° Efficiency (%)	38	38	38	67	41	19	94	24	CC	95	CC
	2 vs 1	42	42	42	56	43	34	91	36	87	91	88
11/15/95	Influent	4.8	12.9	17.8	20.99	38.7	427	10.6	438	8	19	27
	1° Effluent	9.9	23.7	33.6	19.05	52.6	463	12.8	476	12	17	29
	2° Effluent	6.8	18.3	25.2	3.55	28.7	328	2.4	330	7	0	7
	1° Efficiency (%)	-104	-83	-89	9	-36	-8	-21	-9	-50	11	-7
	2° Efficiency (%)	-41	-42	-42	83	26	23	78	25	13	99	73
	2 vs 1	31	23	25	81	45	29	81	31	42	99	75
12/13/95	Influent	47.4	38.5	85.9	34.87	120.8	488	27.9	516	36	73	109
	1° Effluent	46.2	38.7	84.9	28.09	113.0	495	24.1	519	38	34	72
	2° Effluent	35.9	25.1	61.0	6.78	67.8	299	9.6	309	12	2	14
	1° Efficiency (%)	2	0	1	19	6	-1	14	-1	-6	54	34
	2° Efficiency (%)	24	35	29	81	44	39	66	40	67	98	87
	2 vs 1	22	35	28	76	40	40	60	41	68	95	81
Average (%) 2 vs 1		35	31	33	60	40	34	74	35	69	85	77

CC = Cannot calculate (cannot divide by 0)
NA = Not available
(1) broken bottle after sampling

Table 17 compares nutrient concentrations associated with primary and secondary pilot treatment plants with 1995 concentrations in Deer Island primary treatment plant effluents. By comparison, the secondary treatment process reduced concentrations of total nitrogen, particulate nitrogen, total phosphorus, dissolved phosphorus, phosphate, silicate and both the dissolved and particulate forms of organic carbon. Although it appears that nitrate + nitrite may actually have increased, this is most likely not the case, as explained below. Ammonia will be relatively unchanged with secondary treatment.

The following discussion focuses more specifically on the removal efficiencies of each of the nutrient forms measured during the pilot treatment plant studies conducted in 1995. Each of the nutrient elements (nitrogen, phosphorus, silica, organic carbon) is discussed separately.

Nitrogen - Primary treatment alone removed almost no total nitrogen from the influent on an annual basis (0.5%). Secondary treatment removed 10% of the total nitrogen from the influent on an annual basis (Table 15). This is due to removal of PON. It is possible that some of the PON was transformed to DON and NH_3, with subsequent nitrification to nitrite and nitrate.

Average removal efficiencies for nitrite, nitrate and TDN were negative. This could be due to the transformation of PON as mentioned above. The increases in nitrite and nitrate were very small in absolute amounts (the largest was about 10 µM in August). Changes in the NH_3 concentrations were typically in the range of hundreds of µM.

Two alternative possible explanations without invoking potential microbial transformations of total nitrogen for the negative removal efficiencies are:

> 1) No lag-time among influent, primary, and secondary effluent samplings,. A true representation of removal efficiencies in a system requires that the same slug of influent/effluent be sampled and followed through the system. Proper lag-times in sampling should be estimated so that one can sample the same slug as it passes through the treatment in question. If this is not done, samples may reflect the variable concentrations that could be found daily in primary or secondary effluent. Future studies should take this information into consideration to capture a better representation of removal efficiencies. Also the pilot plant was operated under sever conditions in January and recirculation could have occurred.

Table 17

Comparison of nutrient concentrations in the Pilot Treatment Plant effluent with concentrations measured in the Deer Island effluent in 1995 and the range of ambient concentrations in Massachusetts Bay.

Element	1995 Deer Island Concentration Range (uM)	Pilot Plant Effluent Concentration (uM)		Ambient Water Concentrations in Massachusetts Bay [1] (uM)
		1°	2°	
Total Nitrogen	516 - 2250	914 - 2188	745 - 2315	4 - 84
Total Dissolved Nitrogen	379 - 1986	738 - 1928	743 - 2276	0.6 - 40
Ammonia	0 - 2022	636 - 2443	711 - 2132	0 - 15
$NO_2 + NO_3$	0.79 - 59	0 - 5	0.5 - 20	0 - 14
Particulate Nitrogen	137 - 310	176 - 377	2 - 163	0.02 - 19
Total Phosphorus	41 - 313	43 - 395	24 - 225	NA
Dissolved Phosphorus	12 - 310	34 - 369	23 - 214	0.06 - 5
PO_4	0.4 - 31.6	10 - 46	7 - 35	0 - 3.4
Particulate Phosphorus	0.6 - 38	0.5 - 31	0.5 - 13	NA
Silicate	231 - 506	349 - 563	260 - 363	0 - 22
Biogenic Silica	11 - 33	11 - 26	1 - 11	NA
Dissolved Organic Carbon (mg/L)	7 - 61	12 - 72	7 - 14	65 - 560
Particulate Organic (mg/L) Carbon	16 - 42	17 - 54	0.2 - 14	3 - 67

[1] as cited in Hunt *et al.* (1995).

2) Analytical variability. Laboratory error may account for a negative result. TDN removal efficiency was approximately -6%, which is within the range of analytical variability.

Results of the pilot secondary biological treatment plant indicate that the treatment process can lead to small reductions of nitrogen that will be discharged to Massachusetts Bay through the new MWRA outfall.

Phosphorus - Secondary treatment removed approximately 40% annually of the total phosphorus entering the pilot treatment plant (Table 16). The annual removal efficiencies for TDP and POP were 23% and 66%, respectively. Within the dissolved phosphorus phase, phosphate and dissolved organic phosphorus were removed at equal rates (25 and 22% respectively). Estimated removal efficiencies for primary treatment alone were low. In fact, all annual removal averages were negative, except for POP with an annual removal average of 22%.

Silicate - In 1995, secondary treatment of total Si resulted in a 30% removal efficiency. Comparison of secondary treatment and primary treatment data indicates that secondary treatment improved total Si removal by 35%. This contrasts with the 1994 data set which indicated that secondary treatment had little impact on overall loading of Si into Massachusetts Bay.

Organic Carbon - Concentrations of dissolved organic carbon in the influent were approximately half the concentrations of particulate organic carbon. The data suggest that at least 80% of the total organic carbon (sum of dissolved and particulate) entering the pilot treatment plant will be removed by secondary treatment. Secondary treatment will remove over 85% of the particulate organic carbon and approximately 69% of the dissolved organic carbon from primary effluent. The 1995 data suggest that primary treatment removes approximately 15% of the total organic carbon that passes through primary treatment.

Nutrient Ratios - The nitrogen/phosphorus (N/P) ratios in the pilot treatment plant effluents are shown in Table 18. These values are essentially the same as reported for the 1995 Deer Island effluent, in which the dissolved inorganic N/P ratio is 2-4 times higher than the total N/P nutrient ratio.

In contrast, the total N/P nutrient ratios calculated for the secondary effluent are distinctly higher than for the primary effluent. The N/P ratios for dissolved nutrients in secondary effluents are also higher than for the total nutrients at this level of treatment. The higher N/P ratio in the secondary treatment effluent indicates that secondary treatment removes phosphorus more efficiently than nitrogen.

Table 18

Nutrient ratios in the pilot treatment plant primary and secondary effluents.

	Effluent type/ratio			
Event Date	PrimaryTN/TP	Primary DIN/PO_4	Secondary TN,TP	Secondary DIN/PO_4
1/25/95	19.6	45.5	27.3	105.4
5/10/95	22.2	70.5	54.5	111.4
6/14/95	25.3	47.8	28.1	75.6
7/12/95	20.7	64.7	38.1	142.9
8/16/95	17.4	85.6	42.8	139.3
9/13/95	14.7	50.3	16.1	48.1
10/12/95	5.6	78.0	6.8	117.0
11/15/95	17.4	64.3	25.9	106.8
12/13/95	16.5	38.2	20.8	48.1

The question of whether changes in the N/P ratio that will occur during secondary treatment will significantly affect productivity in Massachusetts Bay remains a difficult one to answer. Conditions have not changed from 1993/4 and the typical DIN/P ratio in Massachusetts Bay is still greater than 16 and phosphate concentrations do not fall to zero. This indicates that sufficient phosphate always exists in the water column to support primary production, even as nitrogen is depleted. The N/P ratio in the secondary effluent (whether total or dissolved) is always larger than the primary effluent, which is always greater than 16 (except for the October 12 sample which had a TN/TP ratio of 5.6). Therefore, discharge of secondary effluent that is less rich in phosphorus is unlikely to have more impact than the discharge of primary effluent that is more enriched in phosphorus.

In contrast, more efficient phosphorus removal from the sewage and transfer of the phosphorus to sludge generated by secondary treatment may improve sewage sludge quality. The N/P ratio in the sludge is especially likely to decrease, providing a fertilizer enriched in phosphorus compared to the primary sludge. On the other hand, more effective transfer of contaminants to the sludge from the primary treatment process might indicate a possible decrease in quality. Then again, major changes in concentration may not occur because of a resultant increase in solids removal and production of additional solids by the treatment process. In short, effluent improvements are expected, but sludge quality must be carefully evaluated after secondary treatment system startup.

3.2.4 Implications of the Pilot Treatment Plant Results

The pilot treatment plant confirms that improved effluent quality and distinct decreases in the loading of many contaminants to Massachusetts Bay can be expected once the secondary treatment system is implemented. It is useful to evaluate the reduced effluent loading that are possible if the full-scale treatment plant achieves the pilot plant test efficiencies. Loading estimates based on 1995 effluent characterization monitoring and the pilot secondary treatment plant's 1995 removal efficiencies were used to determine these modified loading estimates (Table 19). The results (Table 20) provide preliminary information on the expected loading. Substantial reductions in the loading of most toxic contaminants can be expected, particularly those that are of major concern in Massachusetts Bay (*e.g.*, Hg, Cu, PAHs, and PCBs). A substantial amount of organic carbon will also be removed, which will significantly reduce the BOD input to the system. In contrast, limited removal of nitrogen will likely occur, with slightly more Si being removed, providing a medium that is slightly more favorable to diatom production than to the other phytoplankton species.

Table19

Revised loading estimates to Massachusetts Bay from the combined Deer Island and Nut Island discharge using the secondary treatment plant efficiency relative to primary treated effluents and 1995 primary effluent loading data. SEIS loading estimates and removal efficiencies are included for comparison.

Compound	SEIS loading estimates-primary effluent (EPA, 1988) (kg/yr)	1995 Loading estimate-primary effluent (kg/yr)	1995 Estimated removal efficiency between 1° and 2° (%)	1995 Loading estimate for full secondary treatment (kg/yr)	SEIS Loading estimates-secondary treatment (EPA, 1988) (kg/yr)	SEIS Removal efficiencies between 1° and 2° (%)
Total PAH	NA	8,873	95	457	NA	NA
Total PCB	527	25	65	9	41	92
Total LAB	NA	5,103	85	781	NA	NA
Total Chlordane	NA	3.1	91	0.3	NA	NA
Lindane	NA	7.9	46	4.2	NA	NA
Total DDTs	27	5.6	98	0.1	28	0
Ag	2,081	1,929	84	310	296	86
Cd	1,186	255	58	106	700	41
Cu	43,059	31,028	74	8,184	11,900	72
Cr	8,802	7,861	49	4,031	3,520	60
Hg	643	50	51	24	205	68
Mo	NA	6,782	20	5,424	NA	NA
Ni	11,135	3,079	17	2,557	8,910	20
Pb	6,219	5,758	81	1,074	4,951	20
Zn	86,125	37,415	62	14,053	34,500	60
Total N	12,000,000	10,003,050	10	8,953,711	12,000,000	0
Total P	NA	1,475,544	40	885,326	NA	NA
Silica	NA	5,071,221	34	3,360,119	NA	NA
DOC	NA	20,784,386	69	6,532,709	NA	NA
POC	NA	14,033,243	85	2,122,736	NA	NA

* Removal efficiencies for July metals data were not included because of the uncertainy of bottle identifications for that sampling.

Removal estimates from the pilot plant studies and expected removals used to develop the loading estimates in the Supplemental Environmental Impact Statement (SEIS) (EPA, 1988) show reasonably good agreement. For example, the SEIS estimated that Hg and Cu removal would be 68% and 72%, respectively, for primary treatment. These figures compare with this study's removal estimates of 51% for Hg and 74% for Cu. The SEIS estimated no nitrogen removal by secondary treatment. This estimate was a conservative assumption by design. The pilot plant data suggest that approximately 10% of the total nitrogen would be removed. Therefore, it appears that the removal estimates used in the SEIS will generally prove accurate, or they will be exceeded, once the MWRA secondary plant is operational. Furthermore, the contaminant loadings projected on the basis of the 1995 pilot treatment plant tests are consistent with, if not less than (25-100%), the projections provided in Shea (1993a). The only exception is Cr which showed two large spikes in January and February of 1995. Shea's Pb loading projections are much higher than estimates in this current report (*i.e.,* 4500 vs 1,074 Kg/year).

Based on the projected low loadings to Massachusetts Bay when secondary treatment is fully operational, two additional implication can be drawn. First, the combination of secondary treatment, dilution and other attenuation processes, as well as source control measures will ensure that toxic contaminant concentrations in Massachusetts Bay will not exceed water quality criteria due to the MWRA discharge except in the immediate vicinity of the diffuser. Second, the substantial reductions in loading will make it very difficult to measure changes in concentrations within the sediments and organisms in Massachusetts Bay, particularly in farfield locations. Measurement of effluent-specific tracers in sediments and biota in the outfall vicinity, as mentioned previously, will likely be the best method for developing an understanding of the transport and fate of discharged contaminants.

4.0 FINDINGS AND CONCLUSIONS

The findings of the effluent characterization and pilot plant studies are summarized in this section. Conclusions, implications, and recommendations for continuing effluent characterization as part of the Harbor and Outfall Monitoring Project are also presented. Many of the findings and recommendations from this study are very similar to those from the 1993/4 study because the contaminant concentrations measured in this study period are similar to what was observed in 1993/4.

4.1 Deer Island Effluent Characteristics

Evaluation of Persistent Anthropogenic Metal and Organic Contaminants in the Effluent- The new Deer Island primary plant became operational in January of 1995. The new plant was run in tandem with the old plant until the end of February. Improved plant efficiencies, in particular with respect to removal of suspended solids, became evident by April. However the 1995 concentrations of metals and organic contaminants in the Deer Island effluent were similar to those reported in 1993/4 (Hunt *et al.*, 1995). This is due to the nature of the sources of these contaminants (*e.g.* some metals such as Cu come primarily from corrosion of copper plumbing), which did not change; and the physico-chemical nature of these contaminants (*e.g.* associated with fine particulates) which are not easily amendable to removal by conventional settling.

Contaminant concentrations measured in the effluent between January and December 1995 ranged as follows: 4,204 - 54,932 ng/L for total PAHs; 7 - 225 ng/L for total PCBs; 0 - 18 ng/L for total chlordanes; 4 - 57 ng/L for lindane; and 6,120 - 16,540 ng/L for total LABs. Metal concentrations (in µg/L) ranged as follows: 1.3 - 5.8 for Ag; 0.3 - 1.7 for Cd; 3.1 - 185 for Cr; 46.7 - 103 for Cu; 0.03 - 0.3 for Hg; 9.2 - 26.9 for Mo; 3.4 - 20.4 for Ni; 4.3 - 29.1 for Pb; and 49.4 - 136.4 for Zn.

Concentrations of all organic compounds measured in undiluted effluent were less than the available EPA marine acute criteria. Values higher than the EPA marine chronic criteria were found consistently only for p,p'- DDT, and occasionally for heptachlor. This is similar to what was observed in 1993/4. Dieldrin was not detected throughout the sampling period. The PAH in the Deer Island primary effluent is dominated by the lighter weight 2- and 3-ring petrogenic compounds, comprising well over 50% of the total PAH by weight. This is consistent with 1993/4 results. For the metals, only Ag and Cu were consistently higher than the available marine acute aquatic life criteria in the undiluted effluent. The recent initiation of corrosion control for drinking water quality purposes in 1996 (specifically for control of copper and lead) should decrease the Cu concentration in the influent, and by extension, the effluent. But it is unlikely that the Cu concentration in undiluted secondary effluent will be decreased to less than the EPA acute marine water quality criteria. Hg and Pb consistently exceeded the chronic marine criteria, while Zn, Ni and Cr were occasionally higher than the chronic marine criteria. The expected dilution that will occur at the diffuser ensures that all contaminants exceeding marine criteria in the primary effluent would be diluted well below applicable criteria in the immediate vicinity of the diffuser. Thus, violations of aquatic life criteria (acute or chronic) for these contaminants would not occur even if the primary effluent discharge is relocated to Massachusetts Bay.

Evaluation of Effluent Nutrient Concentrations and Other Parameters Related to Eutrophication Issues- Total nitrogen, ammonia, nitrate + nitrite, total phosphorus, and phosphate concentrations in the 1995 Deer Island effluents were similar to those reported previously (Hunt *et al.*, 1995). This is again to be expected because there were no real changes in the source and physico-chemical nature of these compounds. Concentrations (in µM) ranged as follows: 516-2250 for total nitrogen; 379-1986 for dissolved nitrogen; 215 - 2022 for ammonia; and 137-310 for particulate nitrogen. Ammonia contributed the largest fraction (~67% annual average) to the total nitrogen and approximately 91% of the total dissolved nitrogen loading. Phosphate concentrations (in µM) remained in the same range as previously reported and were as follows: 41 - 313 for total phosphorus; 12 - 310 for total dissolved phosphorus; 0.4 - 31.6 for phosphate; and 0.6 - 38 for particulate phosphate. Biogenic Si concentrations remained low (less than 31 µM), contributing less than 10% of the total biologically available Si concentrations in the effluent. The average monthly concentrations of dissolved organic carbon were slightly higher than that of particulate organic carbon in the effluent, with the dissolved form consistently contributing approximately 60% of the total organic carbon in the effluents, similar to 1993/4.

Determination of Long-Term (e.g., Monthly and Seasonal) Changes in the Concentrations of Effluent Contaminants and Nutrients- Daily and monthly variability could be detected in the treatment plant effluents as reported previously by Uhler *et al.* (1994) and Hunt *et al.* (1995). This variability was not so great as to mask seasonal trends, particularly for nutrients. Nutrient concentrations were generally higher in the summer when the flow was reduced except Si. Si showed no seasonal trend during 1995 although it generally decreased in the summer during the 1993/4 sampling period. Concentrations of both total and dissolved phosphorus increased during the late half of 1995, with a peak in October and low in November. Particulate phosphorus was relatively constant throughout the sampling period; the increases detected in late 1995 were due to dissolved forms, primarily increases in the dissolved organic phosphorus concentrations. Dissolved Si concentrations were relatively constant although decreases were evident in the summer months. Seasonal trends were also evident for concentrations of PAHs, chlorinated pesticides (*e.g.*, DDTs and lindane), and PCBs. PAH concentrations were highest in the winter/spring period, while concentrations of PCBs were low in the late summer, early fall and spring. Lindane showed lows in the spring and highs in the summer. Seasonal trends in the metals data were not evident, although Mo concentrations increased from approximately 10 to 25 µg/L between March and July, similar to what was observed in 1994.

<u>Estimation of Annual Contaminant-Specific Loading to Massachusetts Bay</u>- The estimated input of contaminants and nutrients in 1995 to the Boston Harbor/Massachusetts Bay system from Deer Island and Nut Island was consistent with estimates developed in 1993 by Alber and Chan (1994), Shea (1993a) and in 1994 by Hunt *et al.* (1995). Nutrients contributed the largest loading on a mass basis. Inputs ranged from 13 mtons/year for nitrite to 10,003 mtons/year for total nitrogen. This is less than the hypotheses/warning level of 12,500 mtons/year of total nitrogen load currently being discussed. Estimated loadings for other nutrients were 1,397 mtons of total phosphorus/year, 5087 mtons of dissolved silicate/year, and 35,251 mtons of total organic carbon/year. The calculated annual loading of PO_4 for 1995 was 236 mtons/year, a greater than three fold decrease from the 1993/4 loading.

Inputs of organic contaminants ranged from less than 10 Kg/year for total chlordanes and lindane to 8873 Kg/year for PAHs. The PAH load for 1995 was less than that of 1993/4, estimated at 10,900 Kg/year. PCBs were discharged at approximately 25 Kg/year, virtually the same as 1993/4 at 26 Kg/year.

For metals, Cu and Zn were discharged at the highest rates, 31,028 and 37,415 Kg/year, respectively. The Cu loading is expected to decrease for 1996 due to the implementation of corrosion control. All other metals were discharged at less than 8000 Kg/year. Cd was discharged at 255 Kg/year and Hg loading was estimated at 50 Kg/year. Both Cd and Hg loadings in 1995 were less than that of 1993/4 (370 Kg/yr and 75 Kg/yr). Cr was the major exception to the metals in that it was far higher than the 1993/4 estimates. This was due to two large spikes in January and February 1995.

<u>Identification of Unique Chemical "Fingerprints."</u> The principal component analysis indicated that PAH compounds grouped together in samples taken from January - June as well as July - December. The first cluster did not resemble any of the four reference materials (kerosene, unleaded gas, bunker fuel oil # 6 and fuel oil # 2), however the second cluster of samples, taken from July - December, were similar to kerosene and unleaded gas. The LABs were similar in composition throughout the 1995 sampling period. The N/P ratio in the effluents, typically 17.5, is consistent with the terrestrial

source of the organic material. Similarly, the stable isotope ratios of nitrogen and sulfur of particulate matter filtered from the effluent are indicative of terrestrial sources. The $\delta^{15}N$ ranged between -0.9 and 3.6‰ (average = 0.24 ‰) and the $\delta^{24}S$ ranged between 3.1 and 7.4‰ (average=4.7‰). Of the effluent tracers, sulfur isotopes remain superior to nitrogen isotopes because of the larger difference in the ratio relative to seawater, and the fact that the sulfur ratios are less responsive to biological degradation. *Clostridium perfringens* spores in the effluent were also measured and ranged between 360 to 49,000 spores/100 mL. This is a decrease from the 1993/4 levels, which ranged between 6,900 and 46,000 spores/100 mL. This is probably due to the improved removal of suspended solids in the new primary plant. The higher spore counts (above 10,000/100 mL) only occurred from January to April. Spore counts decreased to less than 10,000/100 mL in May, concomitant with improved suspended solids removal, although increases were apparent again in November and December.

4.2 Pilot Treatment Plant

Results from the pilot treatment plant studies are presented below. The information focuses on the removal efficiency of the secondary process for various contaminants and how source characteristics may be changed during secondary treatment. The implications of projected removal efficiency on loading changes to Massachusetts Bay and impacts on receiving water quality are discussed.

Treatment Plant Effectiveness - The primary objective of the pilot plant study in 1995 was to continue the evaluation of primary versus secondary treatment for removal of metals and organic contaminants, as well as nutrients. This information is valuable for projecting the characteristics of the effluent that will be discharged from the secondary plant when completed. While there is significant variability among the tests and there are still some issues to be worked out (*e.g.* the contaminant concentration in the primary effluent is sometimes higher than the influent), the results indicate that secondary treatment is clearly effective in reducing the concentrations of several contaminants that are of concern (*e.g.,* Ag, Cu, Pb, DDTs, LABs and PAHs). The results also indicate that other contaminants (*e.g.,* total nitrogen, Ni, Si, and Mo) will not be significantly reduced through secondary treatment.

The biological secondary treatment in the pilot plant resulted in very high removal efficiency (>85%) for total PAHs, total chlordanes, DDTs, LABs and particulate organic carbon, particularly compared to primary treatment removal for these compounds. High removal efficiencies (70-85%) were achieved for Ag, Cu, Pb, PON, Biogenic Si, and total carbon. PCBs, Lindane, Cd, Cr, Hg, Mo, Zn, PO_4, DOP, TDP, POP, TP, Si, and DOC were removed with 20 to 70% efficiency. Ni, NH_3, nitrate, nitrite, DON, TDN and TN were inefficiently (<20%) removed in the pilot secondary treatment test.

Loading - Removal efficiencies identified from the pilot plant secondary treatment process suggest that contaminant loading to Massachusetts Bay will be significantly reduced. Contaminant loading reductions similar to the removal efficiencies listed above can be expected. In particular, there is a very high removal efficiency expected for dissolved and particulate organic carbon (~69% and 85%, respectively, relative to the present primary effluent). The large reduction in organic carbon loading is expected to have significant impacts on the cBOD in the effluent and on the oxygen demand in the receiving waters.

Effluent Quality - The second objective of the pilot plant study was to estimate the effluent quality that will be achieved when full secondary treatment is implemented. The pilot plant results indicate that the quality of the secondary treated effluent will be excellent, particularly with respect to priority pollutants. Only a few contaminants in the secondary effluent will exceed EPA marine water quality criteria prior to discharge. Parameters that do exceed EPA criteria (*e.g.*, Cu, Hg) will be rapidly diluted to well below their applicable aquatic life water quality criteria within a short distance from the diffuser.

Secondary Effluent Characteristics- In addition to reductions in effluent contaminant concentrations, secondary treatment will result in significant changes in the source characteristics of several parameters. In particular, the increased efficiency of phosphorus compared to nitrogen removal due to secondary treatment will result in an increase in the nitrogen to phosphorus ratio (N/P) from approximately 17.5 to 30. This difference in nutrient removal will result in an increase in the P content and correspondingly the quality of the MWRA sewage sludge for fertilizer. This is counter-balanced somewhat by potential increases in the concentration of contaminants that have a tendency to be particle bound and not amendable to degradation.

Also, the secondary treatment pilot data indicate that there will likely be a change in the characteristic fingerprints of the LAB and PAH analytes. Principal component analysis of the 1995 data demonstrate a significant difference between the secondary effluents and the pilot plant influent. For 1995, it appears that secondary treatment did not substantially alter the signature of the primary effluent for PAH. But the 1993/4 data suggested that it was secondary treatment that altered the influent. It is logical that secondary treatment should preferentially remove the more volatile compounds like naphthalene due to the prolonged aeration available. Enhanced microbial degradation could also occur, especially in warmer months. The difference between 1995 and 1994 data for changes in the PAH Principal Component Analysis remain to be explained. The change for LABs in 1995 appears to be due to secondary treatment, consistent with 1994.

Recommendations for Monitoring- It is recommended that effluent characterizations should continue to ensure that the effluent signature is adequately determined, because changes in source characteristics may be useful for tracing the influence of the effluent within the receiving environment. Because of the low expected effluent contaminant concentrations and the high dilution expected, increases in the concentrations of contaminants in the water column will be very difficult to detect. Therefore, the monitoring program should continue to focus on chemical measurements in the effluents. Once the new outfall is operational, the program should also include confirmation of plume dynamics and verification of the predicted dilutions. Furthermore, measurements in the sediments and biota in the vicinity of the diffuser will be the most cost-effective method for evaluating contaminant fate and potential for impact. The significant reductions in loading that are expected from full secondary treatment must also be considered relative to monitoring of sediments for contaminants. The lower loading rate and expected dilution of the effluent by the diffuser mean it will take years before measurable changes in contaminant concentrations in the discharge sediments could possibly occur.

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APPENDIX A

CONTAMINANT AND NUTRIENT DATA

Trace Metals Concentrations

Pilot Treatment Plant:

MWRA ID	39500974	39500974	39500976	39500976	39500975	39500975	39502240	39502240	39502241	39502241	39502243	39502243
Bottle ID	E95A3BA	E95A3CA	E95A4BA	E95A4CA	E95A5BA	E95A5CA	E95C1BA	E95C1CA	E95C2BA	E95C2CA	E95C3BA	E95C3CA
Location	PI	PI	PP	PP	PS	PS	PI	PI	PP	PP	PS	PS
Collection Date	1/25/95	1/25/95	1/25/95	1/25/95	1/25/95	1/25/95	3/1/95	3/1/95	3/1/95	3/1/95	3/1/95	3/1/95
Sample Units	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L
Ag	4.16		3.37		1.30		4.77		3.36		0.57	
Cd	0.39		0.29		0.13		1.30		0.82		0.27	
Cr	3.98		3.12		1.38		29.70		5.29		1.56	
Cu	54.7		47.2		21.1		86.5		69.0		18.5	
Hg		44.5		43.7		16.5		74.0		97.5		10.1
Mo	12.20		10.70		9.58		8.87		7.69		7.10	
Ni	5.24		4.79		4.18		11.30		10.00		7.17	
Pb	6.82		5.74		3.27		45.80		31.80		2.36	
Zn	69.4		61.5		38.8		181.0		128.0		58.4	

Deer Island Effluent:

MWRA ID	39500225	39500226	39500226	39501905	39501905	39501906	39501906	39502737	39502737	39502738	39502738	
Bottle ID	E95A1BA	E95A2BA	E95A2CA	E95B1BA	E95B1CA	E95B2BA	E95B2CA	E95C4BA	E95C4CA	E95C5BA	E95C5CA	
Location	R	R	R	R	R	R	R	R	R	R	R	
Collection Date	1/11/95	1/13/95	1/13/95	2/15/95	2/15/95	2/17/95	2/17/95	3/14/95	3/14/95	3/16/95	3/16/95	
Sample Units	ug/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	
Ag	5.33	4.88		5.58		3.86		4.77		4.58		
Cd	1.50	0.52		0.34		0.58		0.40		0.36		
Cr	60.90	5.64		185.00		5.41		7.45		3.73		
Cu	55.4	56.4		52.5		55.0		53.8		51.2		
Hg	33.2		56.4		30.2		47.1		53.9		62.9	
Mo	9.97	9.71		9.91		9.86		9.61		12.00		
Ni	4.80	7.21		5.58		7.15		6.92		5.06		
Pb	6.65	6.01		4.30		14.70		10.20		8.08		
Zn	68.6	65.4		59.4		85.7		82.8		72.9		

Trace Metals Concentrations

Pilot Treatment Plant:

MWRA ID	39504810	39504810	39504812	39504812	39504814	39504814	39505820	39505820	39504812	39504812	39505822	39505822
Bottle ID	E95E2BA	E95E2CA	E95E3BA	E95E3CA	E95E4BA	E95E4CA	E95F2BA	E95F2CA	E95F3BA	E95F3CA	E95F4BA	E95F4CA
Location	PI	PI	PP	PP	PS	PS	PI	PI	PP	PP	PS	PS
Collection Date	5/10/95	5/10/95	5/10/95	5/10/95	5/10/95	5/10/95	6/14/95	6/14/95	6/14/95	6/14/95	6/14/95	6/14/95
Sample Units	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L
Ag	6.95		5.86		0.37		2.42		4.64		1.29	
Cd	0.44		0.36		0.13		0.44		0.37		0.20	
Cr	6.39		5.84		2.70		7.62		7.46		11.79	
Cu	77.6		63.8		16.1		74.2		61.6		21.6	
Hg		79.8		86.6		59.8		83.6		72.0		71.0
Mo	20.22		20.34		12.72		14.64		18.83		16.15	
Ni	5.11		4.84		3.30		5.08		4.43		4.35	
Pb	16.71		11.26		0.81		25.34		14.62		3.65	
Zn	99.2		79.2		26.8		109.1		80.2		50.9	

Deer Island Effluent:

MWRA ID	39503798	39503798	39503922	39503922	39504845	39504845	39504916	39504916	39505816	39505816		
Bottle ID	E95D1BA	E95D1CA	E95D2BA	E95D2CA	E95E1BA	E95E1CA	E95E5BA	E95E5CA	E95F1BA	E95F1CA	E95F5BA	E95F5CA
Location	R	R	R	R	R	R	R	R	R	R	R	R
Collection Date	4/12/95	4/12/95	4/14/95	4/14/95	5/10/95	5/10/95	5/12/95	5/12/95	6/14/95	6/14/95	6/16/95	6/16/95
Sample Units	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L
Ag	5.39		4.53		5.81		3.88		3.97		2.40	
Cd	0.31		0.40		0.60		0.45		0.45		0.42	
Cr	3.07		7.68		5.21		5.45		8.05		6.43	
Cu	54.6		65.6		73.6		70.1		63.7		66.7	
Hg		90.2		70.8		180.2		232.4		89.0		100.6
Mo	11.60		10.80		17.18		15.73		18.11		18.65	
Ni	20.40		7.45		4.98		5.40		4.56		5.83	
Pb	6.58		19.50		12.81		22.22		15.29		10.71	
Zn	67.8		106.0		86.9		100.1		84.8		73.9	

Trace Metals Concentrations

Pilot Treatment Plant:

MWRA ID	39506625	39506625	39506626	39506626	39506627	39506627	39506691	39506691	39506689	39506689	39506690	39506690
Bottle ID	E95G2BA	E95G2CA	E95G3BA	E95G3CA	E95G4BA	E95G4CA	E95H2BA	E95H2CA	E95H3BA	E95H3CA	E95H4BA	E95H4CA
Location	PI	PI	PP	PP	PS	PS	PI	PI	PP	PP	PS	PS
Collection Date	7/12/95	7/12/95	7/12/95	7/12/95	7/12/95	7/12/95	8/16/95	8/16/95	8/16/95	8/16/95	8/16/95	8/16/95
Sample Units	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L
Ag	2.53		0.61		0.05		4.93		5.67		0.50	
Cd	0.35		0.13		0.08		0.49		0.32		0.07	
Cr	4.47		2.91		1.60		17.36		8.74		2.94	
Cu	36.3		16.6		2.8		57.2		61.5		11.9	
Hg		74.8		49.8		62.4		72.0		79.8		74.0
Mo	20.98		27.78		1.28		16.54		20.54		13.86	
Ni	7.07		6.08		1.42		6.55		4.78		4.09	
Pb	14.23		1.73		2.69		22.12		12.26		1.29	
Zn	99.4		27.0		41.3		121.0		112.2		19.8	

Deer Island Effluent:

MWRA ID	39506615	39506615	39506616	39506616			39506685	39506685	39506686	39506686		
Bottle ID	E95G1BA	E95G1CA	E95G5BA	E95G5CA			E95H1BA	E95H1CA	E95H5BA	E95H5CA		
Location	R	R	R	R			R	R	R	R		
Collection Date	7/12/95	7/12/95	7/14/95	7/14/95			8/16/95	8/16/95	8/18/95	8/18/95		
Sample Units	ug/L	ng/L	ug/L	ng/L			ug/L	ng/L	ug/L	ng/L		
Ag	3.75		2.39				4.26		4.44			
Cd	0.62		0.40				1.72		0.57			
Cr	4.39		7.88				7.82		5.10			
Cu	61.1		72.9				103.0		81.2			
Hg		79.2		148.6				135.0		77.8		
Mo	26.87		20.72				19.47		22.57			
Ni	7.43		9.51				4.81		4.84			
Pb	12.16		13.42				10.05		12.73			
Zn	77.1		72.2				70.0		65.3			

Trace Metals Concentrations

Pilot Treatment Plant:

MWRA ID	39508681	39508681	39508682	39508682	39508683	39508683	39509599	39509599	39509598	39509598	39509597	39509597
Bottle ID	E95I2BA	E95I2CA	E95I3BA	E95I3CA	E95I4BA	E95I4CA	E95J2BA	E95J2CA	E95J3BA	E95J3CA	E95J4BA	E95J4CA
Location	PI	PI	PP	PP	PS	PS	PI	PI	PP	PP	PS	PS
Collection Date	9/13/95	9/13/95	9/13/95	9/13/95	9/13/95	9/13/95	10/12/95	10/12/95	10/12/95	10/12/95	10/12/95	10/12/95
Sample Units	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L
Ag	5.57		5.61		0.59		5.59		4.59		0.41	
Cd	0.36		0.29		0.13		0.33		0.29		0.13	
Cr	5.46		5.81		2.25		5.54		5.09		1.99	
Cu	62.8		64.6		9.3		63.0		54.7		8.0	
Hg		402.0		256.0		8.0		184.0		192.0		140.0
Mo	12.55		19.49		14.21		12.74		12.67		10.00	
Ni	5.39		6.05		5.01		5.51		5.28		4.36	
Pb	9.39		12.74		1.30		9.08		7.69		2.07	
Zn	64.2		63.0		13.4		64.3		69.7		26.1	

Deer Island Effluent:

MWRA ID		39508687	39508687				39509590	39509590	39509591	39509591	39510520	39510520
Bottle ID		E95I1BA	E95I1CA				E95J1BA	E95J1CA	E95J5BA	E95J5CA		
Location		R	R				R	R	R	R		
Collection Date		9/13/95	9/13/95				10/12/95	10/12/95	10/16/95	10/16/95		
Sample Units		ug/L	ng/L				ug/L	ng/L	ug/L	ng/L		
Ag		4.73					4.05		1.30			
Cd		0.29					0.28		0.31			
Cr		3.80					4.29		4.51			
Cu		74.5					49.6		62.4			
Hg			274.0					158.0		80.0		
Mo		19.73					12.51		10.97			
Ni		5.93					5.00		4.23			
Pb		8.94					6.67		12.28			
Zn		62.8					49.4		61.7			

Trace Metals Concentrations

Pilot Treatment Plant:

MWRA ID	39510512	39510512	39510513	39510513	39510514	39510514	39511226	39511226	39511227	39511227	39511228	39511228
Bottle ID	E95K2BA	E95K2CA	E95K3BA	E95K3CA	E95K4BA	E95K4CA	E95L2BA	E95L2CA	E95L3BA	E95L3CA	E95L4BA	E95L4CA
Location	PI	PI	PP	PP	PS	PS	PI	PI	PP	PP	PS	PS
Collection Date	11/15/95	11/15/95	11/15/95	11/15/95	11/15/95	11/15/95	12/13/95	12/13/95	12/13/95	12/13/95	12/13/95	12/13/95
Sample Units	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L
Ag	1.43		2.83		0.34		4.91		4.77		0.71	
Cd	0.79		0.48		0.23		0.30		0.30		0.14	
Cr	4.99		4.14		1.47		5.46		4.75		1.74	
Cu	64.6		43.8		13.2		69.0		59.8		16.2	
Hg		100.0		82.0		18.0		120.0		54.0		16.0
Mo	8.25		12.64		11.08		9.41		10.70		8.84	
Ni	5.76		4.85		3.96		3.76		3.74		3.36	
Pb	72.19		30.59		1.26		9.00		7.11		1.38	
Zn	254.7		151.0		25.9		76.5		62.4		24.0	

Deer Island Effluent:

MWRA ID	39510519	39510519						39511229	39511229	39511230	39511230	
Bottle ID		E95K1BA	E95K1CA	E95K5BA	E95K5CA			E95L1BA	E95L1CA	E95L5BA	E95L5CA	
Location		R	R	R	R			R	R	R	R	
Collection Date		11/15/95	11/15/95	11/17/95	11/17/95			12/13/95	12/13/95	12/15/95	12/15/95	
Sample Units		ug/L	ng/L	ug/L	ng/L			ug/L	ng/L	ug/L	ng/L	
Ag		2.30		1.68				3.81		3.08		
Cd		0.50		0.32				0.39		0.58		
Cr		5.42		3.91				3.39		3.35		
Cu		46.7		57.9				74.4		73.7		
Hg			76.0		78.0				104.0		52.0	
Mo		10.08		9.21				10.12		10.62		
Ni		5.43		4.51				3.36		4.01		
Pb		29.18		9.92				5.48		5.60		
Zn		136.4		66.9				50.4		56.1		

Concentrations of

MWRA ID	39506616	39506616	39506685	39506685	39506691	39506691	39506689	39506689	39506690	39506690	39506686
Bottle ID	E95G5BA	E95G5CA	E95H1BA	E95H1CA	E95H2BA	E95H2CA	E95H3BA	E95H3CA	E95H4BA	E95H4CA	E95H5BA
Location	R	R	R	R	PI	PI	PP	PP	PS	PS	R
Collection Date	7/14/95	7/14/95	8/16/95	8/16/95	8/16/95	8/16/95	8/16/95	8/16/95	8/16/95	8/16/95	8/18/95
Sample Units	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L
Ag	2.39		4.26		4.93		5.67		0.50		4.44
Cd	0.40		1.72		0.49		0.32		0.07		0.57
Cr	7.88		7.82		17.36		8.74		2.94		5.10
Cu	72.9		103.0		57.2		61.5		11.9		81.2
Hg		148.6		135.0		72.0		79.8		74.0	
Mo	20.72		19.47		16.54		20.54		13.86		22.57
Ni	9.51		4.81		6.55		4.78		4.09		4.84
Pb	13.42		10.05		22.12		12.26		1.29		12.73
Zn	72.2		70.0		121.0		112.2		19.8		65.3

Concentrations of												
MWRA ID	39506686	39508687	39508687	39508681	39508681	39508682	39508682	39508683	39508683	39509590	39509590	39509599
Bottle ID	E95H5CA	E95I1BA	E95I1CA	E95I2BA	E95I2CA	E95I3BA	E95I3CA	E95I4BA	E95I4CA	E95J1BA	E95J1CA	E95J2BA
Location	R	R	R	PI	PI	PP	PP	PS	PS	R	R	PI
Collection Date	8/18/95	9/13/95	9/13/95	9/13/95	9/13/95	9/13/95	9/13/95	9/13/95	9/13/95	10/12/95	10/12/95	10/12/95
Sample Units	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L
Ag		4.73		5.57		5.61		0.59		4.05		5.59
Cd		0.29		0.36		0.29		0.13		0.28		0.33
Cr		3.80		5.46		5.81		2.25		4.29		5.54
Cu		74.5		62.8		64.6		9.3		49.6		63.0
Hg	77.8		274.0		402.0		256.0		8.0		158.0	
Mo		19.73		12.55		19.49		14.21		12.51		12.74
Ni		5.93		5.39		6.05		5.01		5.00		5.51
Pb		8.94		9.39		12.74		1.30		6.67		9.08
Zn		62.8		64.2		63.0		13.4		49.4		64.3

Concentrations of

MWRA ID	39509599	39509598	39509598	39509597	39509597	39509591	39509591	39510520	39510520	39510512	39510512	39510513
Bottle ID	E95J2CA	E95J3BA	E95J3CA	E95J4BA	E95J4CA	E95J5BA	E95J5CA	E95K1BA	E95K1CA	E95K2BA	E95K2CA	E95K3BA
Location	PI	PP	PP	PS	PS	R	R	R	R	PI	PI	PP
Collection Date	10/12/95	10/12/95	10/12/95	10/12/95	10/12/95	10/16/95	10/16/95	11/15/95	11/15/95	11/15/95	11/15/95	11/15/95
Sample Units	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L
Ag		4.59		0.41		1.30		2.30		1.43		2.83
Cd		0.29		0.13		0.31		0.50		0.79		0.48
Cr		5.09		1.99		4.51		5.42		4.99		4.14
Cu		54.7		8.0		62.4		46.7		64.6		43.8
Hg	184.0		192.0		140.0		80.0		76.0		100.0	
Mo		12.67		10.00		10.97		10.08		8.25		12.64
Ni		5.28		4.36		4.23		5.43		5.76		4.85
Pb		7.69		2.07		12.28		29.18		72.19		30.59
Zn		69.7		26.1		61.7		136.4		254.7		151.0

Concentrations of												
MWRA ID	39510513	39510514	39510514	39510519	39510519	39511229	39511229	39511226	39511226	39511227	39511227	39511228
Bottle ID	E95K3CA	E95K4BA	E95K4CA	E95K5BA	E95K5CA	E95L1BA	E95L1CA	E95L2BA	E95L2CA	E95L3BA	E95L3CA	E95L4BA
Location	PP	PS	PS	R	R	R	R	PI	PI	PP	PP	PS
Collection Date	11/15/95	11/15/95	11/15/95	11/17/95	11/17/95	12/13/95	12/13/95	12/13/95	12/13/95	12/13/95	12/13/95	12/13/95
Sample Units	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L	ng/L	ug/L
Ag		0.34		1.68		3.81		4.91		4.77		0.71
Cd		0.23		0.32		0.39		0.30		0.30		0.14
Cr		1.47		3.91		3.39		5.46		4.75		1.74
Cu		13.2		57.9		74.4		69.0		59.8		16.2
Hg	82.0		18.0		78.0		104.0		120.0		54.0	
Mo		11.08		9.21		10.12		9.41		10.70		8.84
Ni		3.96		4.51		3.36		3.76		3.74		3.36
Pb		1.26		9.92		5.48		9.00		7.11		1.38
Zn		25.9		66.9		50.4		76.5		62.4		24.0

Concentrations of			
MWRA ID	39511228	39511230	39511230
Bottle ID	E95L4CA	E95L5BA	E95L5CA
Location	PS	R	R
Collection Date	12/13/95	12/15/95	12/15/95
Sample Units	ng/L	ug/L	ng/L
Ag		3.08	
Cd		0.58	
Cr		3.35	
Cu		73.7	
Hg	16.0		52.0
Mo		10.62	
Ni		4.01	
Pb		5.60	
Zn		56.1	

Nutrients

MWRA ID	39500974		39500976		39500975		39501907		39502824		39503799		39503923		39504846		39504920		39504918	
ENSR ID	E95A3		E95A4		E95A5		E95B1		E95C4		E95D1		E95D2		E95E1		E95E2		E95E3	
Location	PI		PP		PS		R		R		R		R		R		PI		PP	
Collection Date	1/25/95		1/25/95		1/25/95		2/15/95		3/14/95		4/12/95		4/14/95		5/10/95		5/10/95		5/10/95	
Biogenic Si (uM)	12.9	k	11.6	k	5.6	j	18.3	k	30.9	k	40.9	k	22.2	k	23.7	k	45.9	k	26.3	k
Silicate (uM)	360		377		363		363		409		402		352		409		456		477	
NH3 (uM)	827		891		976		1000		964		1205		681		1266		1468		1275	
NO2 (uM)	1.4		0.0	U	0.7		2.9		1.6		0.9		1.4		1.2		0.3		0.2	
NO3 (uM)	0.0	U	0.0	U	0.0	U	7.4		42.9		1.4		2.8		3.6		2.1		1.4	
PON (uM)	397		252		164		216		200		217		243		170		280		490	
TKN (uM)	857		979		1050		896		696		1326		1166		2113		2293		1614	
POC (uM)	4368		2862		1183		3064		2847		2573		3171		2425		6541		4522	
DOC (uM)	1499		1499		749		5079		4163		4163		3664		4080		3164		3331	
Part. Phosp. (uM)	0.46		0.52		0.53		0.58		0.76		18.08		19.70		37.78		35.84		31.22	
TDP (uM)	41.7		42.0		23.2		59.1		50.4		11.6		47.5		56.5		57.8		58.4	
PO4 (uM)	17.0		19.6		9.3		30.9		5.5		5.1		0.8		0.4		17.7		18.1	
Urea (uM)	6.65		6.14		4.14		10		11		4.86		6.5		3.2		2.95		2.41	

Nutrients

MWRA ID	39504919		39504917		39505819		39505823		39505824		39505825		39505818		39506613		39506628		39506629	
ENSR ID	E95E4		E95E5		E95F1		E95F2		E95F3		E95F4		E95F5		E95G1		E95G2		E95G3	
Location	PS		R		R		PI		PP		PS		R		R		PI		PP	
Collection Date	5/10/95		5/12/95		6/14/95		6/14/95		6/14/95		6/14/95		6/16/95		7/12/95		7/12/95		7/12/95	
Biogenic Si (uM)	1.	k	24.6	k	22.2	k	23.9	k	20.4	k	10.8	k	17.8	k	18.2	k	27.4	k	22.3	k
Silicate (uM)	313		231		466		438		562		292		420		506		431		562	
NH3 (uM)	1134		801		1121		879		1179		1221		1407		0		801		1159	
NO2 (uM)	1.6		0.7		1.0		0.0		0.2		2.4		1.3		0.9		0.1		0.0	
NO3 (uM)	2.9		2.1		2.8		0.0	U	0.0	U	1.6		1.9		5.0		0.0	ND	0.0	ND
PON (uM)	377		39		235		210		282		271		57		204		158		286	
TKN (uM)	2271		1190		1929		1293		1714		1536		1643		1079		1127		1134	
POC (uM)	268		2434		2426		4078		2728		457		2615		2137		3941		2133	
DOC (uM)	916		1749		4746		1832		2748		833		3414		2914		1832		2415	
Part. Phosp. (uM)	4.71		26.12		19.99		30.42		26.22		13.56		28.90		19.60		44.88		11.53	
TDP (uM)	37.8		38.4		50.7		46.2		52.3		43.3		52.6		53.3		46.8		53.6	
PO4 (uM)	10.2		11.9		4.7		19.4		24.6		16.2		21.1		16.6		15.9		17.9	
Urea (uM)	3.36		6.11		7.55		7		2.63		3.58		8.61		3.94		4.84		4.52	

Nutrients

MWRA ID	39506630		39506614		39506685		39506692		39506693		39506694		39506688		39508689		39508684		39508685	
ENSR ID	E95G4		E95G5		E95H1		E95H2		E95H3		E95H4		E95H5		E95I1		E95I2		E95I3	
Location	PS		R		R		PI		PP		PS		R		R		PI		PP	
Collection Date	7/12/95		7/14/95		8/16/95		8/16/95		8/16/95		8/16/95		8/18/95		9/13/95		9/13/95		9/13/95	
Biogenic Si (uM)	3.8	k	19.5	k	21.4	k	28.7	k	19.9	k	4.4	k	18.6	k	21.2	k	34.7	k	24.2	k
Silicate (uM)	285		484		285		466		466		260		231		309		352		349	
NH3 (uM)	941		0		1629		1079		1514		1644		979		0		1729		1693	
NO2 (uM)	3.6		0.9		0.9		0.4		0.4		3.4		0.8		1.0		0.3		0.4	
NO3 (uM)	2.9		13.6		5.7		0.0	ND	0.0	ND	9.3		0.0	ND	3.6		0.0	u	0.0	u
PON (uM)	212		35		197		201		307		216		43		237		218		448	
TKN (uM)	1047		2257		1562		1922		2109		986		1772		1817		1824		2346	
POC (uM)	220		2370		2227		4095		2028		247		2577		2644		6003		2620	
DOC (uM)	749		3247		4080		3164		4246		916		3830		4663		4829		5995	
Part. Phosp. (uM)	2.10		29.06		21.18		26.25		23.44		5.36		34.42		21.47		33.58		20.15	
TDP (uM)	26.5				55.2		83.6		99.1		45.2		110.4		0.0		123.3		114.9	
PO4 (uM)	6.6		18.1		16.5		16.8		17.7		11.9		17.8		31.6		37.9		33.7	
Urea (uM)	4.69		3.74		4.08		2.22		2.76		4.6		5.24		5.82		4.23		4.69	

Nutrients

MWRA ID	39508686		39508690		39509592		39509594		39509595		39509596		39509593		39510518		39510517		39510516
ENSR ID	E95I4		E95I5		E95J1		E95J2		E95J3		E95J4		E95J5		E95K1		E95K2		E95K3
Location	PS		R		R		PI		PP		PS		R		R		PI		PP
Collection Date	9/13/95		9/15/95		10/12/95		10/12/95		10/12/95		10/12/95		10/16/95		11/15/95		11/15/95		11/15/95
Biogenic Si (uM)	4.9	k	22.9	k	10.5	k	29.	k	19.6	k	1.7	k	19.7	k	16.8	k	10.6	k	12.8
Silicate (uM)	274		310		388		363		445		295		506		231		427		463
NH3 (uM)	1671		1471		1836		2344		2443		2132		2022		215		447		636
NO2 (uM)	0.5		1.4		2.9		0.6		0.9		5.4		1.2		1.3		1.1		1.1
NO3 (uM)	0.0	u	15.9		2.9		4.1		4.1		6.6		3.0		127.1		109.3		0.0
PON (uM)	254		158		310		198		353		261		29		210		154		176
TKN (uM)	1735		1848		2179		1967		1714		1923		1492		1492		285		602
POC (uM)	900		2175		2218		4255		2314		208		2299		0		1583		1405
DOC (uM)	1166		4996		4663		BROKEN BOTTLE		5079		666		3664		583		666		999
Part. Phosp. (uM)	12.08		24.93		8.72		34.55		25.51		2.91		11.30		12.27		20.99		19.05
TDP (uM)	112.7		99.8		310.0		344.8		368.7		213.8		295.1		11.6		17.8		33.6
PO4 (uM)	34.7		31.5		27.8		29.6		31.4		18.3		24.7		3.1		4.8		9.9
Urea (uM)	4.36		4.94		5.22		3.15		3.51		4.92		7.25		14.6		35.98		16.72

Nutrients

MWRA ID		39510515		39510519		39511231		39511233		39511234		39511235		39511232	
ENSR ID		E95K4		E95K5		E95L1		E95L2		E95L3		E95L4		E95L5	
Location		PS		R		R		PI		PP		PS		R	
Collection Date		11/15/95		11/17/95		12/13/95		12/13/95		12/13/95		12/13/95		12/15/95	
Biogenic Si (uM)	k	2.4	k	32.5	k	15.6	k	27.9	k	24.1	k	9.6	k	18.2	k
Silicate (uM)		328		392		374		488		495		299		349	
NH3 (uM)		711		662		1574		1655		1765		1721		1744	
NO2 (uM)		2.4		9.3		0.8		0.2		0.2		0.3		3.6	
NO3 (uM)	u	17.9		50.0		7.1		2.1		1.4		6.4		3.6	
PON (uM)		2		137		251		495		292		17		218	
TKN (uM)		737		723		1461		1549		1570		1389		1729	
POC (uM)		16		1292		2575		6104		2818		146		2171	
DOC (uM)		583		1499		3164		2998		3164		999		3664	
Part. Phosp. (uM)		3.55		19.70		24.86		34.87		28.09		6.78		20.99	
TDP (uM)		25.2		38.7		84.3		85.9		84.9		61.0		77.8	
PO4 (uM)		6.8		11.6		21.5		47.4		46.2		35.9		23.2	
Urea (uM)		5.65		43.07		3.64		2.05		3.56		4.24		4.79	

Stable Isotopes

MWRA ID	39501907	39502824	39503799	39503923	39504846	39504917	39505819	39505818	39506613
Bottle_ID	E95B1LA	E95C4LA	E95D1LA	E95D2LA	E95E1LA	E95E5LA	E95F1LA	E95F5LA	E95G1LA
Location	R	R	R	R	R	R	R	R	R
Collection Date	2/15/95	3/14/95	4/12/95	4/14/95	5/10/95	5/12/95	6/14/95	6/16/95	7/12/95
Sample Units	NA	NA	NA	NA	NA	NA	NA	NA	NA
del 15n(air)	3.6	2	-0.3	0.2	0.3	-0.1	0.3	0.4	-0.5

MWRA ID	39501907	39502824	39503799	39503923	39504846	39504917	39505819	39505818	39506613
Bottle_ID	E95B1MA	E95C4MA	E95D1MA	E95D2MA	E95E1MA	E95E5MA	E95F1MA	E95F5MA	E95G1MA
Location	R	R	R	R	R	R	R	R	R
Collection Date	2/15/95	3/14/95	4/12/95	4/14/95	5/10/95	5/12/95	6/14/95	6/16/95	7/12/95
Sample Units	NA	NA	NA	NA	NA	NA	NA	NA	NA
del 34s(ctd)	7.4	NA	4.2	NA	3.8	3.9	5.6	3.1	3.5

NA = Not analyzed, not enough material present on the filter to process.

Stable Isotopes

MWRA ID	39506614	39506687	39506688	39508689	39509592	39510518	39510519	39511231
Bottle_ID	E95G5LA	E95H1LA	E95H5LA	E95I1LA	E95J1LA	E95K1LA	E95K5LA	E95L1LA
Location	R	R	R	R	R	R	R	R
Collection Date	7/14/95	8/16/95	8/18/95	9/13/95	10/12/95	11/15/95	11/17/95	12/13/95
Sample Units	NA	NA	NA	NA	NA	NA	NA	NA
del 15n(air)	-0.6	0	-0.5	-0.2	0.3	-0.2	-0.9	0.3

MWRA ID	39506614	39506687	39506688	39508689	39509592	39510518	39510519	39511231
Bottle_ID	E95G5LA	E95H1MA	E95H5MA	E95I1MA	E95J1MA	E95K1MA	E95K5MA	E95L1MA
Location	R	R	R	R	R	R	R	R
Collection Date	7/14/95	8/16/95	8/18/95	9/13/95	10/12/95	11/15/95	11/17/95	12/13/95
Sample Units	NA	NA	NA	NA	NA	NA	NA	NA
del 34s(ctd)	5.3	NA	4.8	5.2	5.9	NA	4	3.9

NA = Not analyzed, not enough material present on the filter to process.

Clostridium Perfringens - 1995 data

MWRA ID	39500225	39500226	39501907	39502737	39502738	39502738	39502737	39502738	39503798
Bottle_ID	E95A1DA	E95A2DA	E95B1DA	E95C1DA	E95C2DA	E95C3DA	E95C4DA	E95C5DA	E95D1DA
Location	R	R	R	PI	PP	PS	R	R	R
Collection Date	1/11/95	1/13/95	2/15/95	3/1/95	3/1/95	3/1/95	3/14/95	3/16/95	4/12/95
Sample Units	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml
C. perfringens	600	14,000	15,000	49,000	34,000	6,000	10,000	16,000	8,000
MWRA ID	39503922	39504845	39504916	39505816	39505817	39506615	39506616	39506685	39506686
Bottle_ID	E95D2DA	E95E1DA	E95E5DA	E95F1DA	E95F5DA	E95G1DA	E95G5DA	E95H1DA	E95H5DA
Location	R	R	R	R	R	R	R	R	R
Collection Date	4/14/95	5/10/95	5/12/95	6/14/95	6/16/95	7/12/95	7/14/95	8/16/95	8/18/95
Sample Units	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml
C. perfringens	11,000	900	700	1,700	4,200	3,400	1,600	1,700	360
MWRA ID	39508687	39509590	39509591	39510518	39510517	39511229	39511230		
Bottle_ID	E95I1DA	E95J1DA	E95J5DA	E95K1DA	E95K2DA	E95L1DA	E95L5DA		
Location	R	R	R	R	R	R	R		
Collection Date	9/13/95	10/12/95	10/16/95	11/15/95	11/17/95	12/13/95	12/15/95		
Sample Units	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml	spores/100ml		
C. perfringens	1,400	2,400	1,900	3,800	6,300	8,300	4,000		

PCBs and Pesticides, Field Samples

MWRA ID	39500225	39500226	39500974	39500976	39500975	39501905	39501906	39502240	39502241	39502243	39502737	39502738	39503798	39504845
Bottle ID	E95A1AA	E95A2AA	E95A3AA	E95A4AA	E95A5AA	E95B1AA	E95B2AA	E95C1AA	E95C2AA	E95C3AA	E95C4AA	E95C5AA	E95D1AA	E95E1AA
Location	R	R	PI	PP	PS	R	R	PI	PP	PS	R	R	R	R
Collection Date	01/11/95	01/13/95	01/25/95	01/25/95	01/25/95	02/15/95	02/17/95	03/01/95	03/01/95	03/01/95	03/14/95	03/16/95	4/12/95	5/10/95
Sample Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
2,4,-Cl2 (8)	ND	ND	N	1.3	13 G	47	ND	ND	N	7.3	ND	ND	ND	ND
Hexachlorobenzene	13	10	ND	ND	N	20	43	1.3	1.7	0.4 J	26	27	1.3	2.3
Gamma-BHC	32	13	4.4	14	4.4	25	14	ND	N	3.3	23	9	9.6	5
2,2',5-Cl3 (18)	48 G	24 G	N	24 G	3.4	25 G	51 G	ND	ND	ND	ND	ND	1.6	ND
2,4,4'-Cl3 (28)	ND	ND	ND	ND	5.4	N	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	7.8	6.5	11	ND	ND	ND	N	11	12	5.7	15	15	ND	ND
2,2',5,5'-Cl4 (52)	ND	ND	ND	ND	ND	N	ND	ND	ND	N	2.8	21	ND	ND
Aldrin	ND	ND	ND	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,5'-Cl4 (44)	ND	ND	ND	ND	ND	N	N	3.2	ND	ND	ND	ND	ND	ND
Heptachloroepoxide	ND	ND	ND	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	ND
2,3',4,4'-Cl4 (66)	ND	ND	ND	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	ND
DDMU	ND	ND	ND	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	ND
2,4'-DDE	ND	ND	ND	ND	N	15	ND	ND	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Cl5 (101)	ND	N	6.3	ND	ND	N	N	8.7	5.5	ND	ND	ND	1.1	1.3
ALPHA-CHLORDANE	N	1.9	1.6	ND	ND	N	N	4.7	4.2	N	2.7	ND	2.2	1.7
TRANS-NONACHLOR	4	ND	ND	ND	1.3	N	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	ND	ND	ND	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	ND
4,4'-DDE	1.9	ND	ND	ND	N	5	ND	ND	ND	N	5.7	4.8	2.8	2
3,3',4,4'-Cl4 (77)	ND	ND	ND	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	ND
2,4'-DDD	N	0.32 J	ND	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	2.2
Endrin	ND	ND	ND	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Cl5 (118)	N	1	ND	ND	N	2.8	ND	ND	1.8	N	2.9	2.4	2.4	2.2
4,4'-DDD	1.2	0.54 J	ND	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	ND
2,4'-DDT	ND	ND	ND	ND	ND	N	N	4.3	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Cl6 (153)	2.4	N	2.2	ND	ND	N	4.3	5	1.7	N	4.4	ND	0.52	2.3
2,3,3',4,4'-Cl5 (105)	N	0.19 J	ND	ND	1.9	N	0.64 J	ND	ND	ND	ND	ND	ND	ND
4,4'-DDT	7.4	5.4	ND	ND	3.4	N	7.4	10	10	N	4.7	12	8.7	3.7
2,2',3,4,4',5'-Cl6 (138)	1.8	2.2	0.56 J	ND	0.86	1.7	4.5	5.2	1.6	N	3.9	2.3	0.94	1.3
3,3',4,4',5-Cl5 (126)	ND	N	2.6	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,5,5',6-Cl7 (187)	ND	ND	ND	ND	ND	N	ND	ND	ND	ND	ND	ND	ND	3.1
2,2',3,3',4,4'-Cl6 (128)	ND	ND	ND	ND	ND	N	N	2.2	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5'-Cl7 (180)	44	40	N	30	16	N	ND	ND	ND	ND	ND	ND	ND	1.8
Mirex	ND	N	3.2	ND	ND	N	N	2.5	1.9	ND	ND	ND	ND	ND
2,2',3,3',4,4',5-Cl7 (170)	0.96 J	0.59 J	N	1.5 J	5.8	0.67 J	ND	ND	1.2 J	4.8	0.97 J	0.8 J	ND	0.68
2,2',3,3',4,4',5,6-Cl8 (195)	ND	ND	N	1.7	ND	N	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Cl9 (206)	1.4	N	3.7	0.87 J	5	1.7	2.5	1.6	1.6	N	1.6	1.5	ND	ND
Decachlorobiphenyl-Cl10 (209)	ND	N	5.9	ND	ND	N	0.42	1.4	1.5	N	1.7	ND	ND	ND
Total PCB	98.56	67.98	21.26	59.37	51.36	78.87	63.36	27.3	14.9	12.1	18.27	28	6.56	12.68
Total DDT	10.5	6.26	0	0	3.4	20	7.4	14.3	10	0	10.4	16.8	11.5	7.9
Total Chlordane	11.8	8.4	12.6	0	1.3	0	0	15.7	16.2	5.7	17.7	15	2.2	1.7

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PP = Pilot Plant Primary effluent; Pilot Plant Secondary effluent

PCBs and Pesticides, Field Samples

MWRA ID	39504810	39504812	39504814	39504916	39505816	39505820	39504812	39505822	39505817	39506615	39506625	39506626	39506627	39506616
Bottle ID	E95E2AA	E95E3AA	E95E4AA	E95E5AA	E95F1AA	E95F2AA	E95F3AA	E95F4AA	E95F5AA	E95G1AA	E95G2AA	E95G3AA	E95G4AA	E95G5AA
Location	PI	PP	PS	R	R	PI	PP	PS	R	R	PI	PP	PS	R
Collection Date	5/10/95	5/10/95	5/10/95	5/12/95	6/19/95	6/14/95	6/14/95	6/14/95	6/16/95	7/12/95	7/12/95	7/12/95	7/12/95	7/14/95
Sample Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
2,4,-Cl2 (8)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	ND	ND	ND	1	0.46	ND	2.2	ND	1.8	0.91 J	1.9	1	ND	ND
Gamma-BHC	4.3	4	5	4.2	28	29	24	12	15	57 J	51 J	41 J	11 J	19 J
2,2',5-Cl3 (18)	ND	ND	0.86	ND	51 G	108 G	85 G	2.0	85 G	100 G	200 G	210 G	2.4	160 G
2,4,4'-Cl3 (28)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',5,5'-Cl4 (52)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,5'-Cl4 (44)	ND	ND	ND	ND	ND	0.84	ND	ND	ND	ND	ND	ND	ND	ND
Heptachloroepoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.4	ND	ND	ND
2,3',4,4'-Cl4 (66)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DDMU	ND	ND	ND	ND	0.16	1.3	0.97	ND	0.25	0.23 J	2.9	4.7	ND	0.26 J
2,4'-DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Cl5 (101)	4.8	8.4	ND	1.8	3.0	4.4	2.5	0.90	2.5	3.6	4	3.6	ND	4
ALPHA-CHLORDANE	1.5	2.7	ND	1.4	3.7	3.7	2.5	1.0	2.8	3.1	2.2	2.4	ND	2.8
TRANS-NONACHLOR	ND	ND	ND	ND	3.4	3.8	3.4	1.7	3.4	3.6	3.7	3.8	ND	2.2
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4'-DDE	ND	ND	ND	1.5	ND	5.9	ND	ND	4.7	3.8	6.1	7.1	0.49	4.2
3,3',4,4'-Cl4 (77)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.5	11 G
2,4'-DDD	ND	ND	ND	ND	1.1	3.5	2.0	0.19	0.97	1.4	ND	1.9	ND	1.5
Endrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Cl5 (118)	ND	ND	ND	2.4	5.5	5.7	2.7	1.5	4.3	4.8	ND	4.8	ND	5
4,4'-DDD	0.69	ND	ND	1.5	3.7	3.4	1.8	0.48	3.5	ND	ND	ND	ND	2.2
2,4'-DDT	ND	ND	ND	ND	3.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Cl6 (153)	3.6	2.3	ND	3.3	4.9	6.2	3.5	0.40	1.6	1.8	4.2	2.2	ND	3.2
2,3,3',4,4'-Cl5 (105)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.97 J	ND	ND	ND
4,4'-DDT	8.1	8.7	ND	4.4	22 J	42 J	20 J	ND	13 J	4.4	6.8	2.8	1.5	4.4
2,2',3,4,4',5'-Cl6 (138)	31	1.6	ND	1.4	2.1	3.2	1.6	ND	2.3	2	2.2	2.4	ND	1.9
3,3',4,4',5-Cl5 (126)	ND	ND	ND	ND	ND	1.4	1.1	ND	0.73	ND	ND	ND	ND	ND
2,2',3,4,5,5',6-Cl7 (187)	3.7	1.8	ND	4.7	4.6	ND	ND	0.25	2.8	6.9	4.6	3.6	ND	6
2,2',3,3',4,4'-Cl6 (128)	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.58 J	ND	ND	ND	0.64 J
2,2',3,4,4',5,5'-Cl7 (180)	ND	ND	ND	ND	ND	ND	ND	ND	ND	66	63	66	12	62
Mirex	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5-Cl7 (170)	0.91	0.65	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,6-Cl8 (195)	0.96	0.6	ND	0.64	0.67	1.5	0.73	0.48	0.57	0.86 J	1.1	0.95 J	ND	1
2,2',3,3',4,4',5,5',6-Cl9 (206)	ND	ND	0.02	0.39	0.62	1.4	0.85	0.23	0.27	ND	0.37 J	0.35 J	ND	0.74 J
Decachlorobiphenyl-Cl10 (209)	0.92	ND	ND	ND	0.42	ND	ND	ND	0.068 J	ND	ND	ND	ND	ND
Total PCB	45.89	15.35	0.88	14.63	73.15789	132.2278	97.8481	5.833333	99.99241	186.54	280.44	293.9	15.9	255.48
Total DDT	8.79	8.7	0	7.4	30.75	54.68354	24.05063	0.666667	21.86076	9.6	12.9	11.8	1.89	12.3
Total Chlordane	1.5	2.7	0	1.4	7.105263	7.468354	5.949367	2.690476	6.202532	6.7	12.3	6.2	0	5

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PP = Pilot Plant Primary effluent; Pilot Plant Secondary effluent

PCBs and Pesticides, Field Samples

MWRA ID	39506685	39506691	39506689	39506690	39506686	39508687	39508681	39508682	39508683	39509590	39509599	39509598	39509597	39509591
Bottle ID	E95H1AA	E95H2AA	E95H3AA	E95H4AA	E95H5AA	E95I1AA	E95I2AA	E95I3AA	E95I4AA	E95J1AA	E95J2AA	E95J3AA	E95J4AA	E95J5AA
Location	R	PI	PP	PS	R	R	PI	PP	PS	R	PI	PP	PS	R
Collection Date	8/16/95	8/16/95	8/16/95	8/16/95	8/16/95	9/13/95	9/13/95	9/13/95	9/13/95	10/12/95	10/12/95	10/12/95	10/12/95	10/16/95
Sample Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
2,4,-Cl2 (8)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	ND	0.66 J	0.33 J	ND	ND	ND	0.84	0.49	ND	ND	ND	0.38	ND	1.6
Gamma-BHC	28	17	17	7.1	26	16	24	18	8.7	9.7	11	9.5	3.8	9.5
2,2',5-Cl3 (18)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.6	ND
2,4,4'-Cl3 (28)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',5,5'-Cl4 (52)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,5'-Cl4 (44)	1.9	1 J	ND	ND	1.6	2.2	ND	ND	ND	ND	ND	ND	ND	ND
Heptachloroepoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3',4,4'-Cl4 (66)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DDMU	ND	ND	0.87 J	ND	ND	0.51	1.2	1.4	ND	ND	ND	ND	ND	ND
2,4'-DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Cl5 (101)	5.2	6.5	3.3	ND	5.8	3.1	5.1	3.5	ND	3	3	ND	ND	2.4
ALPHA-CHLORDANE	3.8	2.7	1.8	ND	3.6	3.1	4.5	3.5	ND	1.5	1.9	1.7	ND	2
TRANS-NONACHLOR	4.6	ND	ND	ND	ND	5.9	5.8	4.6	ND	ND	ND	ND	ND	3
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4'-DDE	8.4	7.2	7.7	ND	7.2	3.7	9.1	7.8	ND	2.7	3.1	3.1	ND	2.1
3,3',4,4'-Cl4 (77)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4'-DDD	3.2	ND	ND	ND	2.2	2	6.1	2.6	ND	ND	1.2	ND	ND	0.64
Endrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Cl5 (118)	7.4	ND	ND	ND	7.2	4.1	6.4	4.3	ND	2.4	4	2.9	ND	3.2
4,4'-DDD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4'-DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Cl6 (153)	6.4	6.5	1.4	ND	7.6	3.8	8	9.9	ND	0.86	4.5	1.2	ND	3.5
2,3,3',4,4'-Cl5 (105)	ND	ND	ND	ND	ND	0.77	1.4	ND	ND	ND	ND	ND	ND	ND
4,4'-DDT	18	9.4	5.1	ND	7.6	6.3	8.5	7.1	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5'-Cl6 (138)	3.2	3.3	2.2	0.63 J	2.8	2.2	3.1	2	1.3	ND	ND	ND	3.9	1.4
3,3',4,4',5-Cl5 (126)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,5,5',6-Cl7 (187)	5.2	3.1	1.3	ND	ND	ND	ND	ND	ND	1.2	1.9	1.2	0.32	4.1
2,2',3,3',4,4'-Cl6 (128)	1.6	ND	ND	ND	0.72 J	ND	ND	1.4	ND	0.22	0.67	0.58	ND	0.5
2,2',3,4,4',5,5'-Cl7 (180)	2.4	2.8	1.7	ND	ND	1.3	ND	ND	ND	ND	ND	ND	ND	ND
Mirex	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5-Cl7 (170)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,6-Cl8 (195)	ND	2.7	1.5	ND	ND	1	1.5	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Cl9 (206)	ND	ND	ND	ND	ND	0.38	0.29	ND	ND	ND	ND	ND	ND	ND
Decachlorobiphenyl-Cl10 (209)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total PCB	33.3	25.9	11.4	0.63	25.72	18.85	25.79	21.1	1.3	7.68	14.07	5.88	6.82	15.1
Total DDT	29.6	16.6	12.8	0	17	12	23.7	17.5	0	2.7	4.3	3.1	0	2.74
Total Chlordane	8.4	2.7	1.8	0	3.6	9	10.3	8.1	0	1.5	1.9	1.7	0	5

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PCBs and Pesticides, Field Samples

MWRA ID	39510520	39510512	39510513	39510514	39511229	39511226	39511227	39511228	39511230
Bottle ID	E95K1AA	E95K2AA	E95K3AA	E95K4AA	E95L1AA	E95L2AA	E95L3AA	E95L4AA	E95L5AA
Location	R	PI	PP	PS	R	PI	PP	PS	R
Collection Date	11/15/95	11/15/95	11/15/95	11/15/95	12/13/95	12/13/95	12/13/95	12/13/95	12/15/95
Sample Units	g/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
2,4,-Cl2 (8)	ND	6.5 J	ND	ND	ND	ND	ND	ND	12 J
Hexachlorobenzene	ND	0.26 J	ND	ND	0.049 J	0.44 J	0.23 J	ND	ND
Gamma-BHC	8.7 J	6.4 J	9.9 J	5.7 J	5.7 J	11 J	10 J	6.2 J	10 J
2,2',5-Cl3 (18)	3.1 J	1.4 J	1.5 J	2.2 J	2.8 J	4.6 J	3.6 J	2.6 J	6.2 J
2,4,4'-Cl3 (28)	ND	5.4 J	5.1 J	ND	ND	5.6 J	5.7 J	1.4 J	8.1 J
Heptachlor	3 J	ND	ND	ND	ND	ND	ND	ND	5 J
2,2',5,5'-Cl4 (52)	2.3 J	4.2 J	2 J	ND	ND	ND	ND	ND	2.2 J
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,5'-Cl4 (44)	ND	ND	ND	ND	ND	ND	ND	ND	3.2 J
Heptachloroepoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3',4,4'-Cl4 (66)	ND	ND	ND	ND	ND	ND	ND	ND	ND
DDMU	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4'-DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',4,5,5'-Cl5 (101)	3.3 J	5.9 J	3.6 J	ND	ND	2.2 J	1.7 J	ND	1.3 J
ALPHA-CHLORDANE	3.1 J	3.7 J	2.3 J	ND	ND	2.3 J	1.7 J	ND	2.5 J
TRANS-NONACHLOR	2.8 J	3.1 J	2.8 J	ND	ND	1.7 J	1.5 J	ND	2.8 J
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4'-DDE	2.7 J	3.2 J	2.8 J	ND	ND	3.8 J	3.4 J	ND	0.93 J
3,3',4,4'-Cl4 (77)	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4'-DDD	ND	2.7 J	ND	ND	ND	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3',4,4',5-Cl5 (118)	4.7 J	6.3 J	3.8 J	ND	ND	2.8 J	2.2 J	ND	ND
4,4'-DDD	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4'-DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',4,4',5,5'-Cl6 (153)	4.1 J	7.1 J	4.5 J	ND	ND	3 J	1.7 J	ND	1.4 J
2,3,3',4,4'-Cl5 (105)	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4'-DDT	3.2 J	5.4 J	3.2 J	ND	ND	3.8 J	3.2 J	ND	4.8 J
2,2',3,4,4',5'-Cl6 (138)	3.5 J	5.8 J	3.5 J	1.2 J	0.96 J	2.7 J	1.4 J	0.97 J	2.2 J
3,3',4,4',5-Cl5 (126)	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,5,5',6-Cl7 (187)	4.6 J	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4'-Cl6 (128)	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,2',3,4,4',5,5'-Cl7 (180)	2.8 J	7.1 J	2.9 J	ND	ND	2 J	1.1 J	ND	1.4 J
Mirex	ND	ND	0.4 J	0.6 J	0.39 J	ND	ND	0.64 J	ND
2,2',3,3',4,4',5-Cl7 (170)	10 J,G	15 J	10 J	0.8 J	0.38 J	4.4 J	1.2 J	0.43 J	1.9 J
2,2',3,3',4,4',5,6-Cl8 (195)	ND	1.6 J	0.92 J	ND	ND	ND	ND	ND	ND
2,2',3,3',4,4',5,5',6-Cl9 (206)	1.2 J	1.4 J	0.93 J	ND	ND	1 J	0.82 J	ND	0.68 J
Decachlorobiphenyl-Cl10 (209)	ND	0.88 J	0.64 J	ND	ND	ND	ND	ND	ND
Total PCB	39.6	68.58	39.39	4.2	4.14	28.3	19.42	5.4	40.58
Total DDT	5.9	11.3	6	0	0	7.6	6.6	0	5.73
Total Chlordane	8.9	6.8	5.1	0	0	4	3.2	0	10.3

Notes:
G = Analytical interference
I = Impurity in spiking solution , see text;
J = Below method detection limit; ND = Non detection;
R = Routine Deer Island Sampling;
PI = Pilot Plant Influent
PP = Pilot Plant Primary effluent; Pilot Plant Secondary effluent

PAH and LAB, Field Samples

MWRA ID		39500225	39500974	39500974	39500976	39500975	39501905	39501906	39502240	39502241	39502243	39502737	39502738	39503798
Bottle ID		E95A1AA	E95A2AA	E95A3AA	E95A4AA	E95A5AA	E95B1AA	E95B2AA	E95C1AA	E95C2AA	E95C3AA	E95C4AA	E95C5AA	E95D1AA
Location		R	R	PI	PP	PS	R	R	PI	PP	PS	R	R	R
Collection Date		01/11/95	01/13/95	01/25/95	01/25/95	01/25/95	02/15/95	02/17/95	03/01/95	03/01/95	03/01/95	03/14/95	03/16/95	4/12/95
Sample Units		ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
Naphthalene	C0N	740	780	380	580	8.4 J	920	1300	920	910	200	990	1100	5400
C1Naphthalenes	C1N	730	880	260	530	5.3 J	1300	2100	1700	1700	210	1400	1300	6700
C2Naphthalenes	C2N	1400	1400	340	830	ND	1800	2900	2700	2400	520	2100	1800	9500
C3Naphthalenes	C3N	1300	1000	210	610	ND	1200	1800	1900	1500	530	1600	1100	10000
C4Naphthalenes	C4N	870	660	190	490	ND	860	1300	1400	1100	330	1100	760	4700
Benzothiazole	BTHOL	1200	800	160	110	150	210	310	300	310	370	140	120	750
Acenaphthylene	ACEY	330	300	120	140	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	ACE	100	100	35	77	ND	100	140	150	130	34	130	100	ND
Biphenyl	BIP	130	93	27	56	ND	140	270	190	180	27	190	170	300
Dibenzo Furan	DBF	200	190	58	120	ND	66	110	100	84	28	77	68	270
Fluorene	C0F	110	74	34	75	ND	140	220	240	200	52	170	140	650
C1Fluorenes	C1F	440	370	68	160	38	330	480	390	310	100	410	250	2000
C2Fluorenes	C2F	530 G	410 G	98 G	240 G	20 G	340	530	400	290	110	290	290	2100
C3Fluorenes	C3F	950	720	ND	61	170	640	940	940	930	200	790	630	2300
Phenanthrene	C0P	300	280	75	200	16	290	790	850	740	92	400	300	970
Anthracene	C0A	27	23	15	31	ND	37	58	110	92	16	55	42	130
C1Phenanthrenes/Anthracenes	C1P/A	590	500	110	280	6.3 J	420	760	780	680	120	520	390	1600
C2Phenanthrenes/Anthracenes	C2P/A	630	540	120	260	27	500	900	970	820	110	630	440	1700
C3Phenanthrenes/Anthracenes	C3P/A	59 G	57 G	32 G	30 G	23 G	33 G	61 G	110 G	76 G	88	62 G	97 G	1200
C4Phenanthrenes/Anthracenes	C4P/A	200	160	52	110	79	190	400	460	470	21	300	230	580
Dibenzothiophene	C0D	57	49	13	40	ND	56	110	100	90	29	73	49	180
C1Dibenzothiophenes	C1D	190	160	38	95	ND	140	250	230	200	52	200	130	520
C2Dibenzothiophenes	C2D	300	220	78	140	ND	200	300	280	260	90	220	170	840
C3Dibenzothiophenes	C3D	310	230	36	81	76	210	340	330	340	79	240	230	710
Fluoranthene	FLANT	89	100	40	110	33	110	750	810	760	52	220	170	450
Pyrene	PYR	110	120	39	120	93	96	560	610	570	48	190	150	460
C1Fluoranthenes/Pyrenes	C1F/P	120	130	32	75	70	94	270	350	320	40	180	150	420
C2Fluoranthenes/Pyrenes	C2F/P	86	120	36	71	78	65	260	300	280	ND	110	86	290
C3Fluoranthenes/Pyrenes	C3F/P	67	99	ND	43	40	ND	140	170	160	ND	81	68	180
Benzo(a)anthracene	BAA	30	42	19	47	33	28	180	220	210	17	66	56	140
Chrysene	C0C	29	45	17	52	32	30	340	350	340	16	95	67	200
C1Chrysenes	C1C	36	57	15	45	34	26	140	170	170	ND	76	47	150
C2Chrysenes	C2C	56	83	12	40	34	ND	89	130	100	ND	71	59	180
C3Chrysenes	C3C	32	41	ND	25	23	ND	56	120	100	ND	59	ND	95
C4Chrysenes	C4C	37	36	ND	23	ND	ND	ND	ND	ND	ND	ND	ND	51
Benzo(b)fluoranthene	BBF	52	68	19	60	40	66	1700	440	340	12	140	97	120
Benzo(k)fluoranthene	BKF	11	19	5.9 J	19	14	21	500	140	120	2.9 J	41	28	44
Benzo(e)pyrene	BEP	26	43	11	33	23	37	920	240	200	8.3 J	80	55	74
Benzo(a)pyrene	BAP	13	18	11	38	22	19	240	240	190	5.1 J	57	39	66
Perylene	PER	5.8 J	7.2 J	26	8.6 J	5 J	7.5 J	130	56	45	1.7 J	17	13	13
Indeno(1,2,3-cd)pyrene	IND	23	32	9 J	31	17	28	750	220	170	4.4 J	63	45	59
Dibenzo(a,h)anthracene	DAH	ND	ND	ND	5 J	ND	ND	140	43	33	ND	14	9.5 J	ND
Benzo(g,h,i)perylene	BGP	21	32	8.6 J	28	18	34	830	250	190	4.6 J	78	54	60
Total PAH *		10,984	9,879	2,596	5,876	960	10,443	23,544	19,539	17,276	3,222	13,317	10,758	54,662
Linear Alkyl Benzenes														
C10Linear Alkyl Benzenes	C10	4000 I	3400 I	710 I	2200 I	580 I	4000 I	3700 I	2800	2700	580	5600	4600	6900
C11Linear Alkyl Benzenes	C11	6000 I	5000 I	1000 I	3300 I	550 I	5800 I	4900 I	3600	3900	680	6900	6000	7300
C12Linear Alkyl Benzenes	C12	1500	1300	150	960	260	2100	1600	1400	1300	360	2700	2400	2100
C13Linear Alkyl Benzenes	C13	ND	ND	ND	ND	ND	ND	ND	ND	ND	400 I	ND	ND	240
C14Linear Alkyl Benzenes	C14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total LAB		11500	9700	1860	6460	1390	11900	10200	7800	7900	2020	15200	13000	16540

Notes:
*Total PAH: Non-inclusive of Benzothiazole, Dibenzo Furan, C2Fluoranthenes/Pyrenes, C3Fluoranthenes/Pyrenes
G = Analytical Interference
I = Impurity in spiking solution , see text;
J = Below method detection limit; ND = Non detection;
R = Routine Deer Island Sampling;
PI = Pilot Plant Influent
PP = Pilot Plant Primary effluent; Pilot Plant Secondary effluent

PAH and LAB, Field Samples

MWRA ID	39504845	39504810	39504812	39504814	39504916	39505816	39505820	39504812	39505822	39505817	39506615	39506625	39506626	39506627
Bottle ID	E95E1AA	E95E2AA	E95E3AA	E95E4AA	E95E5AA	E95F1AA	E95F2AA	E95F3AA	E95F4AA	E95F5AA	E95G1AA	E95G2AA	E95G3AA	E95G4AA
Location	R	PI	PP	PS	R	R	PI	PP	PS	R	R	PI	PP	PS
Collection Date	5/10/95	5/10/95	5/10/95	5/10/95	5/12/95	6/19/95	6/14/95	6/14/95	6/14/95	6/16/95	7/12/95	7/12/95	7/12/95	7/12/95
Sample Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
Naphthalene	3000	3600	3300	22	2900	4200 E	6200 E	5200 E	16	4200 E	1200	870	1300	27
C1Naphthalenes	5700	7200	6600	17	6000	8400	13000	11000	17	8700	970	1300	1900	ND
C2Naphthalenes	7100	9800	8200	40	7100	11000	19000	13000	30	10000	2200	1700	2200	ND
C3Naphthalenes	4000	5500	4400	35	4100	5600	10000	6300	ND	5100	1200	1000	1100	ND
C4Naphthalenes	1600	2200	1700	66	1800	2100	3700	2100	ND	1700	570	560	520	ND
Benzothiazole	140	200	190	310	320	450	390	1500	460	280	240	1400	570	460
Acenaphthylene	ND	ND	ND	ND	ND	ND	17	11	ND	ND	ND	ND	ND	ND
Acenaphthene	ND	ND	ND	ND	ND	280	360	250	ND	200	130	88	110	ND
Biphenyl	440	570	500	4.7 J	480	900	1500	1100	4.2 J	910	180	130	190	ND
Dibenzo Furan	110	130	110	ND	120	210	290	210	ND	170	83	56	74	ND
Fluorene	200	280	220	ND	260	390	540	360	ND	300	170	120	140	ND
C1Fluorenes	380	520	390	ND	410	660	840	550	35	450	290	240	250	ND
C2Fluorenes	460	650	440	ND	540	810	1100	650	ND	530	340	280	280	ND
C3Fluorenes	470	690	450	ND	630	660	880	510	ND	420	260	260	250	ND
Phenanthrene	420	490	330	7.3 J	460	720	920	540	7.6 J	430	390	340	340	8.3 J
Anthracene	62	82	54	ND	68	91	130	72	ND	66	59	51	57	ND
C1Phenanthrenes/Anthracenes	530	740	440	10	560	900	1100	650	ND	520	430	400	380	ND
C2Phenanthrenes/Anthracenes	550	930	480	21	620	830	1000	640	4.2 J	520	430	430	380	ND
C3Phenanthrenes/Anthracenes	360	720	330	29	460	480	710	410	ND	350	160	180	150	ND
C4Phenanthrenes/Anthracenes	200	390	210	ND	280	300	490	280	ND	250	94	120	97	ND
Dibenzothiophene	71	77	60	ND	77	120	150	100	ND	68	81	75	92	ND
C1Dibenzothiophenes	170	200	150	ND	180	260	300	200	ND	150	140	140	150	ND
C2Dibenzothiophenes	250	300	220	ND	290	360	440	290	ND	230	200	210	200	ND
C3Dibenzothiophenes	210	270	170	21	260	310	380	260	43	210	160	180	160	ND
Fluoranthene	210	280	170	5.4 J	370	350	610	330	11	250	240	270	230	15
Pyrene	200	280	170	20	330	310	540	290	40	230	210	250	200	55
C1Fluoranthenes/Pyrenes	170	270	140	ND	210	220	390	220	36	180	150	160	130	31
C2Fluoranthenes/Pyrenes	130	280	100	ND	160	180	320	190	52	160	94	120	88	ND
C3Fluoranthenes/Pyrenes	94	220	64	ND	84	100	200	110	29	96	36	60	36	ND
Benzo(a)anthracene	71	100	62	9.8 J	110	97	220	100	14	86	68	93	67	17
Chrysene	83	130	65	4 J	160	110	240	110	17	96	87	110	85	14
C1Chrysenes	64	160	62	ND	93	78	210	91	24	71	51	74	46	ND
C2Chrysenes	62	180	59	ND	83	68	160	81	19	60	36	43	14	ND
C3Chrysenes	48	130	34	ND	52	44	92	47	12	38	ND	ND	ND	ND
C4Chrysenes	33	77	15	ND	24	23	53	32	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	74	100	53	2.7 J	140	100	240	110	24	84	74	99	66	15
Benzo(k)fluoranthene	18	28	18	0.81 J	52	32	88	31	6.9 J	30	20	28	21	4.8 J
Benzo(e)pyrene	42	62	31	ND	79	56	130	59	15	48	39	54	36	8 J
Benzo(a)pyrene	38	74	37	ND	76	54	160	60	13	48	37	59	36	8.4 J
Perylene	9.2 J	20	8.8 J	ND	17	11	36	14	2.7 J	11	7.4 J	13	6.6 J	ND
Indeno(1,2,3-cd)pyrene	33	50	25	ND	66	48	120	54	9.7 J	41	37	45	29	ND
Dibenzo(a,h)anthracene	6.5 J	10	ND	ND	10	7.7 J	25	8.4 J	ND	7.9 J	ND	ND	ND	ND
Benzo(g,h,i)perylene	34	53	28	ND	66	49	130	52	11	43	34	47	30	ND
Total PAH *	27,369	37,213	29,622	316	29,413	41,029	66,201	46,162	412	36,628	10,744	10,019	11,243	204
Linear Alkyl Benzenes														
C10Linear Alkyl Benzenes	5600	6200	5900	280	3600	2900	3500	3000	960	4100	3900	3700	4700	300
C11Linear Alkyl Benzenes	5300	5800	5600	230	3800	3000	3500	3200	1000	4500	4100	3800	4700	230
C12Linear Alkyl Benzenes	2200	2400	2400	380	1800	1400	1500	1400	680	1900	1700	1900	2300	200
C13Linear Alkyl Benzenes	180	260	190	ND	250	240	240	220	56	290	200	180	180	ND
C14Linear Alkyl Benzenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total LAB	13280	14660	14090	890	9450	7540	8740	7820	2696	10790	9900	9580	11880	730

Notes:
*Total PAH: Non-inclusive of Benzothiazole, Dibenzo Furan, C2Fluoranthenes/Pyrenes, C3Fluoranthenes/Pyrenes
G = Analytical interference
I = Impurity in spiking solution , see text;
J = Below method detection limit; ND = Non detection;
R = Routine Deer Island Sampling;
PI = Pilot Plant Influent
PP = Pilot Plant Primary effluent; Pilot Plant Secondary effluent

PAH and LAB, Field Samples

MWRA ID	39506616	39506685	39506691	39506689	39506690	39506686	########	########	########	########	########	########	########	########	########	########
Bottle ID	E95G5AA	E95H1AA	E95H2AA	E95H3AA	E95H4AA	E95H5AA	E95I1AA	E95I2AA	E95I3AA	E95I4AA	E95J1AA	E95J2AA	E95J3AA	E95J4AA	E95J5AA	E95K1AA
Location	R	R	PI	PP	PS	R	R	PI	PP	PS	R	PI	PP	PS	R	R
Collection Date	7/14/95	8/16/95	8/16/95	8/16/95	8/16/95	8/16/95	9/13/95	9/13/95	9/13/95	9/13/95	10/12/95	10/12/95	10/12/95	10/12/95	10/16/95	11/15/95
Sample Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
Naphthalene	1200	810	880	820	14	680	960	1100	1000	8.6 J	780 L	840	780	18	590	620
C1Naphthalenes	1700	1000	1200	1100	7 J	850	1200	1600	1300	ND	1000 L	1000	1000	ND	710	1000
C2Naphthalenes	2000	1200	1800	1300	ND	1000	1700	2500	1800	ND	1600	1700	1600	ND	1200	1500
C3Naphthalenes	990	960	1600	1000	ND	840	1700	2500	1700	ND	1600	1800	1600	ND	1200	1400
C4Naphthalenes	410	480	770	530	ND	430	850	1400	850	ND	1200	1200	960	ND	640	480
Benzothiazole	200	190	310	230	120	200	190	230	250	210	240 L	980	360	240	620	170
Acenaphthylene	ND	6.6 J	12	5.9 J	ND	7 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	160	100	130	110	ND	100	ND	ND	ND	ND	120	120	120	ND	130	ND
Biphenyl	190	110	130	110	ND	87	120	150	120	ND	91	88	90	ND	63	120
Dibenzo Furan	100	59	72	58	3.2 J	52	71	92	68	ND	63	65	64	4 J	61	65
Fluorene	180	120	150	110	2.2 J	100	150	210	140	ND	130	130	130	ND	130	150
C1Fluorenes	240	300	460	320	11	170	240	380	230	ND	250	310	250	ND	180	240
C2Fluorenes	220	210	350	240	16	180	380	580	360	ND	320	370	310	31	250	340
C3Fluorenes	190	250	420	280	55	220	460	690	420	ND	450	550	450	120	330	320
Phenanthrene	390	280	450	280	3.6 J	240	390	600	380	ND	300	330	290	7.2 J	340	430
Anthracene	75	31	75	39	ND	30	64	110	62	ND	42	56	45	1.5 J	47	41
C1Phenanthrenes/Anthracenes	330	300	520	320	ND	240	520	840	500	ND	350	440	370	2.1 J	300	480
C2Phenanthrenes/Anthracenes	320	350	660	360	20	270	600	1000	620	ND	380	500	440	20	340	430
C3Phenanthrenes/Anthracenes	120	220	410	240	33	140	400	720	440	ND	230	310	270	44	200	210
C4Phenanthrenes/Anthracenes	67	120	220	110	ND	82	230	420	250	ND	130	200	160	ND	140	140
Dibenzothiophene	55	35	61	39	ND	35	62	87	56	ND	44	55	50	ND	49	62
C1Dibenzothiophenes	110	91	150	99	ND	82	200	310	190	ND	120	140	120	ND	94	130
C2Dibenzothiophenes	150	140	240	150	ND	120	210	360	210	ND	190	240	190	ND	150	180
C3Dibenzothiophenes	110	120	220	140	ND	96	180	350	180	ND	160	210	180	ND	130	140
Fluoranthene	230	140	280	140	6.6 J	110	190	320	180	6.3 J	160	230	180	7.6 J	260	370
Pyrene	200	140	280	140	26	100	190	340	190	26	150	220	160	33	220	320
C1Fluoranthenes/Pyrenes	120	110	220	120	16	80	180	330	180	ND	110	160	130	26	140	150
C2Fluoranthenes/Pyrenes	90	94	190	97	16	63	150	340	170	ND	84	120	97	23	100	100
C3Fluoranthenes/Pyrenes	32	58	120	58	ND	42	110	280	120	ND	47	76	60	ND	58	47
Benzo(a)anthracene	66	42	98	44	6.3 J	28	61	110	63	7.8 J	52	83	60	9.4 J	81	130
Chrysene	80	53	110	52	6 J	35	76	140	76	5.5 J	60	93	72	9.8 J	110	160
C1Chrysenes	43	43	96	46	6.1 J	30	75	160	81	ND	40	66	52	7.7 J	50	65
C2Chrysenes	14	41	92	43	ND	27	93	200	97	ND	26	42	37	ND	35	ND
C3Chrysenes	ND	28	70	32	ND	16	61	140	70	ND	ND	32	ND	ND	28	ND
C4Chrysenes	ND	ND	33	23	ND	ND	ND	76	39	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	66	44	110	44	3.9 J	29	53	110	56	3.2 J	41	63	46	7.9 J	85	200
Benzo(k)fluoranthene	20	16	41	14	1.5 J	8.8 J	16	42	17	1.4 J	13	20	15	3 J	32	56
Benzo(e)pyrene	38	27	66	26	2.8 J	18	30	66	32	ND	25	37	29	5.2 J	49	98
Benzo(a)pyrene	38	26	79	30	2.5 J	17	33	83	39	ND	26	42	31	4.7 J	53	87
Perylene	6.3 J	6.8 J	19	7.2 J	0.8 J	4.1 J	8.2 J	21	10	ND	6.2 J	11	7.5 J	1.2 J	14	20
Indeno(1,2,3-cd)pyrene	24	19	53	18	ND	12	22	54	23	ND	36	30	20	3.5 J	49	100
Dibenzo(a,h)anthracene	ND	4.1 J	12	4.2 J	ND	2.8 J	5.7 J	15	6.8 J	ND	6.3 J	7.9 J	5 J	1.5 J	8.9 J	16
Benzo(g,h,i)perylene	26	20	54	21	1.5 J	13	24	61	28	ND	21	29	22	4.6 J	42	94
Total PAH *	10,178	7,994	12,621	8,507	242	6,530	11,734	18,175	11,996	59	10,260	11,755	10,272	369	8,470	10,279
Linear Alkyl Benzenes																
C10Linear Alkyl Benzenes	4700	3800	5600	3500	210	3100	3400	4400	3400	260	3200	3700	3000	180	2500	2300
C11Linear Alkyl Benzenes	5400	3800	5100	3500	170	3200	3900	4500	3700	200	4000	4100	3300	200	3100	2600
C12Linear Alkyl Benzenes	2500	1400	2000	1400	290	1200	1600	2200	1700	260	1700	2100	1700	330	1300	1100
C13Linear Alkyl Benzenes	230	130	150	160	ND	88	ND	ND	ND	ND	210	250	170	ND	160	120
C14Linear Alkyl Benzenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total LAB	12830	9130	12850	8560	670	7588	8900	11100	8800	720	9110	10150	8170	710	7060	6120

Notes:
*Total PAH: Non-inclusive of Benzothiazole, Dibenzo Furan, C2Fluoranthenes/Pyrenes, C3Fluoranthenes/Pyrenes
G = Analytical interference
I = Impurity in spiking solution , see text;
J = Below method detection limit; ND = Non detection;
R = Routine Deer Island Sampling;
PI = Pilot Plant Influent
PP = Pilot Plant Primary effluent; Pilot Plant Secondary effluent

Non-inclusive of Be
Analytical interfere
Impurity in spiking s
Below method dete
Routine Deer Islan
Pilot Plant Influent
Pilot Plant Primary

PAH and LAB, Field Samples

MWRA ID	########	########	########	########	########	########	########	########
Bottle ID	E95K2AA	E95K3AA	E95K4AA	E95L1AA	E95L2AA	E95L3AA	E95L4AA	E95L5AA
Location	PI	PP	PS	R	PI	PP	PS	R
Collection Date	11/15/95	11/15/95	11/15/95	12/13/95	12/13/95	12/13/95	12/13/95	12/15/95
Sample Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
Naphthalene	380	490	ND	4.6 J	590	560	3.5 J	570
C1Naphthalenes	ND	910	ND	ND	580	510	ND	540
C2Naphthalenes	ND	1600	ND	ND	730	600	ND	600
C3Naphthalenes	2000	1400	ND	ND	700	550	ND	500
C4Naphthalenes	850	590	ND	ND	250	180	ND	170
Benzothiazole	220	170	120	130	150	160	140	140
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	130	100	ND	ND	77	66	ND	68
Biphenyl	160	130	ND	ND	54	49	ND	50
Dibenzo Furan	78	61	9.1 J	ND	39	32	2.9 J	32
Fluorene	190	150	ND	ND	82	66	ND	69
C1Fluorenes	440	310	21	ND	180	110	ND	210
C2Fluorenes	620	390	ND	ND	160	120	ND	110
C3Fluorenes	590	390	ND	ND	160	120	ND	120
Phenanthrene	680	380	5.8 J	4 J	200	150	3.2 J	160
Anthracene	92	43	ND	ND	29	21	ND	21
C1Phenanthrenes/Anthracenes	860	510	13	5.1 J	200	150	6 J	140
C2Phenanthrenes/Anthracenes	840	490	27	19	200	150	18	150
C3Phenanthrenes/Anthracenes	420	220	20	16	91	76	16	69
C4Phenanthrenes/Anthracenes	260	130	ND	ND	76	42	ND	37
Dibenzothiophene	95	63	ND	ND	30	26	ND	21
C1Dibenzothiophenes	240	150	ND	ND	66	52	ND	43
C2Dibenzothiophenes	360	210	ND	ND	94	78	ND	67
C3Dibenzothiophenes	270	160	ND	ND	72	52	ND	55
Fluoranthene	730	310	13	13	120	84	11	97
Pyrene	640	290	28	26	110	80	26	86
C1Fluoranthenes/Pyrenes	300	130	ND	12	70	49	12	48
C2Fluoranthenes/Pyrenes	210	92	ND	ND	44	30	ND	36
C3Fluoranthenes/Pyrenes	88	41	ND	ND	23	ND	ND	ND
Benzo(a)anthracene	260	100	9.1 J	9.3 J	43	28	8.3 J	32
Chrysene	310	120	5.6 J	7.3 J	48	30	7.5 J	33
C1Chrysenes	100	47	ND	ND	24	16	ND	15
C2Chrysenes	73	ND	ND	ND	ND	ND	ND	ND
C3Chrysenes	ND	ND	ND	ND	ND	ND	ND	ND
C4Chrysenes	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	400	150	ND	7.5 J	51	29	8.6 J	35
Benzo(k)fluoranthene	110	40	ND	1.7 J	12	6.9 J	1.7 J	11
Benzo(e)pyrene	180	70	ND	3.8 J	25	14	ND	19
Benzo(a)pyrene	200	72	ND	3.2 J	24	13	ND	17
Perylene	47	17	ND	ND	5.4 J	3.3 J	ND	3.4 J
Indeno(1,2,3-cd)pyrene	200	74	ND	ND	21	14	ND	22
Dibenzo(a,h)anthracene	31	12	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	190	67	ND	ND	21	16	ND	16
Total PAH *	13,248	10,315	143	133	5,195	4,111	122	4,204
Linear Alkyl Benzenes								
C10Linear Alkyl Benzenes	6500	2300	440	420	3800	3200	450	3300
C11Linear Alkyl Benzenes	6800	2600	370	340	4100	3500	350	4100
C12Linear Alkyl Benzenes	2900	1300	460	570	2100	1800	420	1900
C13Linear Alkyl Benzenes	56	30	ND	ND	240	280	ND	210
C14Linear Alkyl Benzenes	18	10	ND	ND	ND	ND	ND	ND
Total LAB	16274	6240	1270	1330	10240	8780	1220	9510

Notes:

*Total PAH: zothiazole, Dibenzo Furan, C2Fluoranthenes/Pyrenes, C3Fluoranthenes/Pyrenes

G = ce

I = olution , see text;

J = tion limit; ND = Non detection;

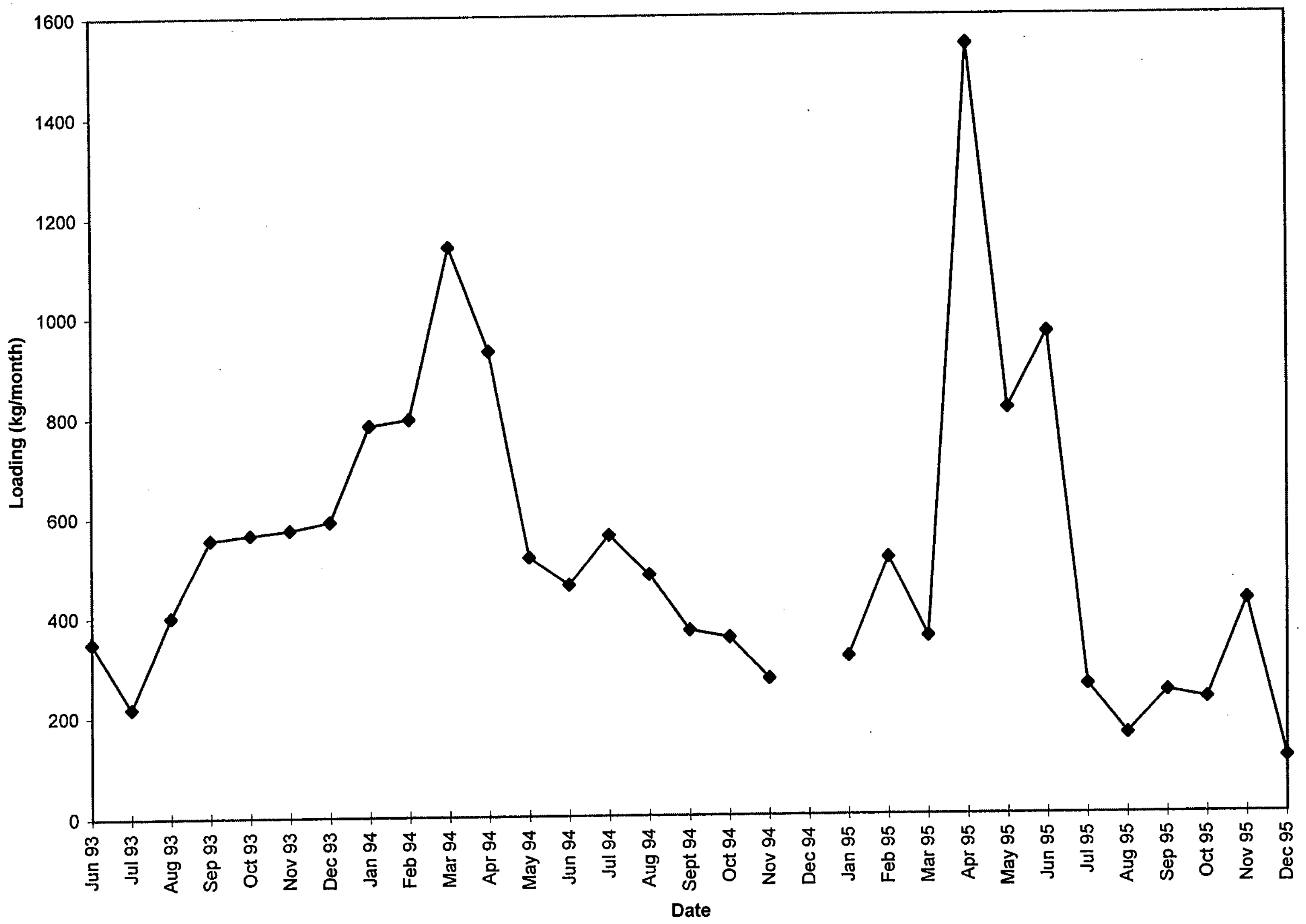
R = Sampling;

PI =

PP = ffluent; Pilot Plant Secondary effluent

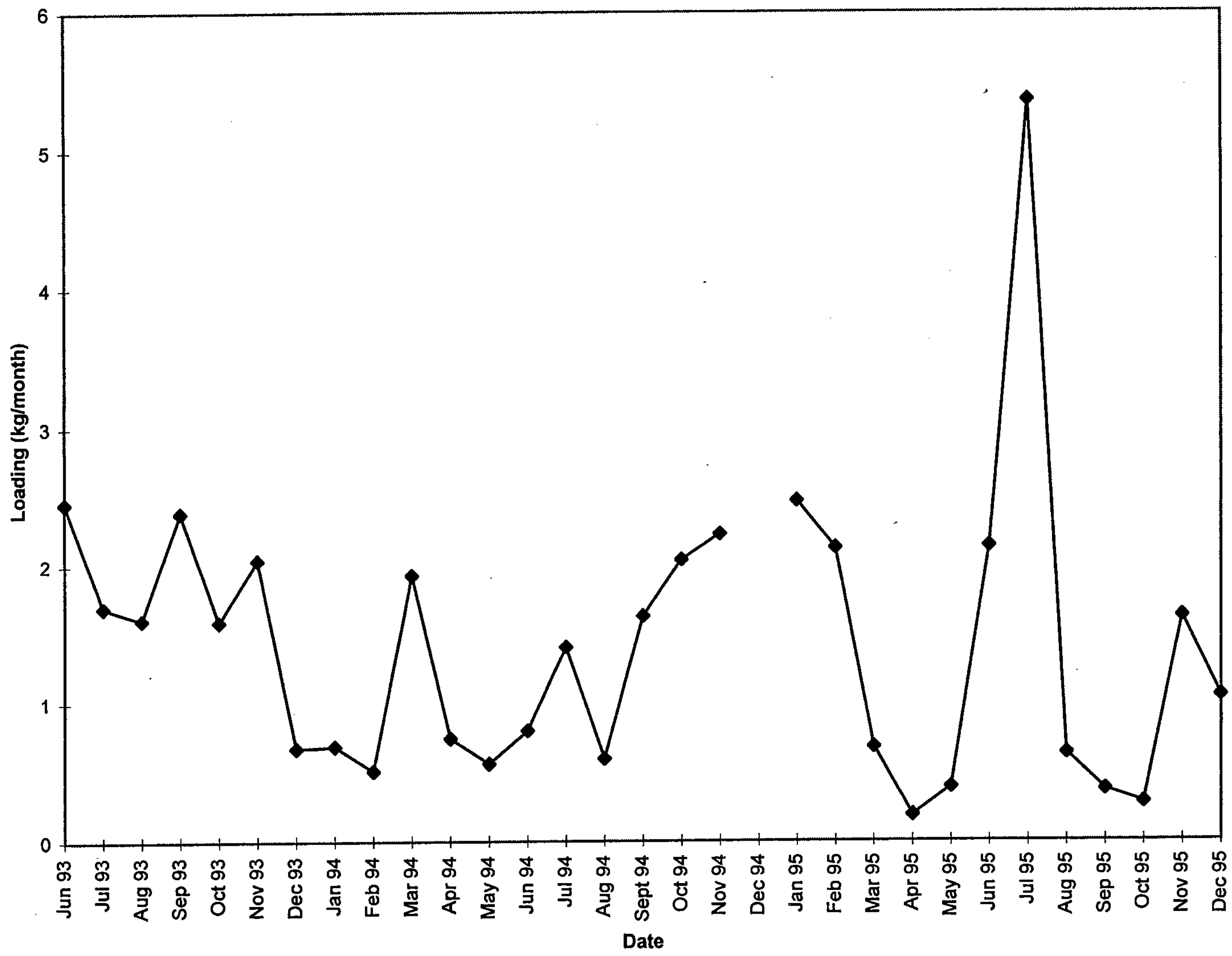
APPENDIX B

MONTHLY CONTAMINANT AND NUTRIENT LOADING PLOTS

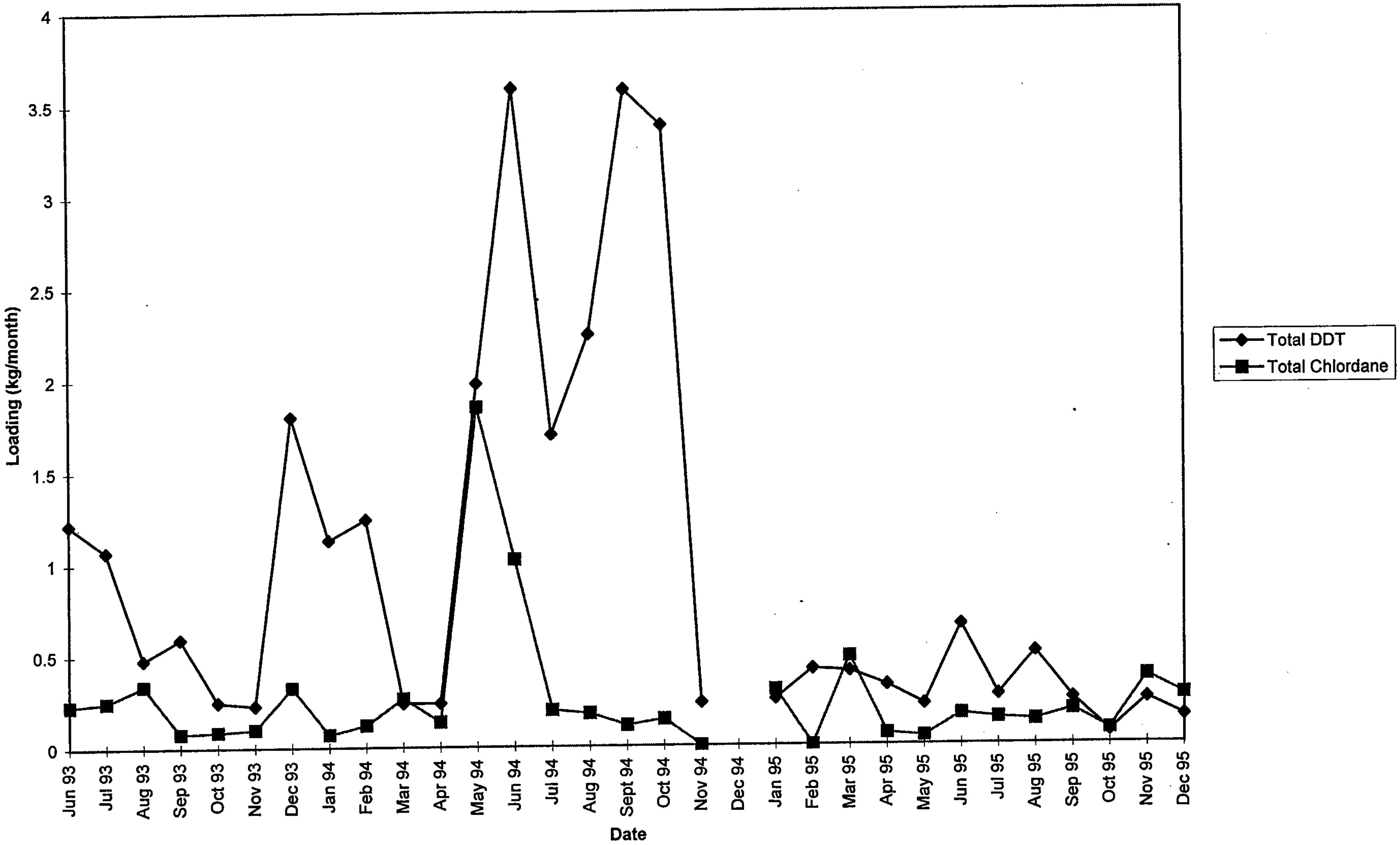


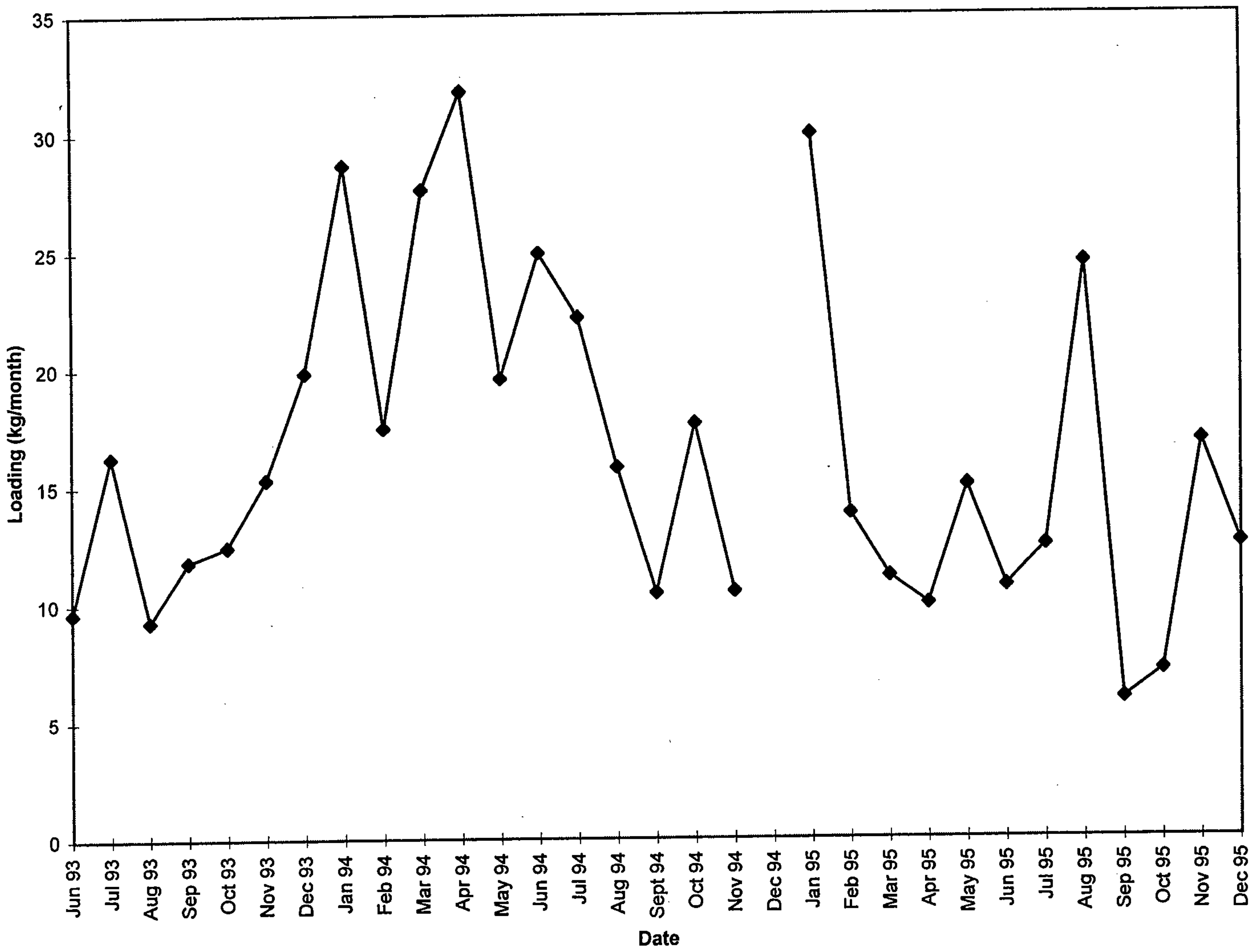
1993 - 1995 Loading - PAH's

1993 - 1995 Loading - PCBs



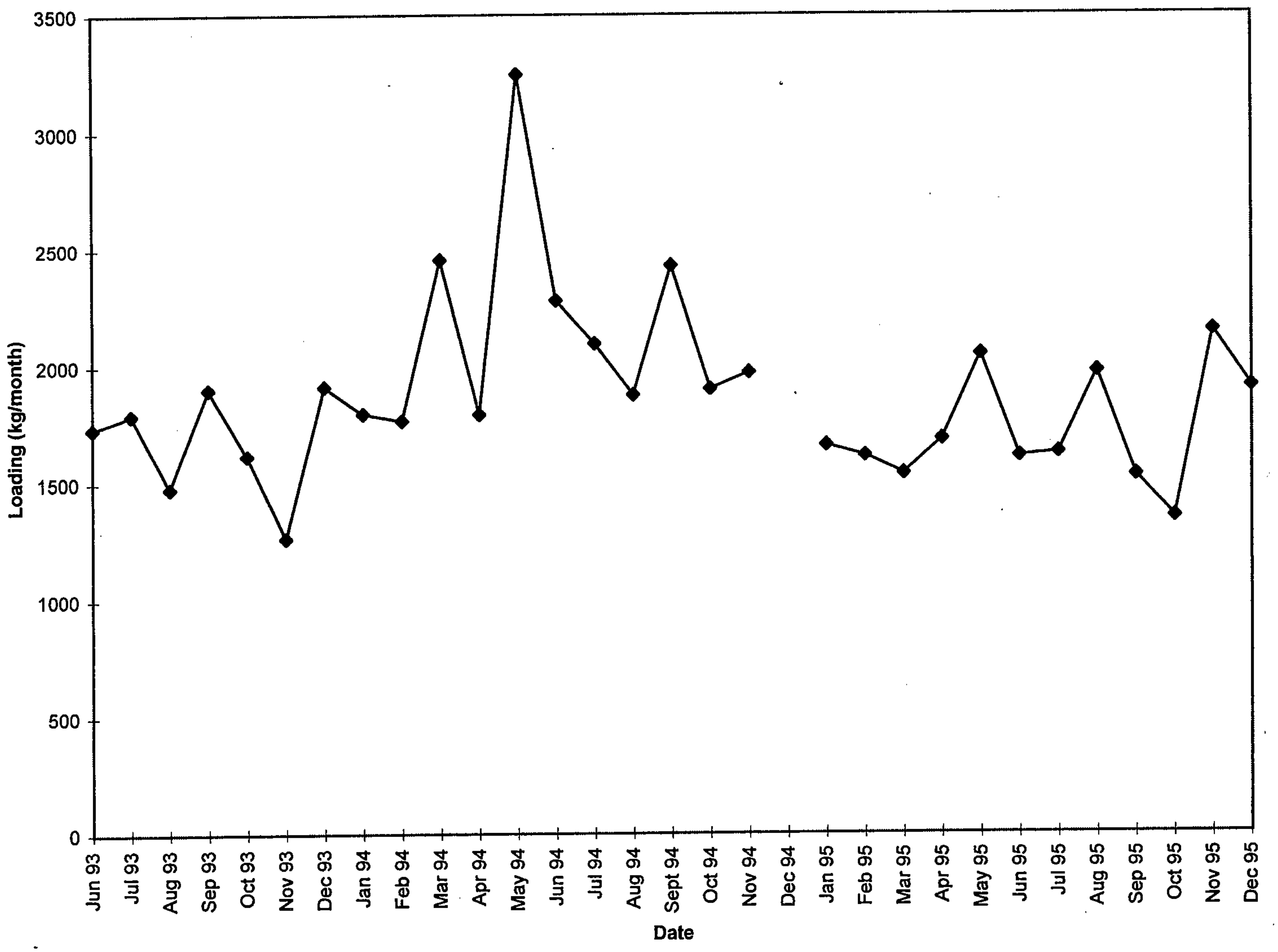
1993 - 1995 Loading - Total DDT & Total Chlordanes



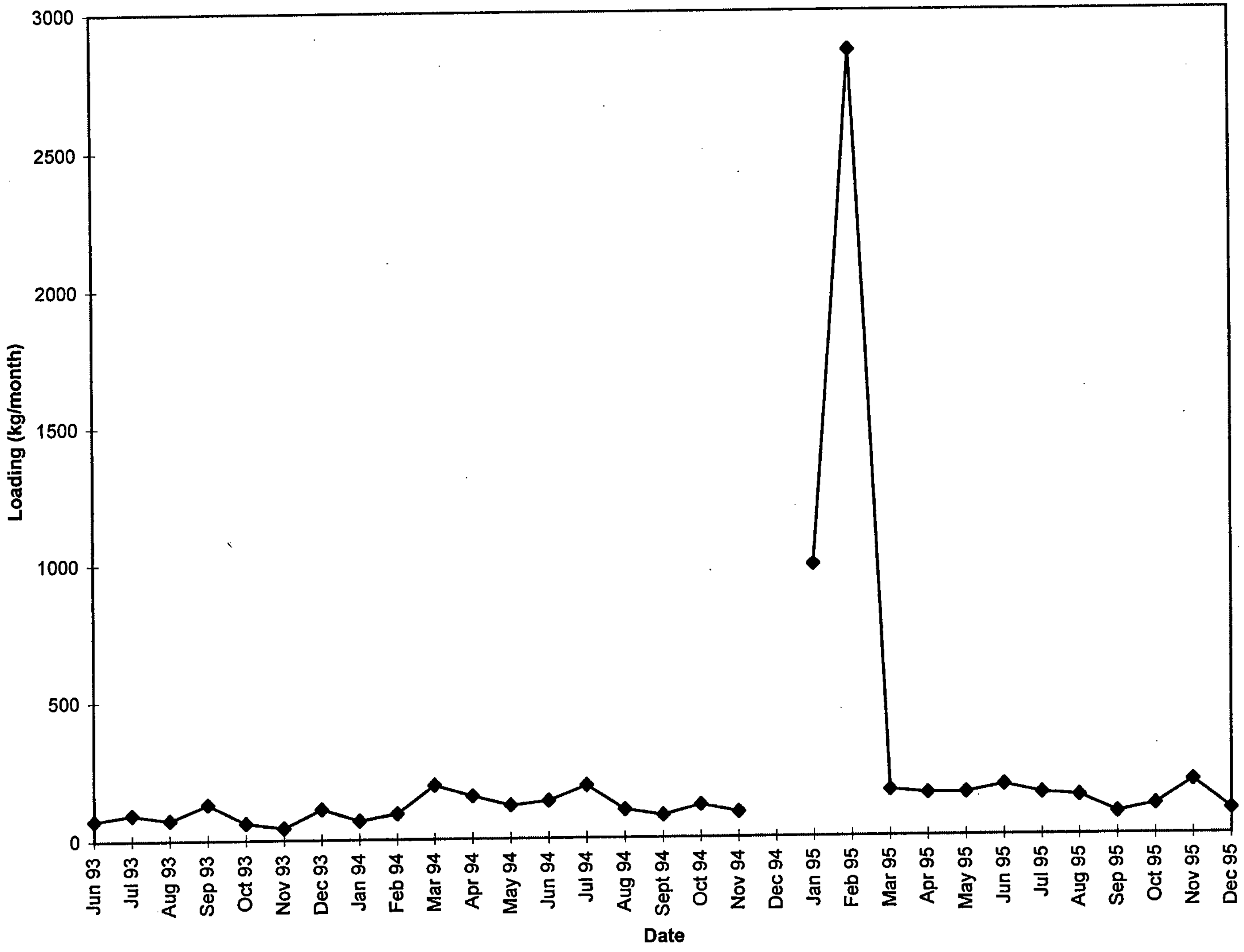


1993 - 1995 Loading - Cadmium

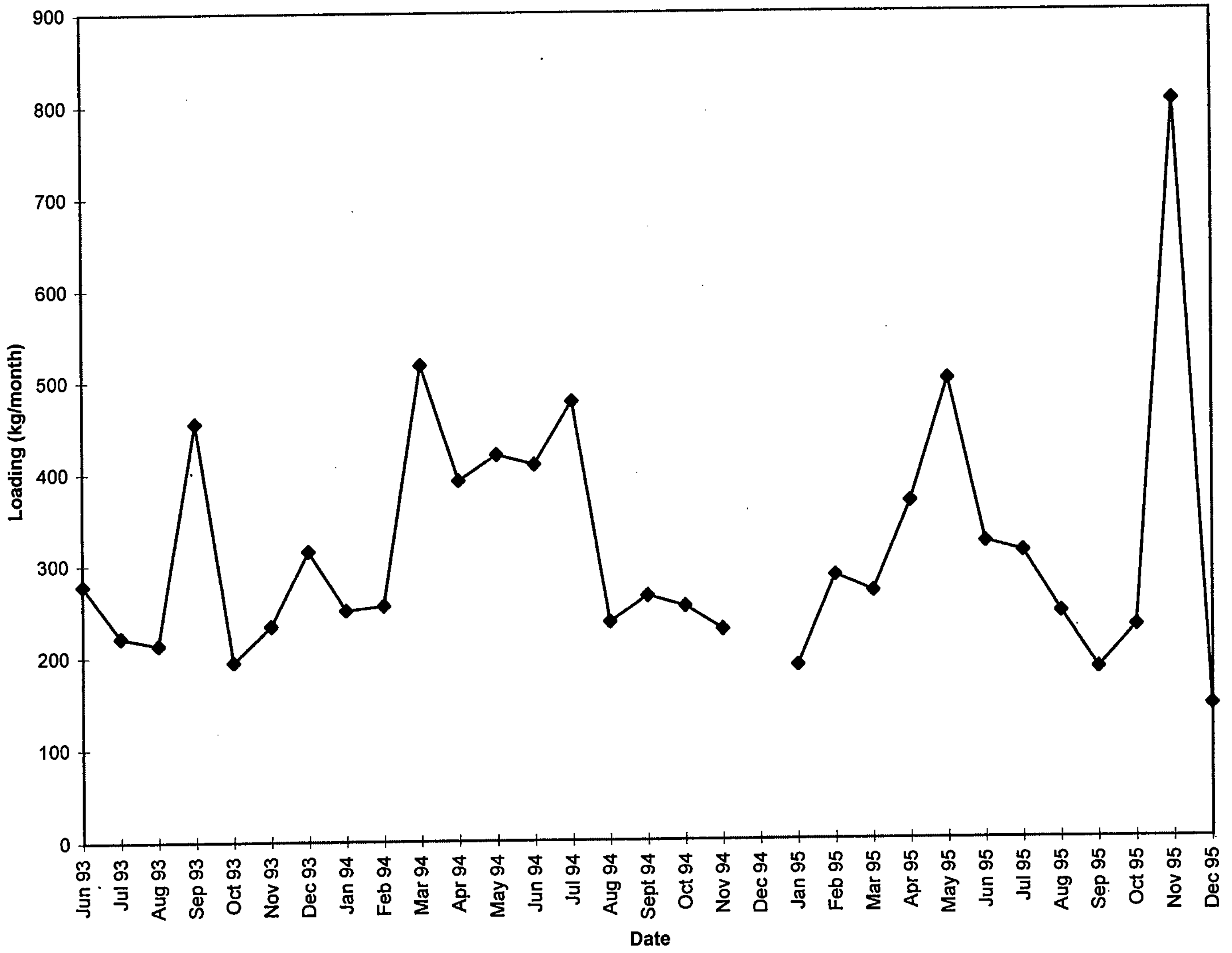
1993 - 1995 Loading - Copper

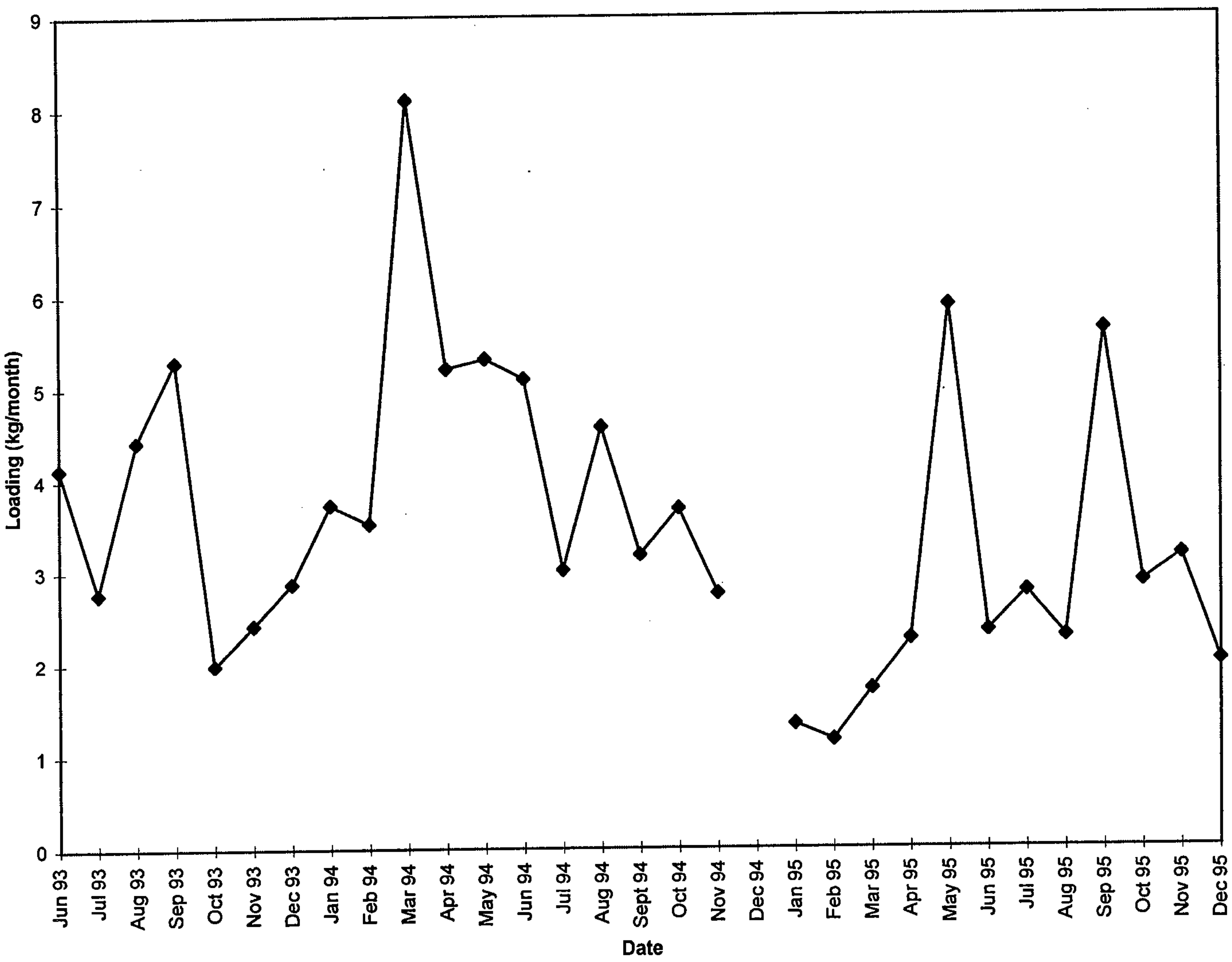


1993 - 1995 Loading - Chromium



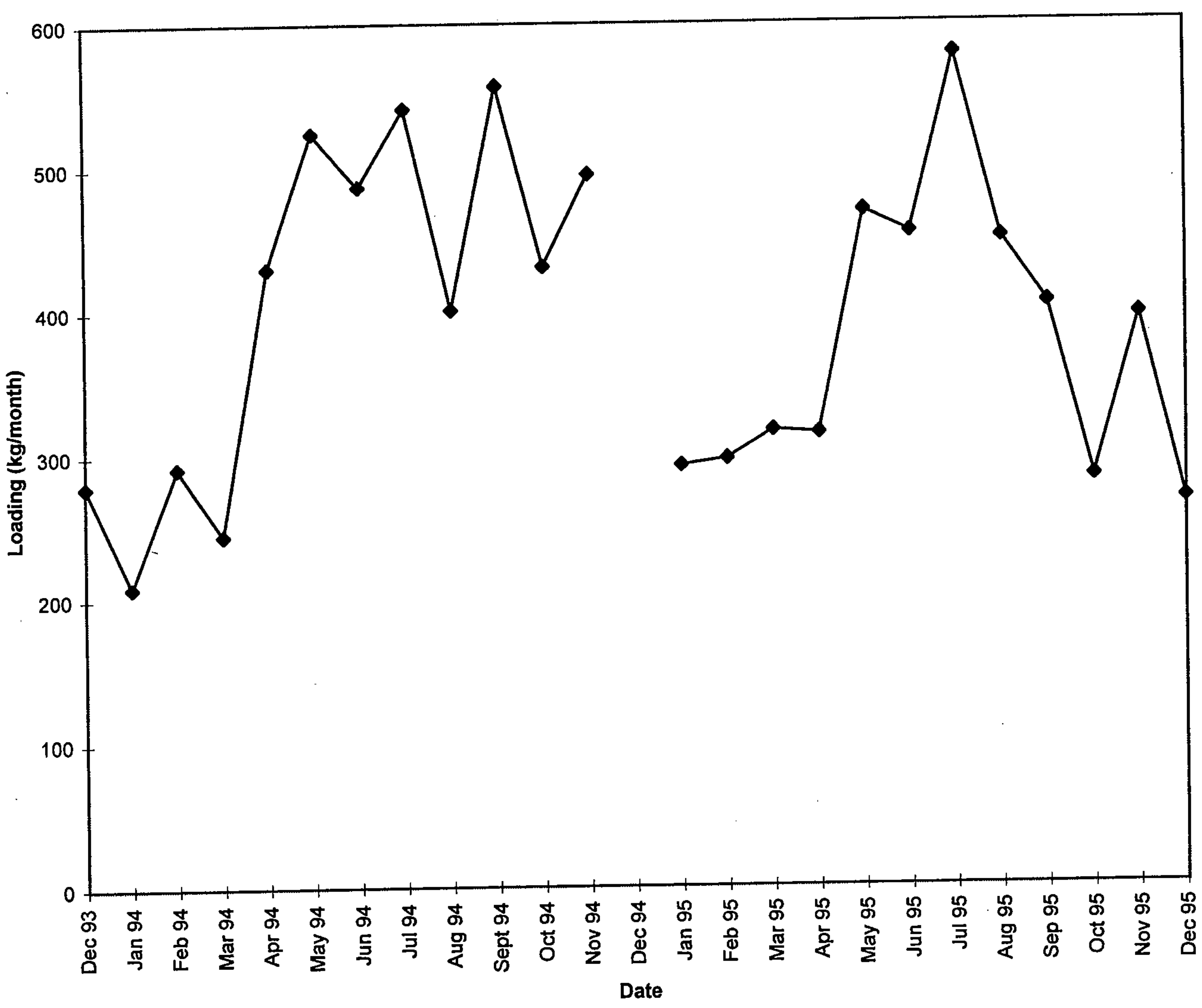
1993 - 1995 Loading - Lead



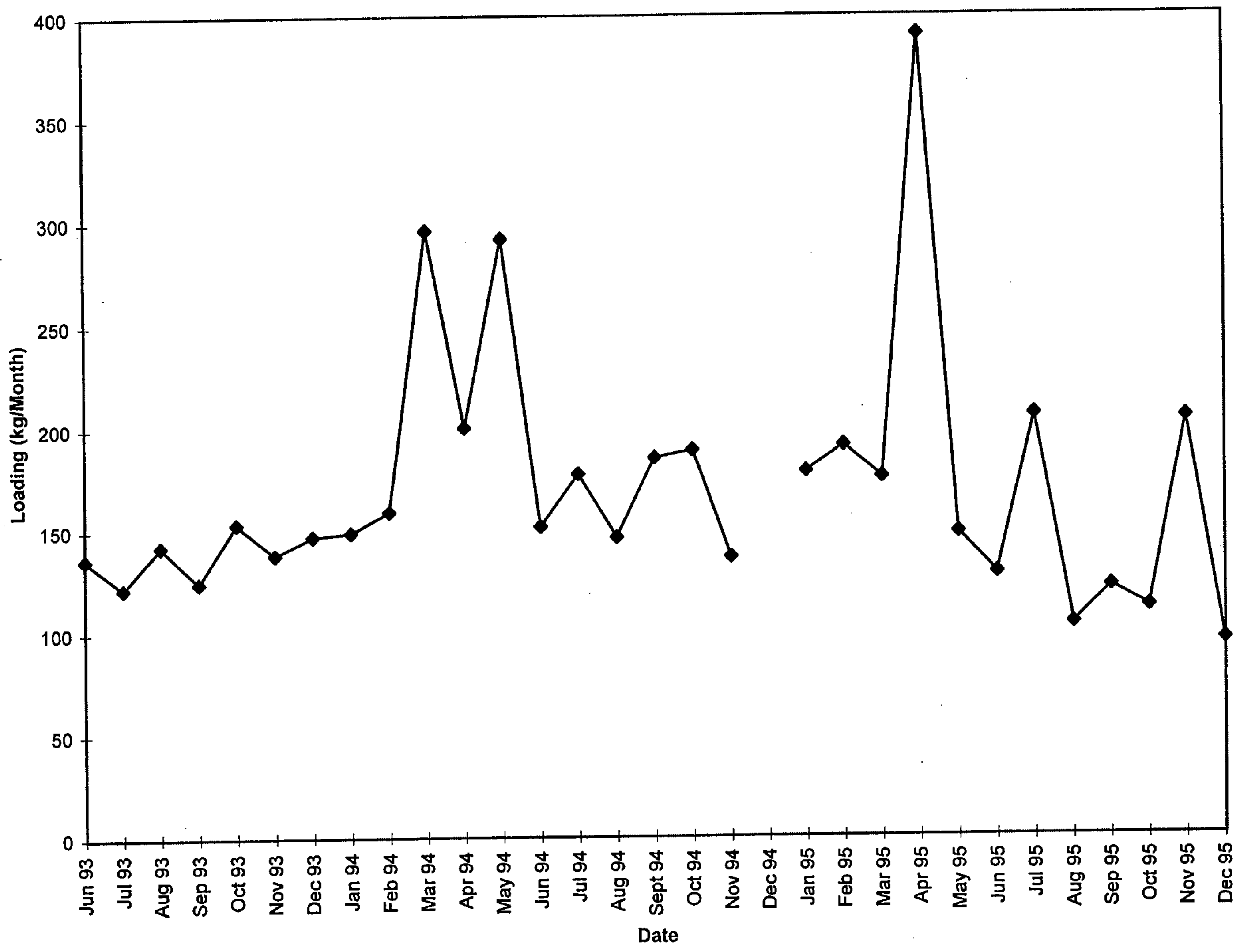


1993 - 1995 Loading - Mercury

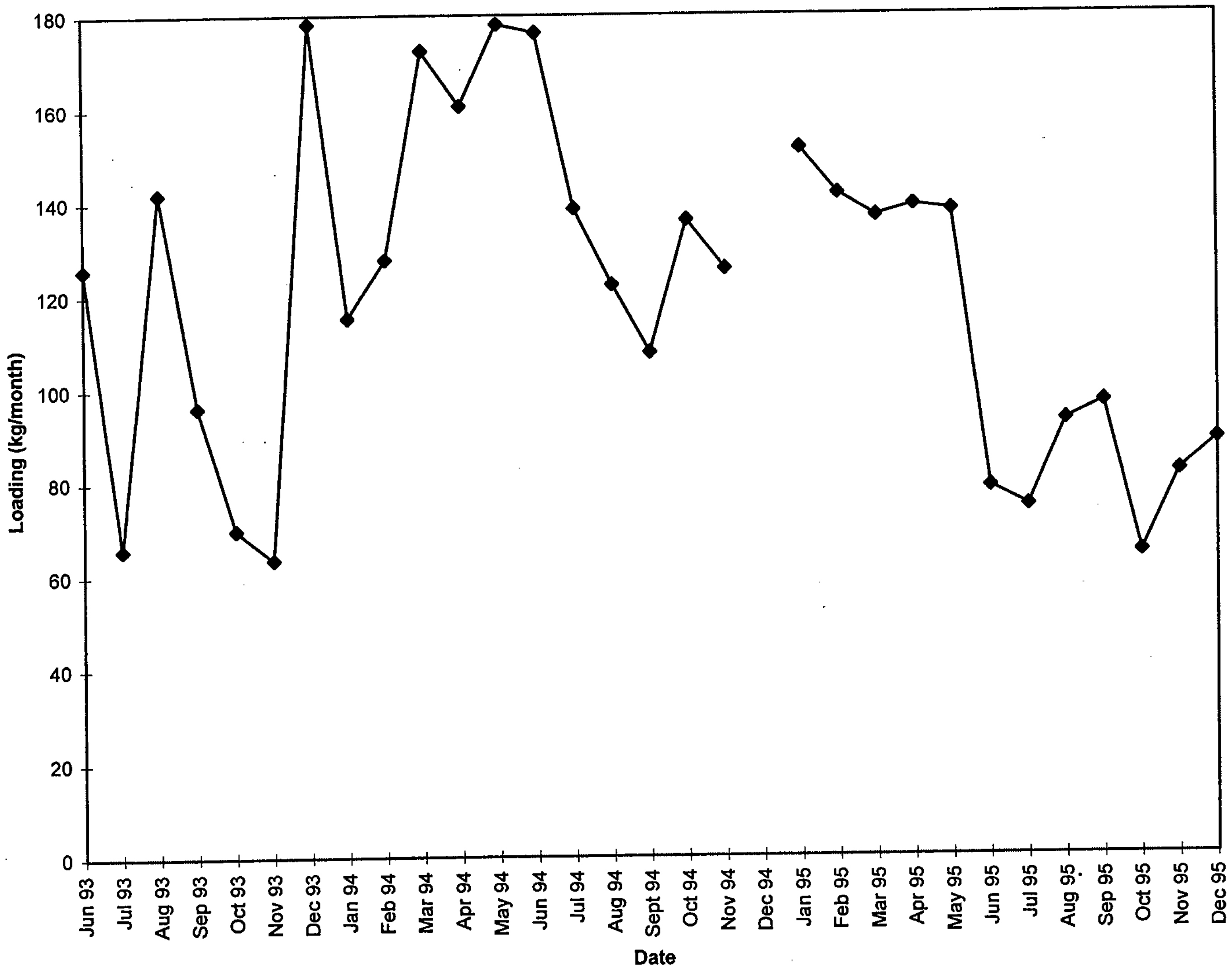
1993 - 1995 Loading - Molybdenum

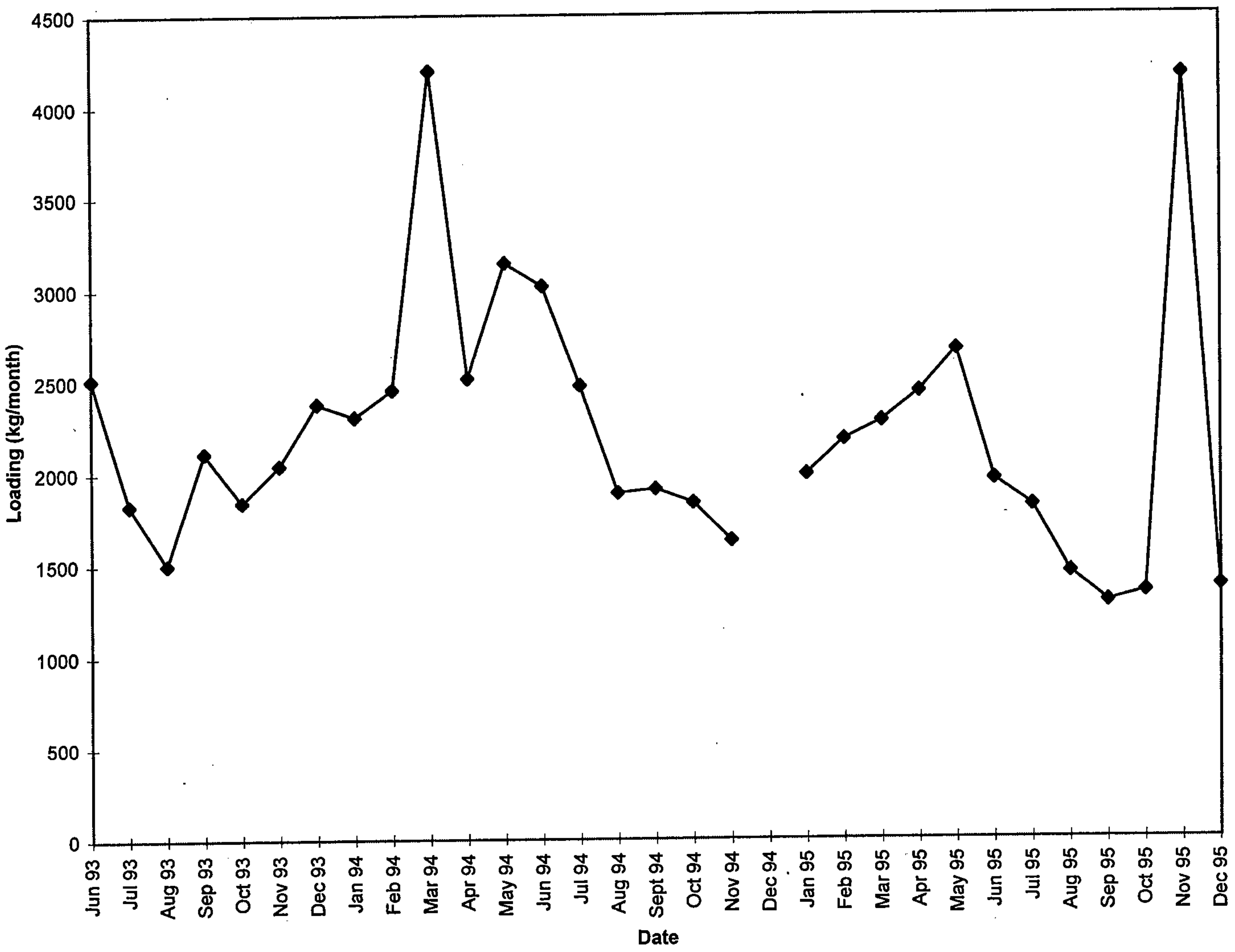


1993 - 1995 Loading - Nickel



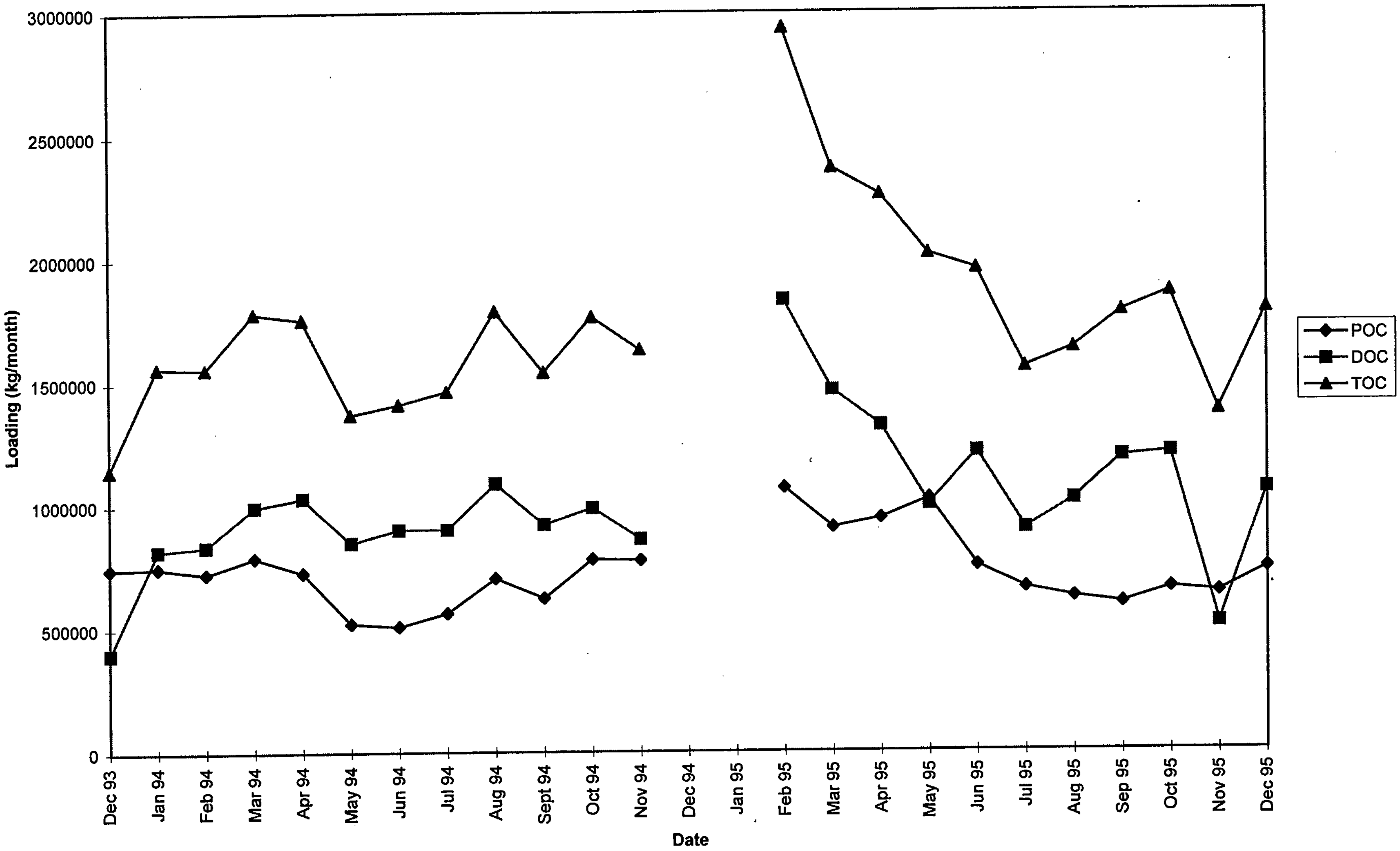
1993 - 1995 Loading - Silver



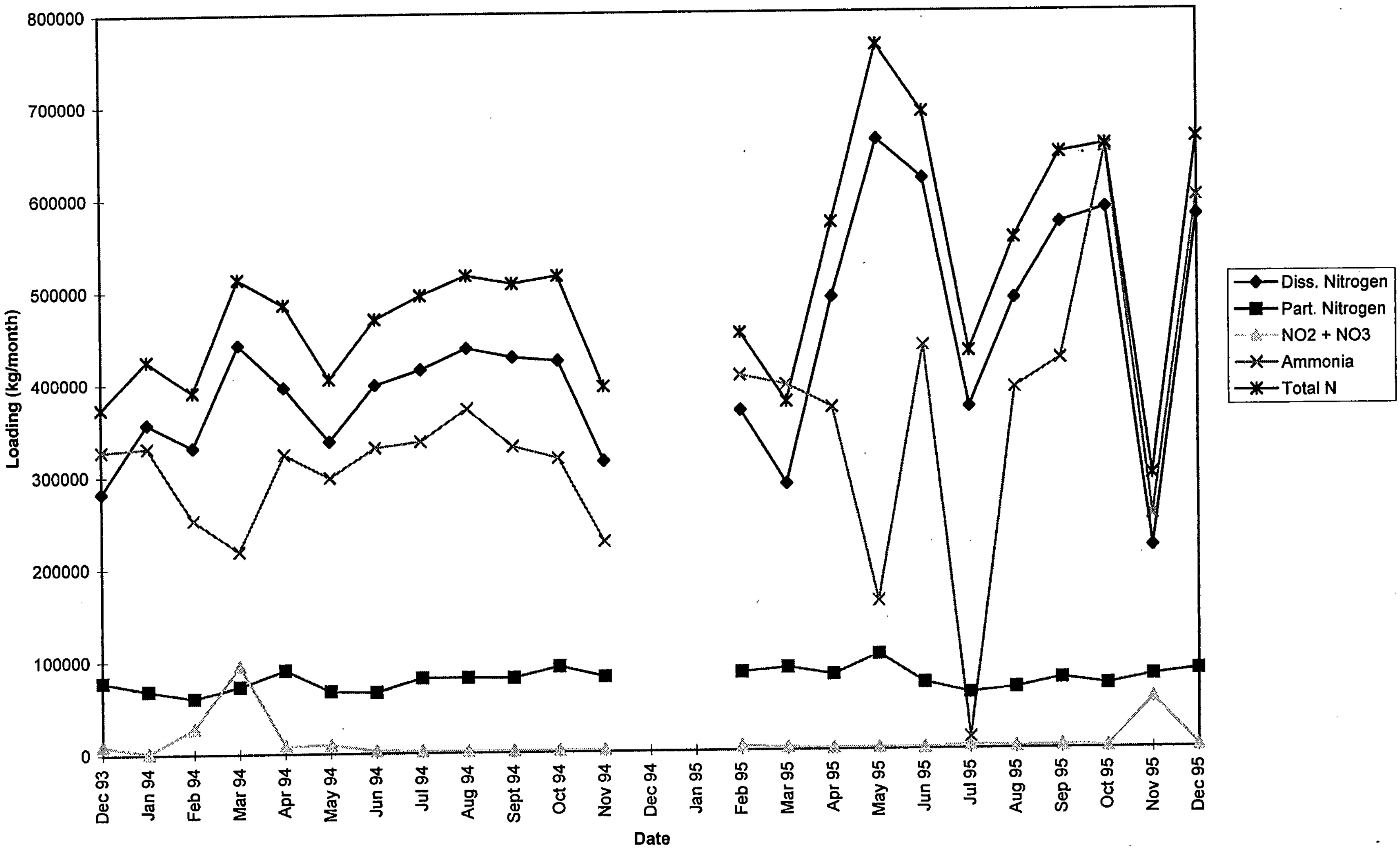


1993 - 1995 Loading - Zinc

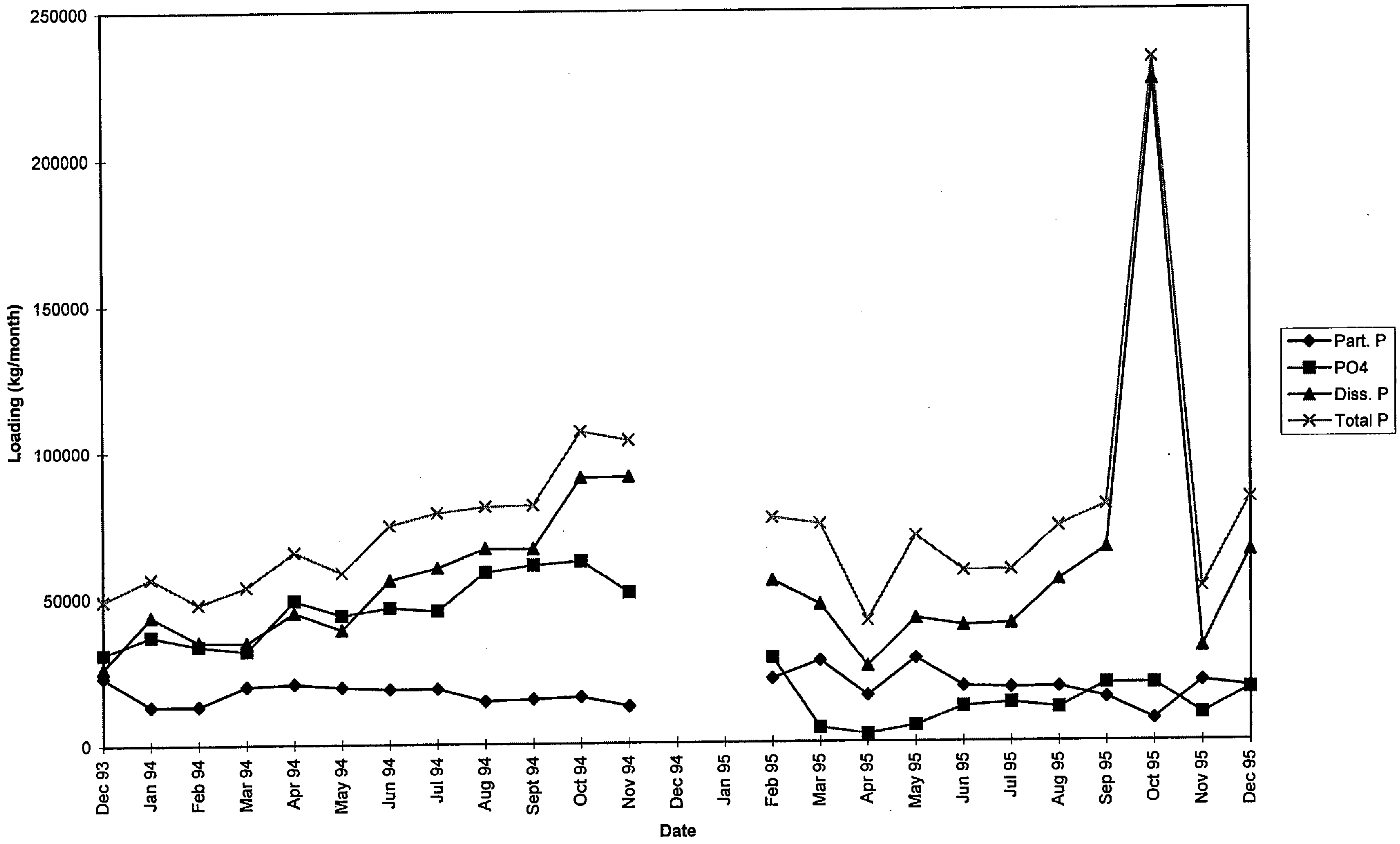
1993 - 1995 Loading - Organic Carbons

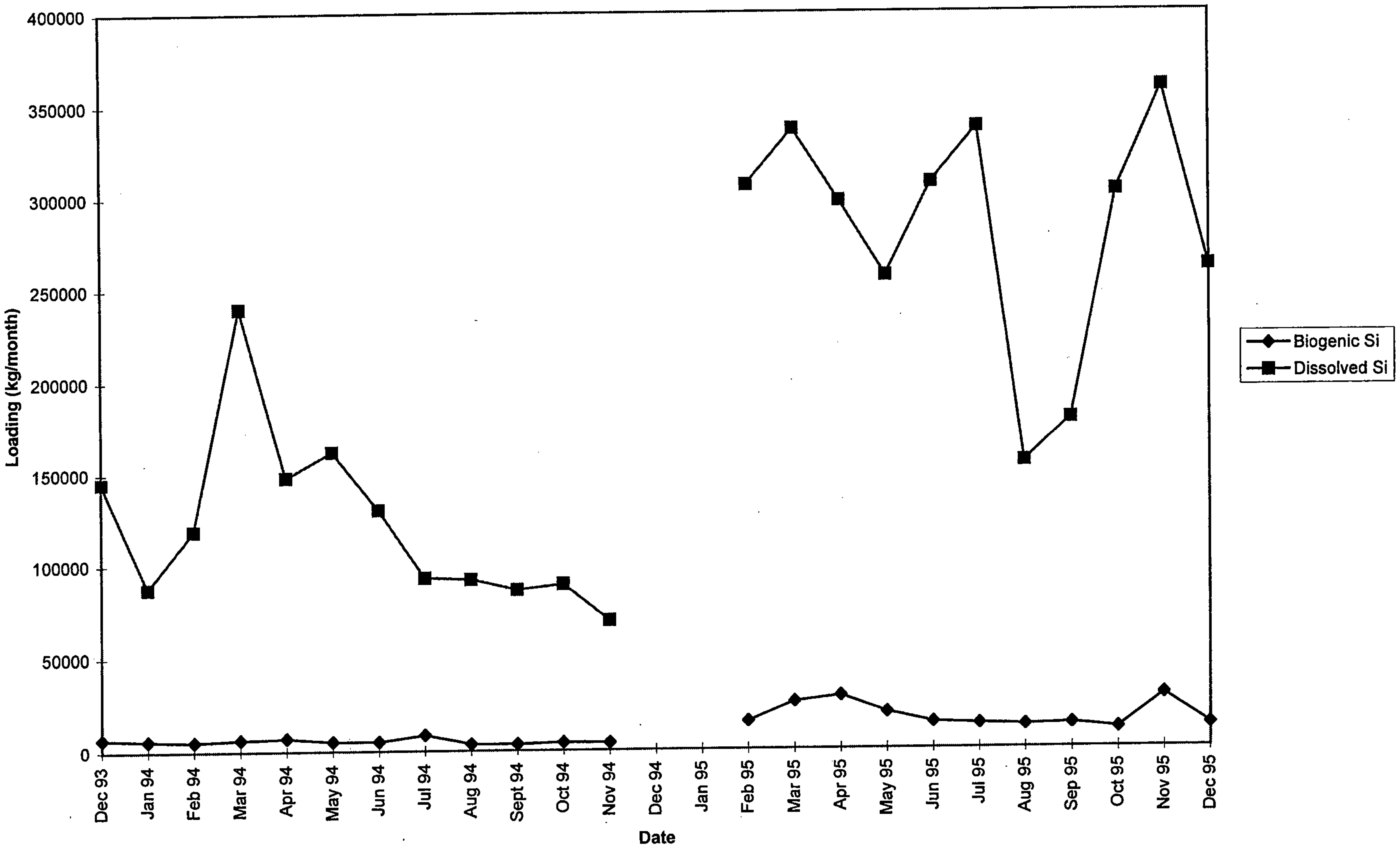


1993 - 1995 Loading - Nitrogen



1993 - 1995 Loading - Phosphorus





1993 - 1995 Loading - Biogenic Si & Dissolved Si

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