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James River Sediment Study: Operation Agnes Final Report

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JAMES RIVER SEDIMENT STUDY

Operation Agnes

Final Report

Submitted to the U. S. Army Corps of Engineers, Norfolk District

by

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INTRODUCTION

Bottom sediment samples were collected from the James River in Virginia and analyzed to evaluate the effects of tropical storm Agnes (summer, 1972) upon the sediment chemistry. The results of these analyses, from hereon called "post Agnes data," were compared with data from a similar study carried out during the summer of 1971 ("pre-Agnes data"), reported under contract no. DACW-65-71-C-0047.

The post Agnes samples encompass three distinct shoaling areas involving a total of 34.75 nautical miles of the James River. The first area extending from mile 24.75 to 33.50 can be considered as the Oligohaline James River estuary; the second and third areas extending from nautical mile 36.50 to 40.75 and 57.00 to 59.50 respectively are considered part of the lower tidal fresh water James.

METHODS

Exact sampling sites were specified by the Corps of Engineers and achieved with the aid of Corps personnel and navigational equipment. Care was taken to collect the top one centimeter of sediment by removing only the surface layer from a Ponar grab sample. The samples were stored in plastic bags, iced in the field and returned to the laboratory where they were sieved through a 2 mm screen, homogenized and refrigerated.

Parameters Studied and Methods Used	Symbol
Total Solids[1]	TS
Volatile Solids[1]	VS
Chemical Oxygen Demand[1]	COD
Total Kjeldahl Nitrogen[1]	TKN
Total Phosphorus[2]	TP
Total Zinc[3]	Tot. Zn
Total Copper[3]	Tot. Cu
Total Lead[3]	Tot. Pb
Total Mercury[4]	Tot. Hg

1. Determinations of % Total Solids, % Volatile Solids, % Chemical Oxygen Demand, and Total Kjeldahl Nitrogen were made as prescribed in "Chemistry Laboratory Manual, Bottom Sediments," compiled by the Great Lakes Regional Committee on Analytical Methods, EPA (1969).

2. Total Phosphorus determinations were made using a VIMS modification of the procedure described in "Standard Methods for the Examination of Water and Wastewater," 13th ed. (1971). One-half gram samples were fumed with sulfuric and nitric acids. Digested sediments were removed by filtration and diluted filtrates were analyzed colorimetrically.

Duplicate analysis showed that this method compared favorably with the EPA technique for sediment analysis, but consumed much less time per sample.

3. Total Zinc, Copper and Lead were determined by digesting one-half gram sediment samples in concentrated nitric acid for 24 hours and were analyzed by atomic absorbtion spectrophotometry (Varian Techtron, AA-5).

4. Mercury determinations were made by wet digestion and flameless atomic absorbtion spectrophotometry. One-half gram samples were digested in 10.0 ml concentrated sulfuric acid for 24 hours followed by oxidation with 20.0 ml 5.0% $KMnO_4$, reduction with hydroxylamine and stannous sulfate, and analyzed using a Coleman Mercury Analyzer, MAS 50.

All weights reported in techniques of analysis are wet weights unless otherwise specified. Final results have been corrected for % Total Solids and represent dry weight concentrations.

In addition to the above, sediment samples were divided into greater than (>) 63μ and less than (<) 63μ fractions. Less than 63μ fractions were analyzed separately for inorganic as well as total heavy metal concentrations. The inorganic associated metal concentrations were determined by the following procedure:

Inorganic metal extraction - A .5 g (dry wgt.) sediment sample was digested in 25.0 ml of 0.10 molar hydrochloric acid (ACS grade). After shaking for one (1) hour, the sample was centrifuged and the supernatant liquid analyzed by atomic absorbtion spectrophotometry.

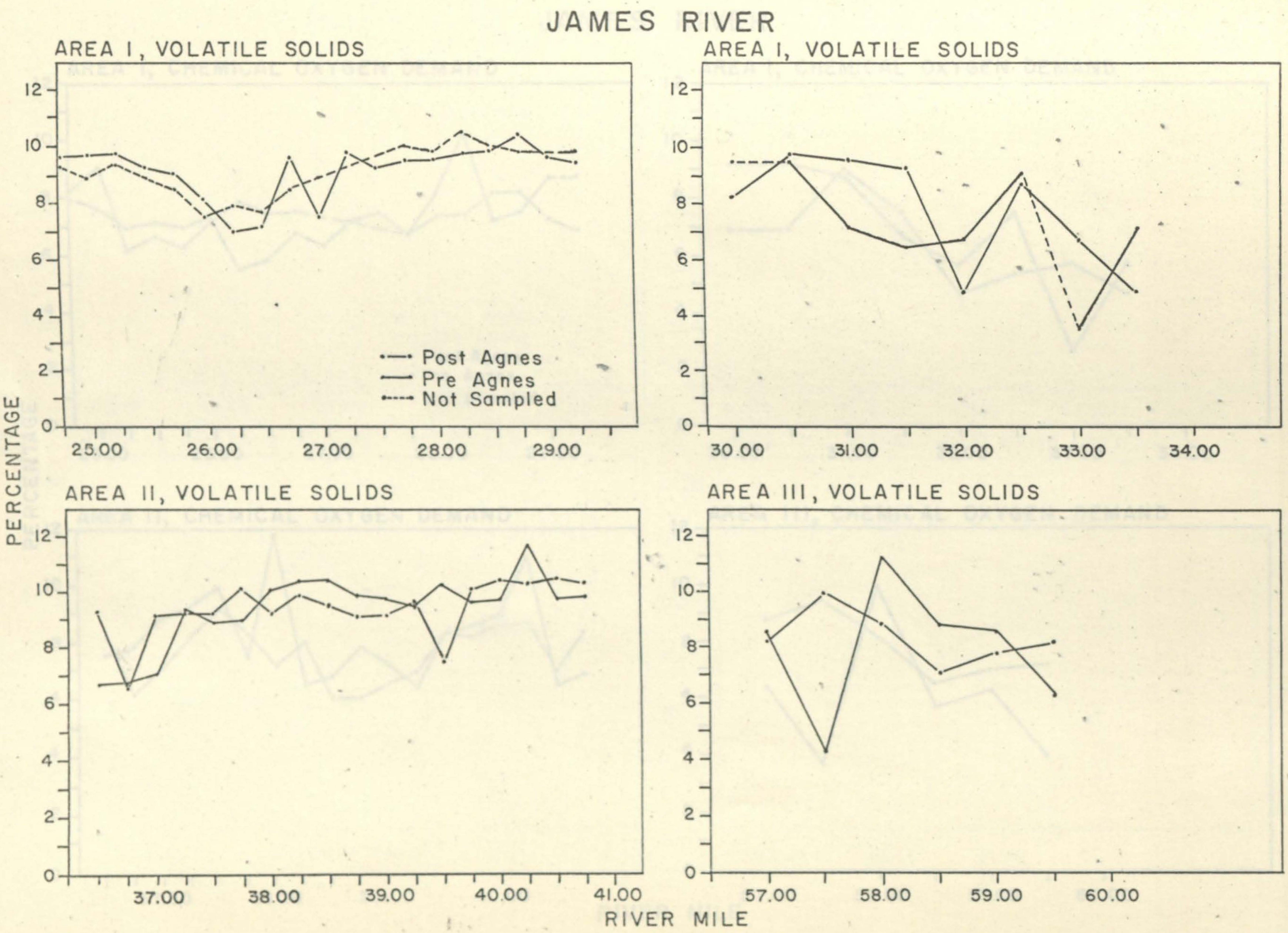
The organic associated heavy metal concentration was derived by subtracting the inorganic from the total metal concentration.

In comparing the pre- and post Agnes data, it should be noted that analytical techniques are the same for all except the total phosphorus analyses. The more rigorous digestion applied to the total phosphorus analysis in the post Agnes study is comparable to the EPA recommended method (EPA, 1969) as indicated by comparison studies (VIMS, unpublished), but can be carried out more quickly and without special equipment.

Figures were prepared to allow the visual comparison of pre-Agnes with post Agnes data. These were constructed by calculating the mean concentration of the measured parameters at each transect and plotting these concentrations against river miles. Comparison figures are available for volatile solids (Figure 1), chemical oxygen demand (Figure 2), total Kjeldahl nitrogen (Figure 3), total lead (Figure 4), total zinc (Figure 5) and total mercury (Figure 6). Where the pre- and post Agnes studies did not produce comparable data such as in the case of copper where the pre-Agnes data is inadequate or total phosphorus where a change in technique accounts for significant recovery differences, the available post Agnes data has been plotted against river miles. Copper is shown in Figure 7 and total phosphorus in Figure 8. These plots indicate both the mean concentration and the range of concentrations at a given transect.

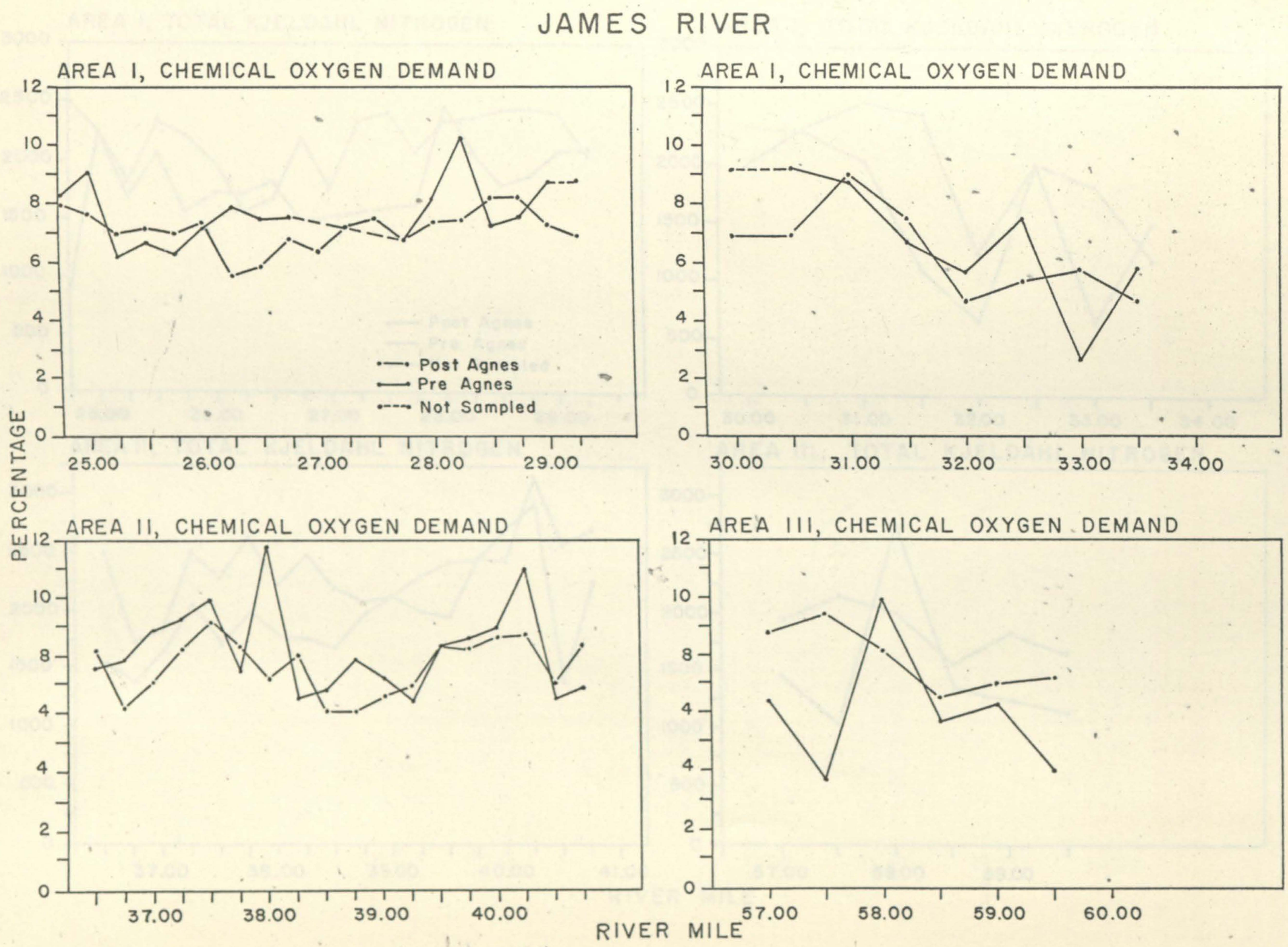
Data from each station are given in appendices A and B.

Figure 1


JAMES RIVER
AREA I, VOLATILE SOLIDS
AREA I, VOLATILE SOLIDS
AREA II, VOLATILE SOLIDS
AREA III, VOLATILE SOLIDS
PERCENTAGE
RIVER MILE
Post Agnes
Pre Agnes
Not Sampled
0
2
4
6
8
10
12
25.00
26.00
27.00
28.00
29.00
30.00
31.00
32.00
33.00
34.00
37.00
38.00
39.00
40.00
41.00
57.00
58.00
59.00
60.00

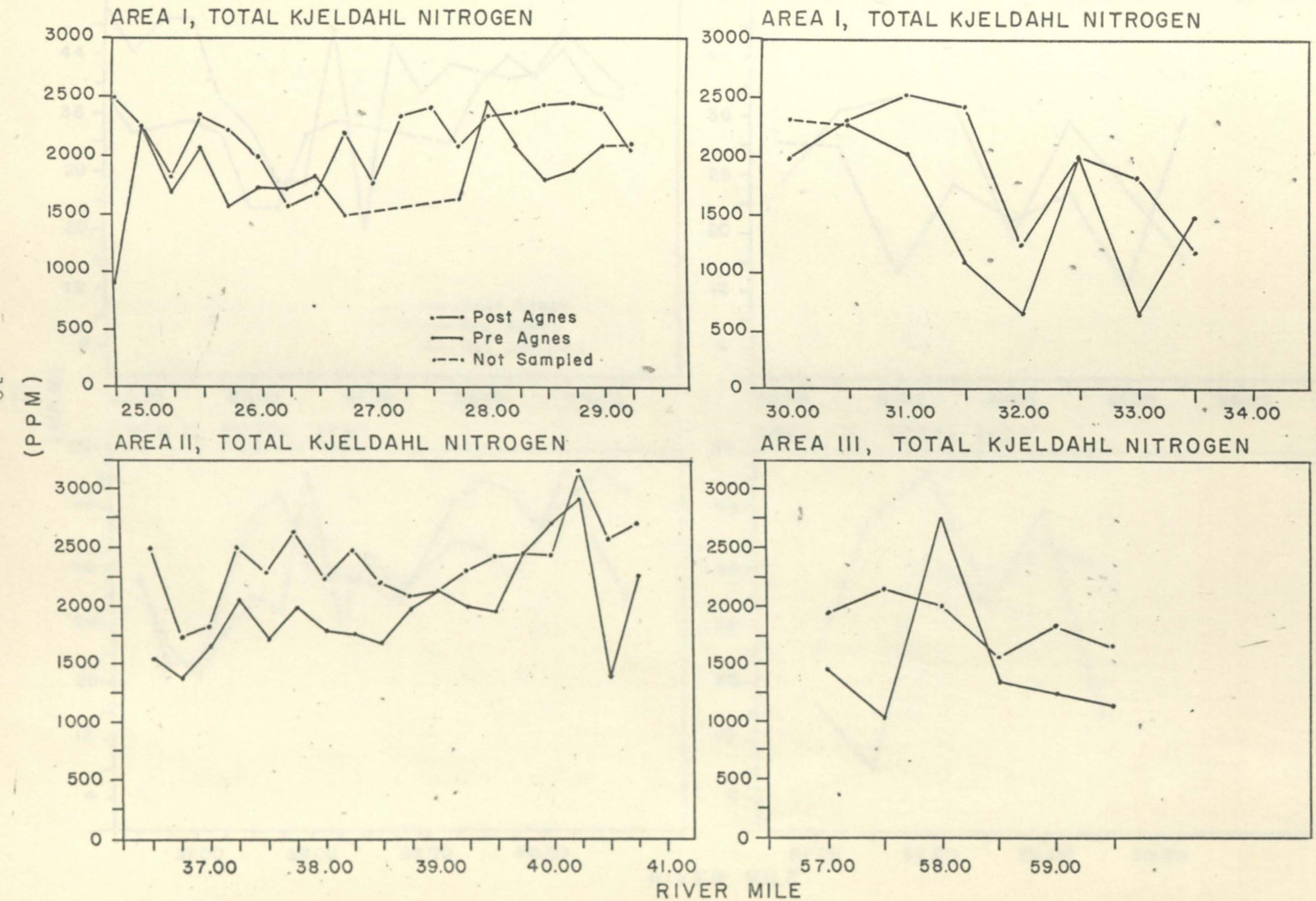
8

Figure 2



JAMES RIVER
AREA I, CHEMICAL OXYGEN DEMAND
AREA I, CHEMICAL OXYGEN DEMAND
AREA II, CHEMICAL OXYGEN DEMAND
AREA III, CHEMICAL OXYGEN DEMAND
Post Agnes
Pre Agnes
Not Sampled
PERCENTAGE
RIVER MILE
0
2
4
6
8
10
12
25.00
26.00
27.00
28.00
29.00
30.00
31.00
32.00
33.00
34.00
37.00
38.00
39.00
40.00
57.00
58.00
59.00
60.00

JAMES RIVER



AREA I, TOTAL KJELDAHL NITROGEN
AREA I, TOTAL KJELDAHL NITROGEN
AREA II, TOTAL KJELDAHL NITROGEN
AREA III, TOTAL KJELDAHL NITROGEN
(PPM)
Post Agnes
Pre Agnes
Not Sampled
RIVER MILE
0
500
1000
1500
2000
2500
3000
25.00
26.00
27.00
28.00
29.00
30.00
31.00
32.00
33.00
34.00
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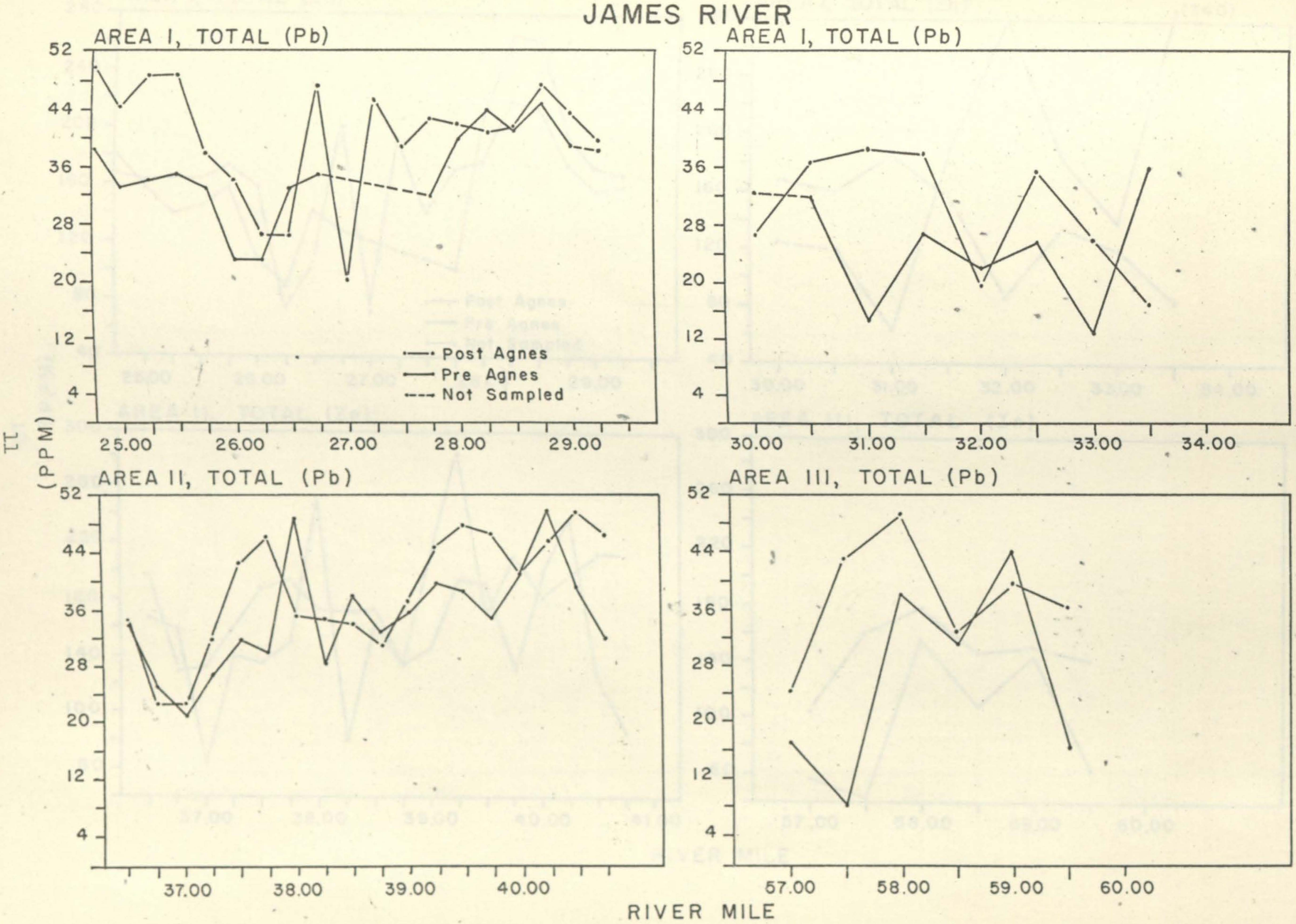
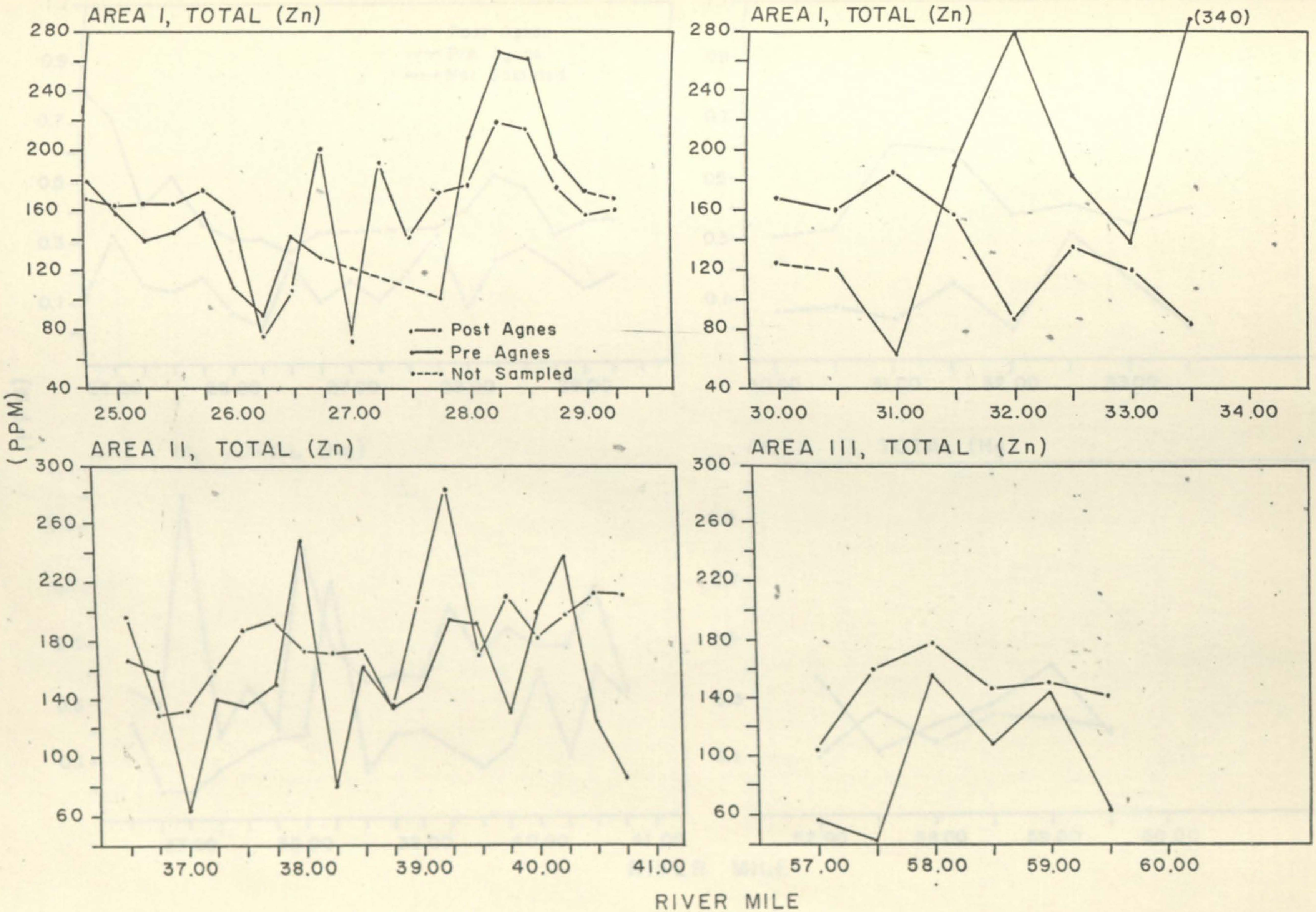
41.00
57.00
58.00
59.00


JAMES RIVER
AREA I, TOTAL (Pb)
AREA I, TOTAL (Pb)
AREA II, TOTAL (Pb)
AREA III, TOTAL (Pb)
Post Agnes
Pre Agnes
Not Sampled
Tl (PPM)
52
44
36
28
20
12
4
25.00
26.00
27.00
28.00
29.00
30.00
31.00
32.00
33.00
34.00
37.00
38.00
39.00
40.00
57.00
58.00
59.00
60.00
RIVER MILE

JAMES RIVER



AREA I, TOTAL (Zn)
280
240
200
160
120
80
40
25.00
26.00
27.00
28.00
29.00
Post Agnes
Pre Agnes
Not Sampled
AREA I, TOTAL (Zn)
(340)
30.00
31.00
32.00
33.00
34.00
(PPM)
AREA II, TOTAL (Zn)
300
260
220
180
140
100
60
37.00
38.00
39.00
40.00
41.00
AREA III, TOTAL (Zn)
57.00
58.00
59.00
60.00
RIVER MILE

JAMES RIVER

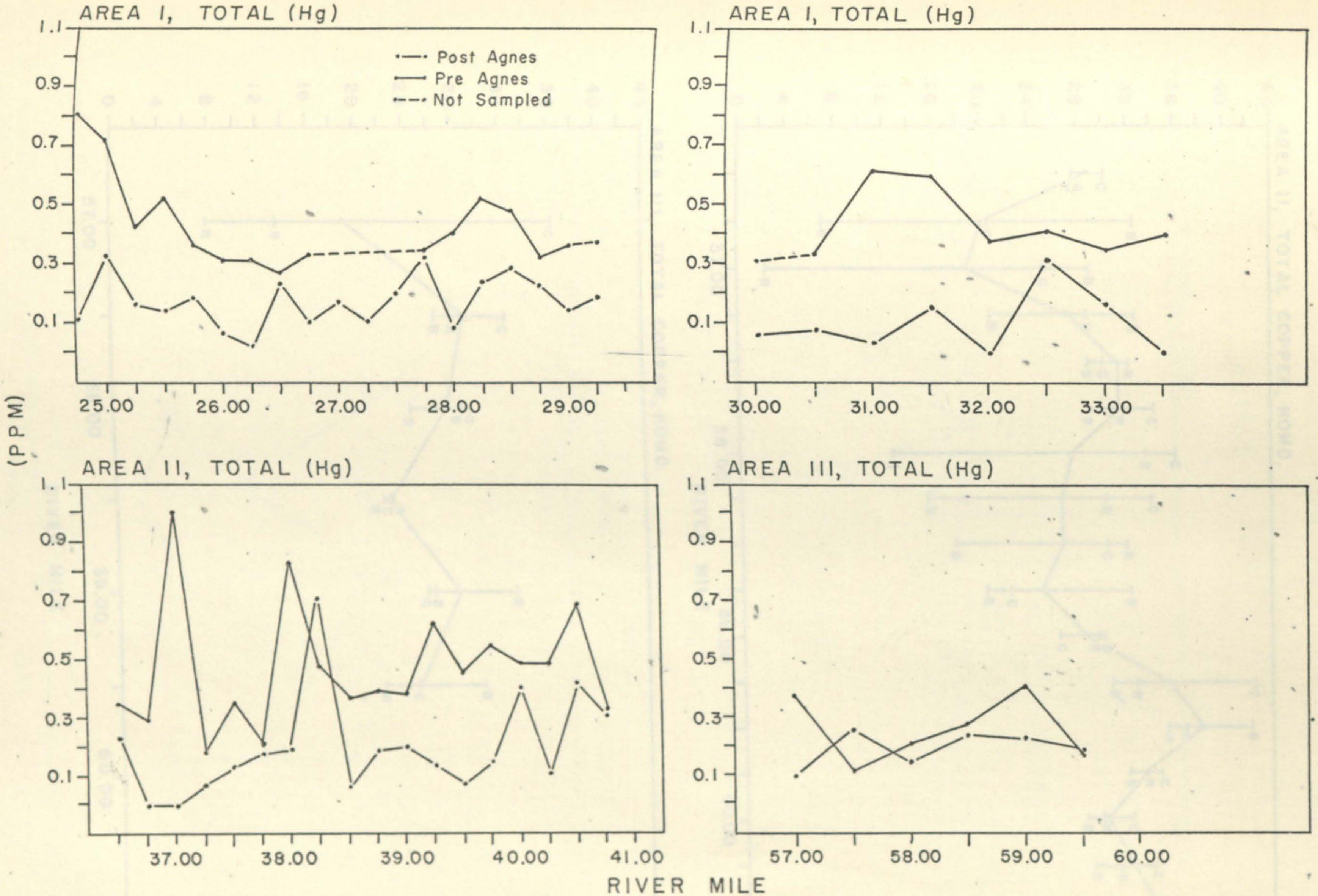
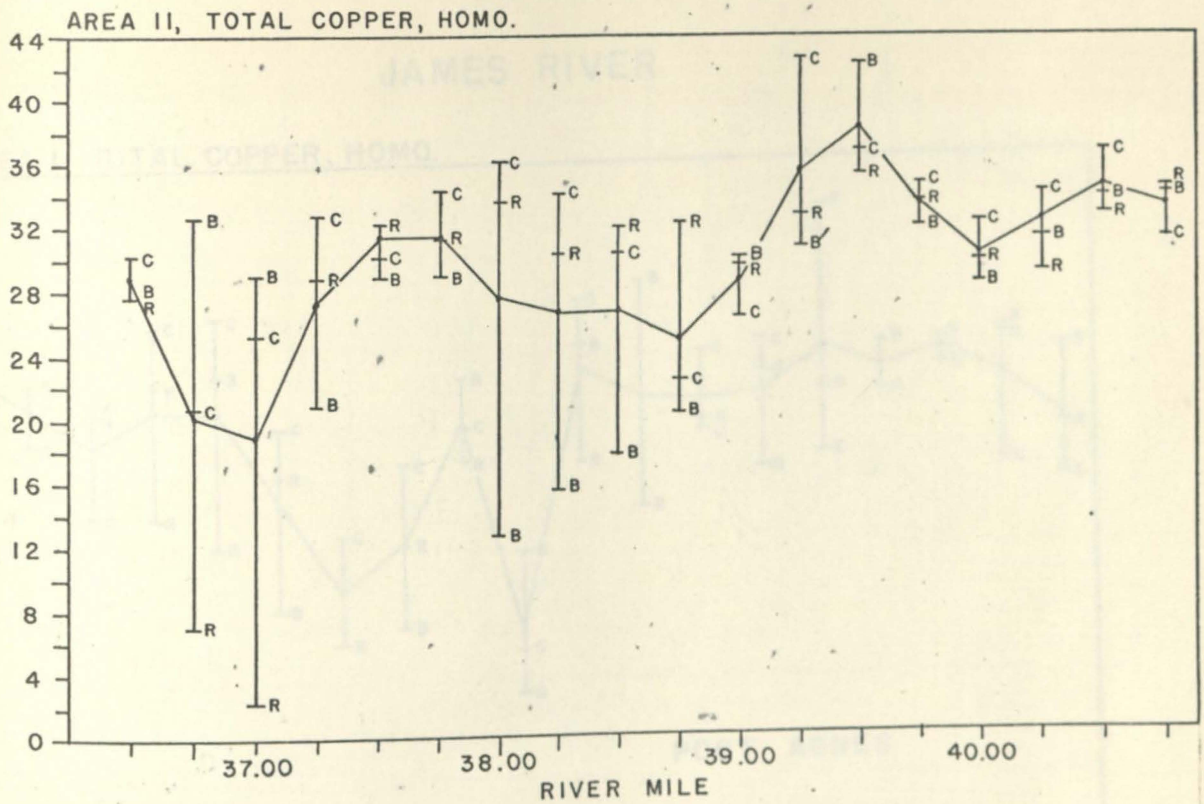

AREA I, TOTAL (Hg)
Post Agnes
Pre Agnes
Not Sampled
AREA I, TOTAL (Hg)
AREA II, TOTAL (Hg)
AREA III, TOTAL (Hg)
(PPM)
1.1
0.9
0.7
0.5
0.3
0.1
25.00
26.00
27.00
28.00
29.00
30.00
31.00
32.00
33.00
37.00
38.00
39.00
40.00
41.00
57.00
58.00
59.00
60.00
RIVER MILE

Figure 7

JAMES RIVER



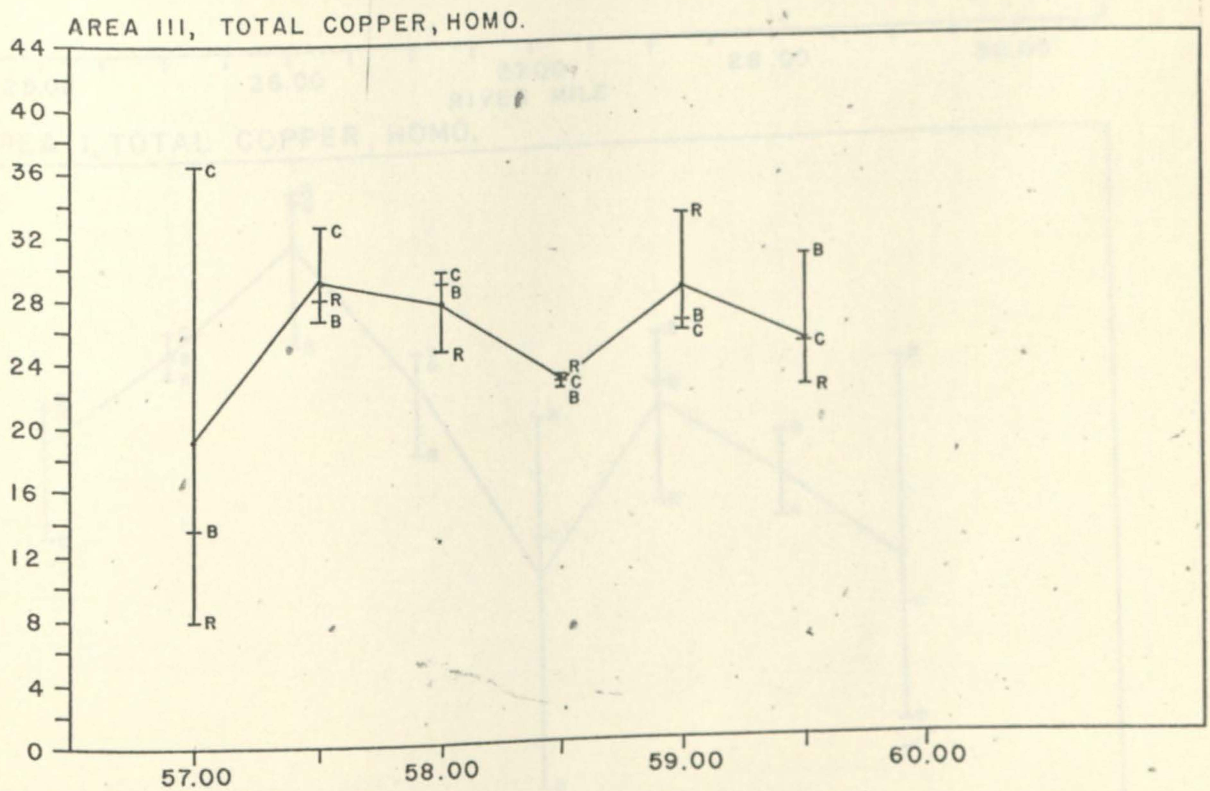
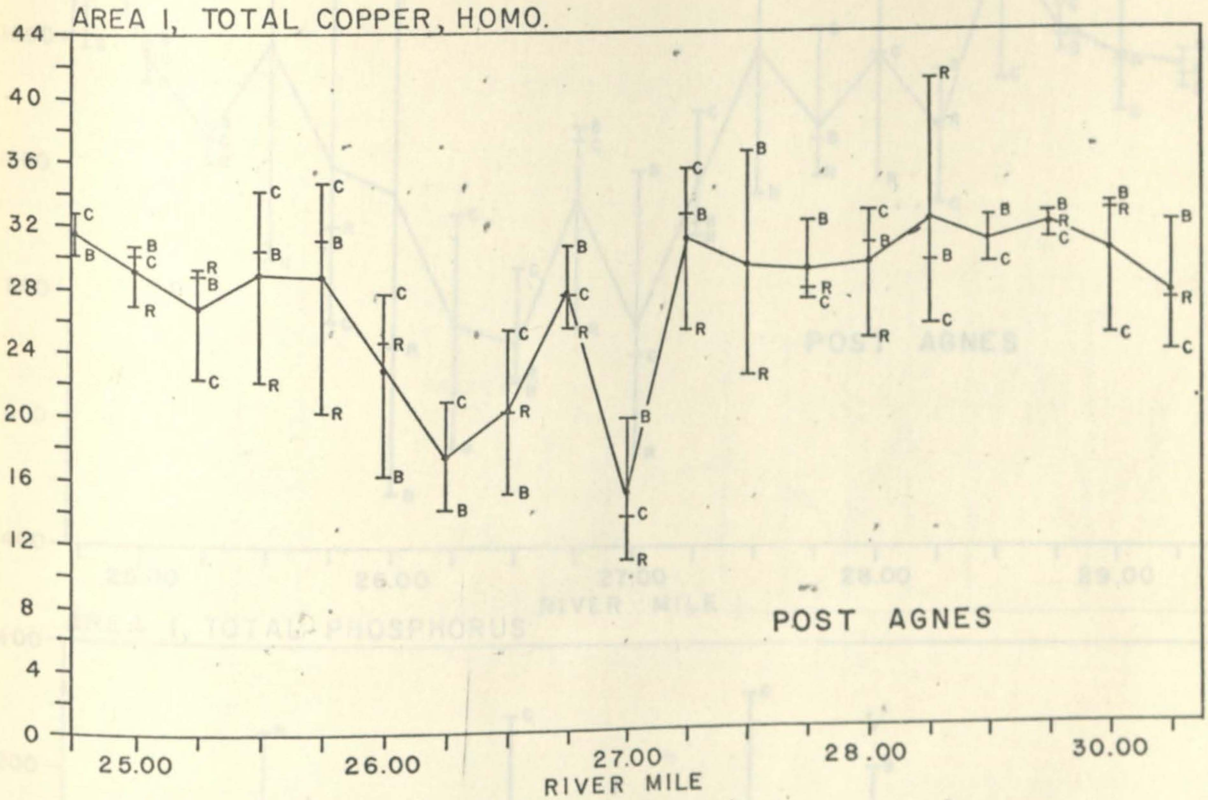
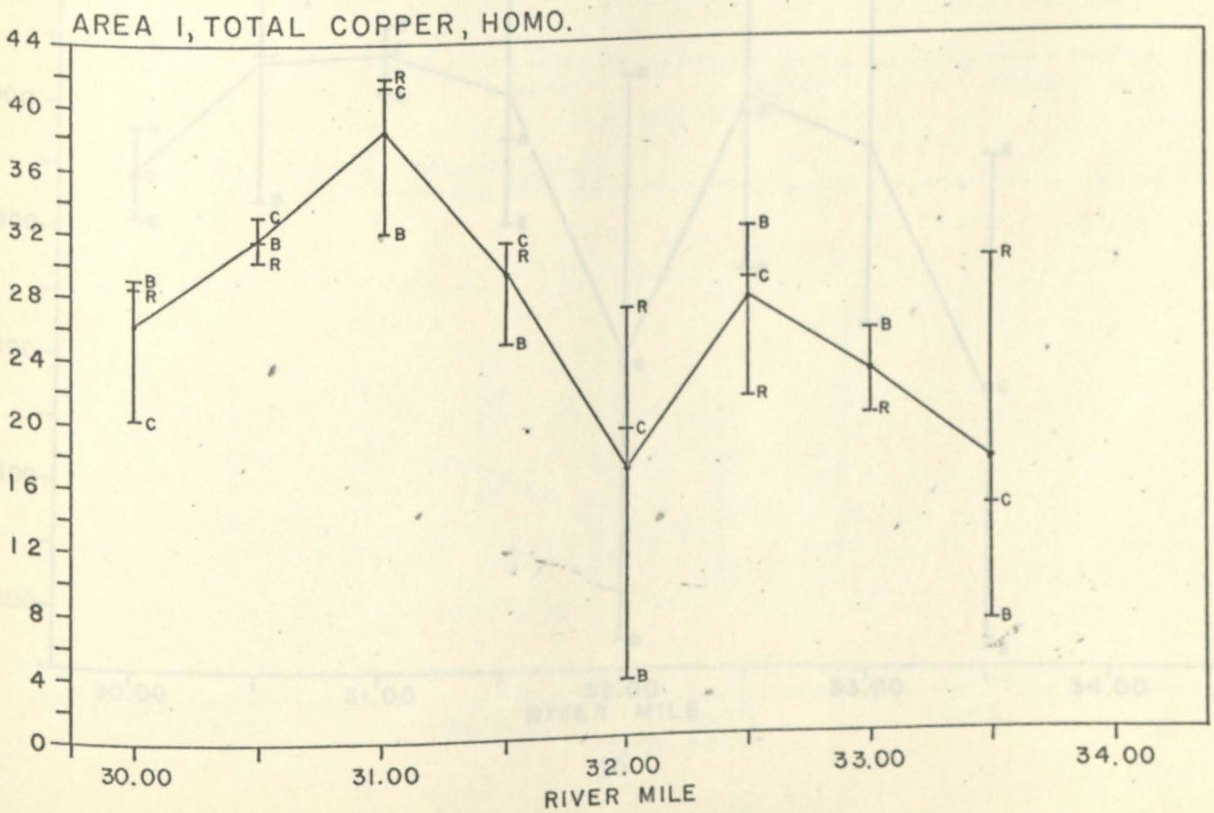


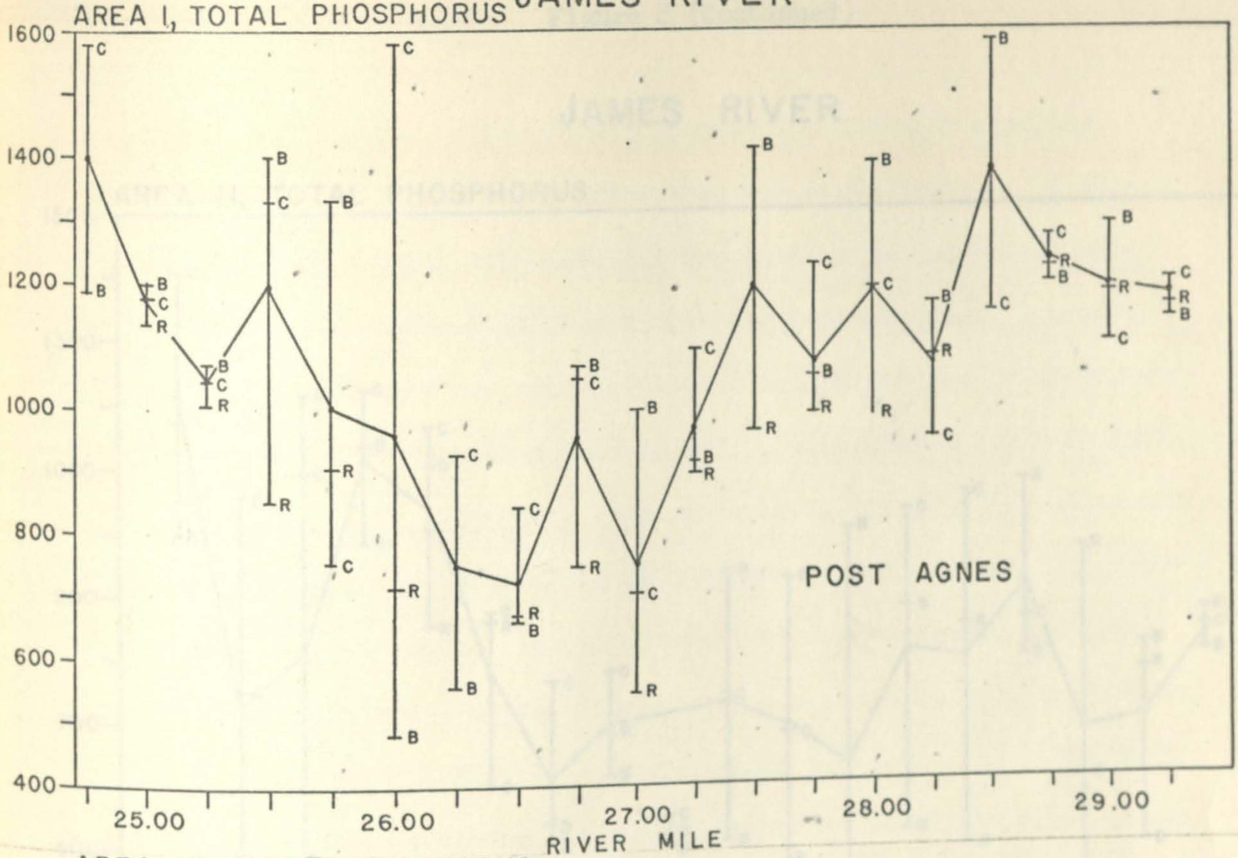
Figure 7 (Continued)

JAMES RIVER





JAMES RIVER


AREA I, TOTAL PHOSPHORUS
POST AGNES
1600
1400
1200
1000
800
600
400
25.00
26.00
27.00
28.00
29.00
RIVER MILE

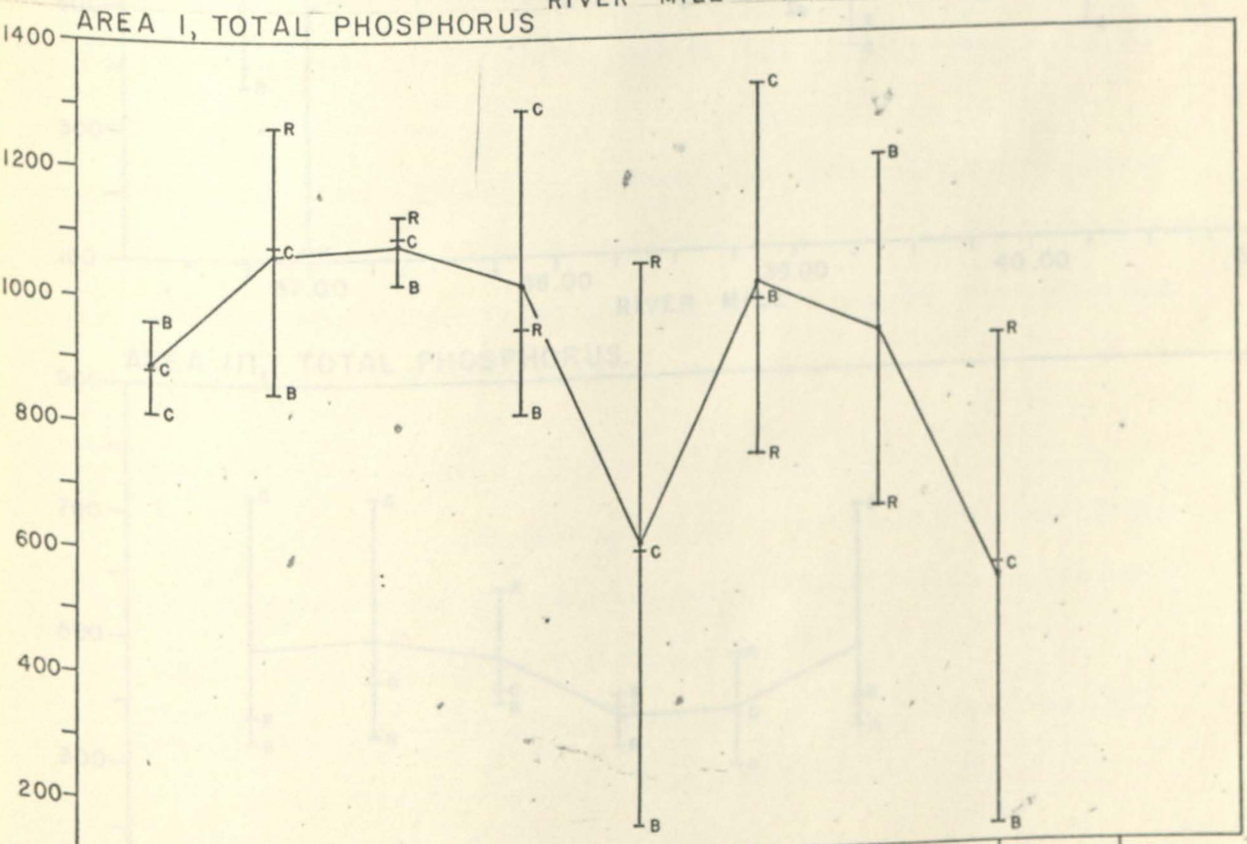
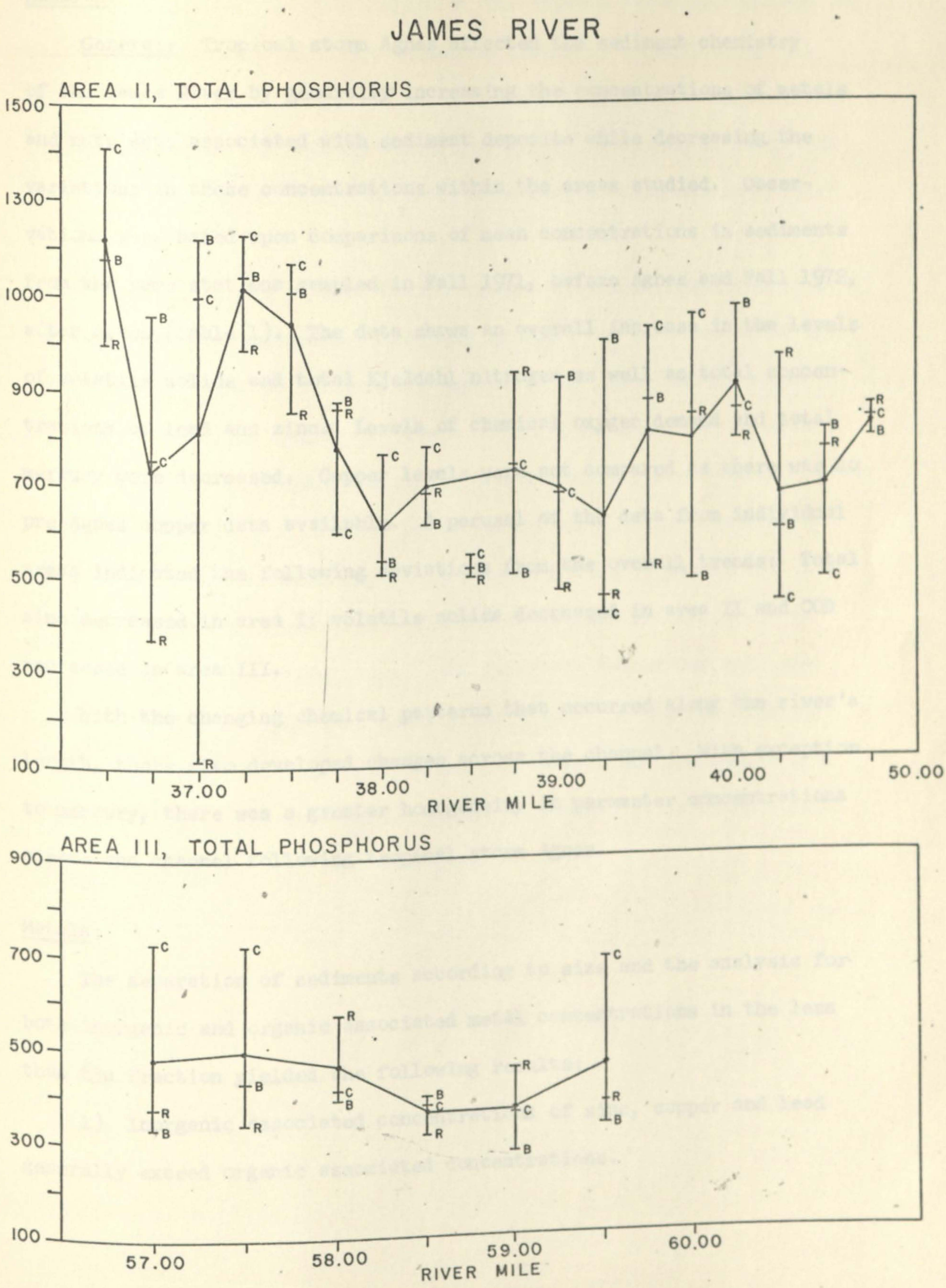

AREA I, TOTAL PHOSPHORUS
1400
1200
1000
800
600
400
200
30.00
31.00
32.00
33.00
34.00
RIVER MILE

Figure 8 (Continued)



Results:

General: Tropical storm Agnes affected the sediment chemistry of the James River by generally increasing the concentrations of metals and nutrients associated with sediment deposits while decreasing the variations in these concentrations within the areas studied. Observations were based upon comparisons of mean concentrations in sediments from the same stations sampled in Fall 1971, before Agnes and Fall 1972, after Agnes (Table 1). The data shows an overall increase in the levels of volatile solids and total Kjeldahl nitrogen as well as total concentrations of lead and zinc. Levels of chemical oxygen demand and total mercury were decreased. Copper levels were not compared as there was no pre-Agnes copper data available. A perusal of the data from individual areas indicated the following deviations from the overall trends: Total zinc decreased in area I; volatile solids decreased in area II and COD increased in area III.

With the changing chemical patterns that occurred along the river's length, there also developed changes across the channel. With exception to mercury, there was a greater homogeneity in parameter concentrations across the channel following tropical storm Agnes.

Metals:

The separation of sediments according to size and the analysis for both inorganic and organic associated metal concentrations in the less than 63μ fraction yielded the following results:

1) Inorganic associated concentrations of zinc, copper and lead generally exceed organic associated concentrations.

2) In rating the contribution of the organic associated metals to the total metals burden of the sediments (Table 2) as defined by the analytical techniques described in the methods section, it is observed that more zinc is organically bound than copper, followed by lead. At a few stations organic zinc concentrations exceed inorganic zinc fractions.

3) There exists a trend toward increasing zinc, copper and lead concentrations in sediments proceeding upriver. An examination of the data however, might be misleading, especially if mean concentrations for a given area are compared. There occurs along the river at mile 39.25 and 58.50, sediments containing extraordinarily high concentrations of metals. These locations may be correlated with their proximity to the mouths of the Chickahominy and Appomatox Rivers respectively. The outlying nature of these areas with respect to adjacent sediments is very apparent if one plots organic and inorganic associated sediment metals concentrations against James River miles. Of special interest are the concentrations of organic zinc proximal to and downstream from these tributaries and the concentrations of inorganically bound copper downstream from the high zinc stations.

Table I

Mean Chemical Concentrations in James River Sediments

Parameter	Units	All Stations Mean Fall 71	All Stations Mean Fall 72	All Stations Std. Dev. Fall 71	All Stations Std. Dev. Fall 72	Zone I Mean Fall 71	Zone I Mean Fall 72	Zone I Std. Dev. Fall 71	Zone I Std. Dev. Fall 72
Volatile Solids	%	8.74	8.91	2.47	1.98	8.43	8.76	2.45	2.00
Chem. Oxy. Dmd.	%	7.56	7.30	2.95	1.82	7.46	6.94	2.53	1.70
Tot. Kjeldahl Nit.	ppm	1779	2171	505	541	1707	2106	496	514
Total Lead	ppm	32.4	37.8	16.9	12.1	32.2	37.3	15.0	12.5
Total Zinc	ppm	154.3	165.4	117	60	172.0	154.8	116	49
Total Mercury	ppm	0.43	0.17	0.31	0.20	0.44	0.15	0.23	0.15

Parameter	Units	Zone II Mean Fall 71	Zone II Mean Fall 72	Zone II Std. Dev. Fall 71	Zone II Std. Dev. Fall 72	Zone III Mean Fall 71	Zone III Mean Fall 72	Zone III Std. Dev. Fall 71	Zone III Std. Dev. Fall 72
Volatile Solids	%	9.40	9.30	2.23	2.06	7.77	8.38	2.87	1.51
Chem. Oxy. Dmd.	%	8.27	7.63	3.09	1.90	5.74	7.85	3.24	1.79
Tot. Kjeldahl Nit.	ppm	1965	2365	420	566	1485	1861	641	354
Total Lead	ppm	34.9	38.7	17.0	14.2	25.2	37.4	20.5	10.7
Total Zinc	ppm	152.9	186.4	123	66	91.6	147.1	76	40
Total Mercury	ppm	0.48	0.20	0.41	0.27	0.25	0.19	0.19	0.08

Table 2

Percent Organic and Inorganic Associated Metals in
James River Sediments - Post Agnes

River Mile	Cu % Organic	Cu % Inorganic	Zn % Organic	Zn % Inorganic	Pb % Organic	Pb % Inorganic
24.75	32.7	67.2	41.4	58.6	20.1	79.9
25.00	28.2	71.8	43.2	56.8	24.9	75.1
25.25	30.7	69.3	42.3	57.7	21.7	78.3
25.50	34.9	65.1	36.5	63.5	16.6	83.4
25.75	20.2	79.8	47.1	52.9	11.3	88.7
26.00	29.0	71.0	*50.6	49.4	22.5	77.5
26.25	40.1	59.9	*57.8	42.2	34.1	65.9
26.50	29.8	70.2	38.3	61.7	28.9	71.1
26.75	27.8	72.2	28.9	71.1	19.6	80.4
27.00	25.8	74.2	*64.4	35.6	41.5	58.5
27.25	34.3	65.7	42.1	57.9	30.9	69.1
27.50	29.2	70.8	36.5	63.5	16.1	83.9
27.75	26.6	73.4	37.2	62.8	21.1	78.9
28.00	32.9	67.1	42.4	57.6	29.4	70.6
28.25	33.5	76.5	24.7	75.3	12.1	87.9
28.50	19.1	80.9	31.5	68.5	20.4	79.6
28.75	36.1	63.9	42.0	58.0	27.2	72.8
29.00	28.5	71.5	38.6	61.4	21.5	78.5
29.25	26.6	73.4	44.2	55.8	23.9	76.1
30.00	23.7	76.3	33.7	66.3	22.6	77.4
30.50	28.2	71.8	42.9	57.1	27.0	73.0
31.00	32.1	67.9	42.7	57.3	23.5	76.5
31.50	48.8	51.2	43.4	56.6	25.6	74.4
32.00	30.7	69.3	39.6	60.4	22.6	77.4
32.50	21.6	78.4	37.8	62.2	20.7	79.3
33.00	32.5	67.5	*51.2	48.8	36.4	63.6
33.50	34.3	65.7	*66.1	33.9	33.8	66.2
Area I Mean	30.3	69.7	42.5	57.5	24.3	75.7
36.50	37.9	72.1	39.1	60.9	20.3	79.7
36.75	26.3	73.7	42.0	58.0	28.4	71.6
37.00	21.4	78.6	38.0	62.0	16.3	83.7
37.25	53.3	46.7	43.7	56.3	28.2	71.8
37.50	22.4	77.6	42.5	57.5	15.8	84.2
37.75	27.4	72.6	45.2	54.8	26.1	73.9
38.00	42.2	57.8	51.8	48.2	34.2	65.8
38.25	34.2	65.8	51.5	48.5	36.8	63.2
38.50	26.8	73.2	37.0	63.0	19.8	80.2
38.75	15.5	84.5	48.5	51.5	21.0	79.0
39.00	35.8	64.2	41.0	59.0	30.7	69.3
39.25	23.8	76.2	*65.0	35.0	21.5	78.5
39.50	18.8	81.2	32.1	67.9	17.6	82.4

Table 2 (Continued)

River Mile	Cu % Organic	Cu % Inorganic	Zn % Organic	Zn % Inorganic	Pb % Organic	Pb % Inorganic
39.75	25.4	74.6	41.6	58.4	22.1	77.9
40.00	27.7	72.3	46.5	53.5	26.5	73.5
40.25	33.0	67.0	48.2	51.8	30.0	70.0
40.50	26.8	73.2	43.8	56.2	21.2	78.8
40.75	25.1	74.9	39.9	60.1	23.6	76.4
Area II Mean	29.1	70.9	44.3	55.7	24.2	75.8
57.00	18.2	81.8	46.1	53.9	22.1	77.9
57.50	31.7	68.3	46.0	54.0	22.2	77.8
58.00	20.3	79.7	46.3	53.7	30.1	69.9
58.50	0.9	99.1	39.0	61.0	17.2	82.8
59.00	19.8	80.2	*57.6	42.4	29.3	70.7
59.50	9.5	90.5	36.7	63.3	14.4	85.6
Area III Mean	16.7	83.3	45.3	54.7	22.5	77.5
TOTAL AREA MEAN	28.3	71.7	43.4	56.6	24.1	75.9

* Indicates stations at which the organic associated zinc concentration exceeded the inorganic associated zinc concentration

Discussion:

The effects of tropical storm Agnes upon the sediment chemistry of the James are logical in light of what is known about processes which control the distribution of sediments in estuarine systems. With special consideration to sedimentation in navigational channels, some of these factors would include:

1. A shoaling factor which transports and deposits clays and organic rich sediments in particular locations.
2. A chemical factor which promotes floculation and settling.
3. A settling factor related to the geometry of the channel.

Tropical storm Agnes effectively resuspended much of the material that had accumulated in the James River's channels as a result of these processes. In addition, the heavy rainfall and flooding which accompanied Agnes introduced large amounts of nutrients and metals into the system from terrestrial and municipal sources.

The increase in concentrations of metals and nutrients indicated by post Agnes results, the decrease in chemical variation along the course of the river and the greater homogeneity in the sediment chemistry of channel transects are all logical consequences of Agnes.

The observed general decreases in the chemical oxygen demand and mercury levels are not as easily explained. Considering the possibility of analytical interference, the procedure followed (see analytical techniques) does not oxidize aromatic hydrocarbons and even though steps are taken to minimize it, the technique is still subject to halide interference. The mercury cycle remains as yet incompletely understood. The recent literature has made significant contribution to our understanding of the processes whereby mercury may be converted from inorganic to soluble organic and even volatile phases. The application of this knowledge to form a hypothesis concerning the loss of mercury from the James River could be advanced. It is also possible that new particulate matter carried into the James system acted as a diluent to the existing sediments with respect to chemical oxygen demand and mercury. This could be the case if the new sediments were relatively deficient in COD and Hg.

In summary, for the period during and immediately following tropical storm Agnes, the introduction, resuspension, transport and distribution of sediments in the James River with their associated materials can explain the changes in the chemical load of the bottom material. Biological processes such as biodeposition and chemical processes such as floculation, sorption, etc. were of secondary importance.

Appendix A

James River

"Homogenized" Surface Sediments

Post Agnes

James River Surface Sediments

"Post Agnes"

River Mile Nautical	Channel Location	Total Solids TS(%)	Volatile Solids VS(%)	Chem. Oxy. Dmd. COD(%)	Total Phos. TP(ppm)	Total Kjeldahl N. TKN(ppm)	Total Copper Cu(ppm)	Total Zinc Zn(ppm)	Total Lead Pb(ppm)	Total Mercury Hg(ppm)
24.75	B	35.50	9.26	6.77	1187	2428	30.3	166.5	47.7	0.23
"	C	32.92	10.02	9.17	1623	2595	32.8	172.5	52.9	0.00
"	R	-	-	-	-	-	-	-	-	-
"	$\overline{X}$	34.21	9.64	7.97	1405	2511	31.6	169.5	50.3	0.11
25.00	B	30.80	9.83	7.18	1197	2427	30.8	160.9	53.6	0.46
"	C	31.73	9.08	6.94	1174	1906	30.1	158.4	39.8	0.24
"	R	32.03	10.09	8.80	1 35	2426	27.1	168.7	39.2	0.27
"	$\overline{X}$	31.51	9.67	7.64	1169	2253	29.3	162.7	44.2	0.32
25.25	B	38.89	9.55	7.97	1070	1199	28.9	174.2	43.8	0.19
"	C	31.15	9.86	7.92	1047	2295	22.5	172.1	55.1	0.25
"	R	36.31	9.79	4.95	1008	1946	29.3	146.4	46.9	0.05
"	$\overline{X}$	35.45	9.73	6.95	1042	1813	26.9	164.2	48.6	0.16
25.50	B	34.30	9.53	7.25	1400	2541	30.5	162.2	55.2	0.36
"	C	27.91	10.48	7.75	1330	2631	34.2	181.6	44.7	0.05
"	R	42.37	7.63	6.50	851	1864	22.2	148.2	46.5	0.00
"	$\overline{X}$	34.86	9.21	7.17	1194	2345	29.0	164.0	48.8	0.14
25.75	B	31.72	9.14	7.41	1332	2221	31.2	158.8	43.7	0.45
"	C	31.07	10.48	8.15	751	2730	34.7	185.8	42.9	0.04
"	R	42.52	7.42	5.40	905	1734	20.2	176.9	27.0	0.06
"	$\overline{X}$	35.10	9.01	6.99	996	2228	28.7	173.8	37.9	0.18
26.00	B	41.35	5.91	7.19	484	1703	16.3	65.9	15.0	0.13
"	C	32.26	10.57	8.89	1677	2397	27.7	169.6	47.7	0.06
"	R	40.87	7.94	6.04	713	1873	24.7	239.8	39.9	0.00
"	$\overline{X}$	38.16	8.14	7.37	958	1991	22.9	158.4	34.2	0.06
26.25	B	41.69	5.32	6.39	559	1699	14.0	69.6	16.4	0.00
"	C	44.45	8.65	4.74	925	1428	20.8	79.5	36.7	0.04
"	R	-	-	-	-	-	-	-	-	-
"	$\overline{X}$	43.07	6.98	5.56	742	1563	17.4	74.5	26.5	0.02

James River Surface Sediments

"Post Agnes" (continued)

River Mile Nautical	Channel Location	Total Solids TS(%)	Volatile Solids VS(%)	Chem. Oxy. Dmd. COD(%)	Total Phos. TP(ppm)	Total Kjeldahl N. TKN(ppm)	Total Copper Cu(PPM)	Total Zinc Zn(ppm)	Total Lead Pb(ppm)	Total Mercury Hg(ppm)
26.50	B	39.05	5.98	6.84	656	1916	15.0	66.9	14.9	0.12
"	C	40.55	7.44	5.91	842	1779	25.3	177.1	37.5	0.35
"	R	40.86	8.14	4.86	665	1351	20.1	76.1	27.1	0.00
"	$\bar{X}$	40.15	7.19	5.87	720	1682	20.1	106.7	47.2	0.12
26.75	B	34.68	9.08	7.47	1064	2544	30.6	169.1	54.7	0.00
"	C	35.37	9.25	6.84	1046	2016	27.6	202.2	47.9	0.31
"	R	41.02	10.48	6.20	746	2061	25.4	229.8	39.0	0.00
"	$\bar{X}$	37.02	9.60	6.84	952	2207	27.9	200.4	47.2	0.10
27.00	B	41.65	8.44	5.54	990	1577	19.6	90.0	29.7	0.22
"	C	34.77	7.41	7.51	702	1919	13.5	72.0	17.8	0.13
"	R	40.86	6.75	6.15	544	1808	10.8	56.4	13.8	0.15
"	$\bar{X}$	39.13	7.53	6.40	745	1768	14.6	72.8	20.4	0.17
27.25	B	39.93	10.35	6.19	911	2417	32.4	241.4	38.8	0.03
"	C	34.09	10.30	7.88	1086	2507	35.3	169.1	54.6	0.24
"	R	37.18	8.75	7.60	894	2143	25.1	163.7	42.6	0.04
"	$\bar{X}$	37.07	9.80	7.22	964	2356	30.9	191.4	45.3	0.10
27.50	B	32.72	10.76	8.95	1423	2775	36.4	184.1	57.8	0.30
"	C	-	-	-	-	-	-	-	-	-
"	R	39.78	7.72	6.14	960	2066	22.1	100.4	19.5	0.09
"	$\bar{X}$	36.25	9.24	7.54	1191	2420	29.3	142.3	38.7	0.20
27.75	B	38.10	10.11	7.72	1044	2263	31.9	175.0	49.2	0.34
"	C	34.89	9.55	6.99	1225	2159	27.0	167.3	42.2	0.22
"	R	43.63	8.83	5.75	919	1857	27.8	172.2	36.8	0.41
"	$\bar{X}$	38.87	9.50	6.82	1063	2093	28.9	171.5	42.8	0.32
28.00	B	34.68	10.49	8.34	1387	2424	30.6	170.1	43.2	0.16
"	C	33.19	10.45	7.59	1187	2663	32.5	181.1	47.2	0.08
"	R	37.00	7.68	6.30	978	1969	24.6	180.2	35.3	0.00
"	$\bar{X}$	34.96	9.54	7.41	1184	2352	29.2	177.1	41.9	0.08

James River Surface Sediments

"Post Agnes" (continued)

River Mile Nautical	Channel Location	Total Solids TS(%)	Volatile Solids VS(%)	Chem. Oxy. Dmd. COD(%)	Total Phos. TP(ppm)	Total Kjeldahl N. TKN(ppm)	Total Copper Cu(ppm)	Total Zinc Zn(ppm)	Total Lead Pb(ppm)	Total Mercury Hg(ppm)
28.25	B	35.97	10.15	7.38	1161	2344	29.4	172.4	45.3	0.06
"	C	41.46	9.65	7.11	946	2295	25.4	255.6	31.5	0.60
"	R	39.54	9.50	7.90	1073	2486	41.1	231.8	46.5	0.05
"	X̄	38.99	9.77	7.46	1060	2375	32.0	219.9	41.1	0.24
28.50	B	35.20	10.96	8.09	1617	2789	32.2	161.0	36.1	0.09
"	C	34.70	8.72	8.41	1139	2120	29.2	268.2	46.8	0.48
"	R	-	-	-	-	-	-	-	-	-
"	X̄	34.95	9.84	8.25	1378	2444	30.7	214.6	41.5	0.28
28.75	B	32.73	10.50	7.62	1189	2371	32.4	177.2	47.6	0.05
"	C	30.41	10.24	8.68	1265	2549	30.7	165.9	47.4	0.31
"	R	31.21	10.45	8.51	1219	2469	32.3	185.6	47.5	0.31
"	X̄	31.45	10.40	8.27	1224	2463	31.8	176.2	47.5	0.22
29.00	B	27.65	9.89	7.44	1285	2660	32.9	165.4	47.2	0.04
"	C	39.33	9.01	6.10	1096	1936	24.6	152.5	32.0	0.29
"	R	36.51	9.95	8.39	1174	2651	32.6	152.6	51.4	0.09
"	X̄	34.50	9.62	7.31	1185	2416	30.0	156.8	43.5	0.14
29.25	B	32.40	10.29	7.82	1133	2424	31.8	180.6	41.4	0.11
"	C	42.11	9.70	6.51	1197	1783	23.5	145.2	36.4	0.31
"	R	41.69	8.31	6.46	1153	2008	26.8	158.0	40.9	0.14
"	X̄	38.73	9.42	6.93	1174	2072	27.4	161.3	39.6	0.19
30.00	B	39.85	8.45	7.52	962	1834	29.2	169.1	41.3	0.00
"	C	42.37	7.46	6.28	819	1732	20.5	122.2	17.3	0.15
"	R	32.79	8.86	7.06	888	2396	28.8	213.7	22.3	0.03
"	X̄	38.34	8.26	6.95	890	1987	26.2	168.3	27.0	0.06
30.50	B	36.53	9.81	7.90	849	2332	31.6	156.6	36.2	0.00
"	C	36.09	9.82	6.74	1082	2293	33.2	184.8	42.2	0.25
"	R	29.74	9.62	6.41	1265	2325	30.4	142.7	31.9	0.00
"	X̄	34.12	9.75	7.02	1065	2317	31.7	161.4	36.8	0.08

James River Surface Sediments

"Post Agnes" (continued)

River Mile Nautical	Channel Location	Total Solids TS(%)	Volatile Solids VS(%)	Chem. Oxy. Dmd. COD(%)	Total Phos. TP(ppm)	Total Kjeldahl N. TKN(ppm)	Total Copper Cu(ppm)	Total Zinc Zn(ppm)	Total Lead Pb(ppm)	Total Mercury Hg(ppm)
31.00	B	32.31	9.04	9.49	1024	2411	32.1	181.1	23.0	0.00
"	C	35.43	9.51	8.24	1095	2539	41.4	205.8	47.0	0.10
"	R	28.07	10.13	9.47	1123	2654	41.9	171.4	46.3	0.00
"	$\bar{X}$	31.94	9.56	9.07	1081	2535	38.5	186.1	38.8	0.03
31.50	B	36.75	7.14	6.70	814	1787	25.0	127.7	29.8	0.17
"	C	30.09	10.17	8.57	1292	2630	31.3	151.9	40.5	0.06
"	R	29.60	10.49	7.37	949	2878	31.3	193.5	44.0	0.25
"	$\bar{X}$	32.15	9.26	7.55	1018	2432	29.2	157.7	38.1	0.16
32.00	B	77.97	0.48	0.42	147	105	3.6	25.4	0.9	0.00
"	C	45.90	5.52	5.93	585	1487	19.3	102.0	22.1	0.00
"	R	33.57	8.60	7.84	1044	2170	26.9	139.1	35.6	0.00
"	$\bar{X}$	52.48	4.87	4.73	592	1254	16.6	88.8	19.5	0.00
32.50	B	36.82	10.20	1.10	981	2304	32.1	155.6	41.3	0.49
"	C	34.75	9.68	9.13	1322	2240	28.8	143.4	36.1	0.29
"	R	45.91	6.28	6.07	733	1517	21.2	109.2	29.5	0.17
"	$\bar{X}$	39.16	8.72	5.43	1012	2020	27.4	136.1	35.6	0.32
33.00	B	42.05	7.80	6.08	1205	2025	25.4	128.1	30.4	0.06
"	C	-	-	-	-	-	-	-	-	-
"	R	48.69	5.80	5.64	642	1627	20.1	112.8	21.9	0.28
"	$\bar{X}$	45.37	6.80	5.86	923	1826	22.8	120.4	26.1	0.17
33.50	B	74.86	0.65	0.35	127	149	6.9	20.4	3.5	0.00
"	C	53.09	4.39	5.73	546	1130	14.2	95.4	17.1	0.00
"	R	35.67	9.78	8.18	915	2336	29.9	135.7	30.5	0.03
"	$\bar{X}$	54.51	4.94	4.75	529	1205	17.0	83.8	17.0	0.01
36.50	B	32.84	9.75	7.58	1179	2595	27.7	195.2	25.3	0.24
"	C	34.33	9.78	8.42	1414	2690	30.3	209.1	46.2	0.20
"	R	40.49	8.41	8.44	1011	2183	27.7	182.7	32.8	0.25
"	$\bar{X}$	35.89	9.30	8.15	1201	2489	28.6	195.7	34.8	0.23

James River Surface Sediments

"Post Agnes" (continued)

River Mile Nautical	Channel Location	Total Solids TS(%)	Volatile Solids VS(%)	Chem. Oxy. Dmd. COD(%)	Total Phos. TP(ppm)	Total Kjeldahl N. TKN(ppm)	Total Copper Cu(ppm)	Total Zinc Zn(ppm)	Total Lead Pb(ppm)	Total Mercury Hg(ppm)
36.75	B	32.45	10.18	8.43	1060	2730	32.8	191.4	30.2	0.00
"	C	43.81	6.82	8.13	755	1802	20.8	148.5	27.9	0.00
"	R	63.15	2.63	2.08	374	657	7.1	48.8	9.9	0.00
"	$\bar{X}$	46.47	6.54	6.21	730	1730	20.2	129.6	22.7	0.00
37.00	B	33.93	9.72	8.87	1220	2510	29.1	190.5	24.4	0.00
"	C	34.96	10.39	11.60	1099	2754	25.3	181.1	43.1	0.00
"	R	76.09	0.88	0.84	116	181	2.4	24.5	0.5	0.00
"	$\bar{X}$	48.33	9.18	7.10	812	1815	18.9	132.0	22.7	0.00
37.25	B	31.96	9.59	6.76	1139	2818	20.8	115.5	23.9	0.10
"	C	32.15	10.01	9.89	1225	2816	32.8	190.0	37.3	0.00
"	R	43.51	8.25	8.10	989	1851	28.8	172.8	35.0	0.12
"	$\bar{X}$	35.87	9.28	8.25	1118	2495	27.5	159.4	32.1	0.07
37.50	B	36.63	9.04	8.06	1106	2471	29.0	207.2	43.0	0.12
"	C	42.52	9.16	9.66	1163	2126	30.2	142.5	41.4	0.22
"	R	40.96	9.39	9.99	851	2248	32.1	212.6	43.4	0.06
"	$\bar{X}$	40.04	9.20	9.24	1040	2282	30.4	187.4	42.6	0.13
37.75	B	37.55	10.32	8.42	876	2642	29.1	178.4	44.2	0.11
"	C	35.12	10.14	8.75	600	2717	34.3	191.5	49.0	0.43
"	R	37.29	9.95	7.78	862	2517	31.3	211.6	45.7	0.00
"	$\bar{X}$	36.65	10.14	8.32	779	2625	31.6	193.8	46.3	0.18
38.00	B	39.46	7.21	4.66	536	1699	12.8	80.5	14.3	0.00
"	C	39.22	10.53	8.57	768	2570	36.2	234.0	43.2	0.31
"	R	37.33	10.03	8.38	505	2409	33.7	205.7	48.6	0.27
"	$\bar{X}$	38.67	9.26	7.20	603	2226	27.6	173.4	35.4	0.19
38.25	B	35.38	8.71	8.67	612	2538	15.5	88.2	14.6	0.14
"	C	36.14	10.97	8.50	781	2386	34.1	212.7	46.7	1.65
"	R	36.74	10.08	6.84	679	2507	30.2	215.5	42.8	0.33
"	$\bar{X}$	36.09	9.92	8.00	691	2477	26.6	172.1	34.7	0.71

James River Surface Sediments
"Post Agnes" (continued)

River Mile Nautical	Channel Location	Total Solids TS(%)	Volatile Solids VS(%)	Chem. Oxy. Dmd. COD(%)	Total Phos. TP(ppm)	Total Kjeldahl N. TKN(ppm)	Total Copper Cu(ppm)	Total Zinc Zn(ppm)	Total Lead Pb(ppm)	Total Mercury Hg(ppm)
38.50	B	39.15	8.49	4.97	515	1661	17.7	84.2	13.9	0.13
"	C	39.55	9.85	7.19	545	2266	30.4	194.7	41.9	0.07
"	R	43.35	10.12	6.01	499	2685	32.0	242.4	46.5	0.00
"	$\bar{X}$	41.35	9.49	6.06	520	2204	26.7	173.8	34.1	0.07
38.75	B	39.09	9.17	3.78	509	1635	20.2	84.7	19.1	0.15
"	C	38.19	8.13	5.87	739	1777	22.2	110.4	29.7	0.00
"	R	32.31	10.13	8.56	931	2826	32.3	206.8	44.2	0.40
"	$\bar{X}$	36.53	9.14	6.07	726	2079	24.9	134.0	31.0	0.18
39.00	B	36.25	9.64	7.32	919	2389	30.0	274.0	41.4	0.35
"	C	42.82	8.93	5.14	673	1719	26.3	106.9	28.0	0.18
"	R	35.94	8.96	7.22	468	2258	29.6	238.8	42.0	0.06
"	$\bar{X}$	38.34	9.18	6.56	687	2122	28.6	206.6	37.1	0.20
39.25	B	42.28	9.84	6.78	996	2318	30.8	392.5	46.0	0.00
"	C	39.46	9.22	6.67	412	2154	42.6	270.0	40.2	0.29
"	R	39.92	9.88	7.36	450	2437	32.7	283.2	48.7	0.11
"	$\bar{X}$	40.55	9.65	6.94	619	2303	35.4	315.2	45.0	0.13
39.50	B	40.12	10.50	8.60	870	2590	42.4	291.1	46.9	0.00
"	C	33.94	1.56	8.96	1024	2191	36.8	24.9	52.7	0.17
"	R	45.37	10.34	7.39	514	2484	35.4	194.3	44.4	0.15
"	$\bar{X}$	39.81	7.47	8.32	803	2422	38.2	170.1	48.0	0.07
39.75	B	34.49	9.84	7.96	484	2478	31.9	205.2	46.4	0.07
"	C	40.60	10.58	8.34	1047	2490	34.7	224.6	47.8	0.00
"	R	37.18	9.93	8.47	836	2378	33.5	197.9	46.3	0.37
"	$\bar{X}$	37.42	10.12	8.26	789	2449	33.4	209.2	46.8	0.15
40.00	B	28.75	10.46	9.13	1067	2519	28.4	177.3	41.1	0.45
"	C	38.55	10.57	8.84	848	2555	32.2	196.5	45.7	0.26
"	R	37.14	10.33	8.03	789	2222	29.8	174.5	36.3	0.49
"	$\bar{X}$	34.81	10.45	8.67	901	2432	30.1	182.8	41.0	0.40

James River Surface Sediments
"Post Agnes" (continued)

River Mile Nautical	Channel Location	Total Solids TS(%)	Volatile Solids VS(%)	Chem. Oxy. Dmd. COD(%)	Total Phos. TP(ppm)	Total Kjeldahl N. TKN(ppm)	Total Copper Cu(ppm)	Total Zinc Zn(ppm)	Total Lead Pb(ppm)	Total Mercury Hg(ppm)
40.25	B	39.36	9.85	8.35	595	2426	31.3	194.4	46.3	0.00
"	C	32.26	10.53	9.13	438	2730	34.2	204.3	47.8	0.00
"	R	33.64	10.64	8.72	968	4339	31.2	195.7	43.1	0.33
"	$\bar{X}$	35.09	10.34	8.73	667	3165	32.2	198.1	45.7	0.11
40.50	B	38.82	10.01	8.50	803	2639	33.8	202.1	49.1	0.97
"	C	35.13	10.62	8.39	487	2370	36.7	236.8	51.9	0.29
"	R	37.04	10.94	4.07	763	2699	32.8	196.8	47.7	0.00
"	$\bar{X}$	37.00	10.52	6.99	684	2569	34.4	211.9	49.6	0.42
40.75	B	34.97	10.22	8.50	787	2486	33.9	210.4	45.5	0.41
"	C	36.86	10.58	8.25	832	2716	31.3	211.1	42.8	0.28
"	R	34.08	10.27	8.31	858	2875	34.4	210.7	51.0	0.24
"	$\bar{X}$	35.30	10.36	8.35	826	2692	33.2	210.7	46.4	0.31
57.00	B	44.88	9.93	11.97	335	2424	13.6	79.1	15.2	0.05
"	C	43.81	9.27	8.47	730	2164	36.6	187.8	45.4	0.15
"	R	57.14	5.46	6.03	377	1247	7.8	49.7	12.1	0.07
"	$\bar{X}$	48.61	8.22	8.82	481	1945	19.3	105.5	24.2	0.09
57.50	B	45.21	8.57	7.89	431	2036	26.7	158.5	40.1	0.28
"	C	35.65	11.45	11.64	720	2400	32.5	181.1	45.9	0.22
"	R	50.87	9.95	8.79	341	2040	28.1	142.5	42.7	0.26
"	$\bar{X}$	43.91	9.99	9.44	497	2158	29.1	160.7	42.9	0.25
58.00	B	45.84	9.23	8.79	396	2042	29.0	171.0	48.1	0.15
"	C	47.64	8.39	8.00	412	2169	29.6	224.5	45.1	0.15
"	R	48.31	9.12	7.76	576	1842	24.6	139.8	53.9	0.13
"	$\bar{X}$	48.79	8.21	7.19	464	2018	27.7	178.4	49.0	0.14
58.50	B	54.78	6.96	6.17	397	1530	151.4	32.1	0.30	0.30
"	C	53.66	7.25	6.53	379	1584	144.3	32.0	0.25	0.25
"	R	53.98	7.11	6.74	319	1557	145.2	33.5	0.16	0.16
"	$\bar{X}$	54.14	7.11	6.48	365	1556	22.5	147.0	32.5	0.24

James River Surface Sediments
"Post Agnes" (continued)

River Mile Nautical	Channel Location	Total Solids TS(%)	Volatile Solids VS(%)	Chem. Oxy. Dmd. COD(%)	Total Phos. TP(ppm)	Total Kjeldahl N. TKN(ppm)	Total Copper Cu(ppm)	Total Zinc Zn(ppm)	Total Lead Pb(ppm)	Total Mercury Hg(ppm)
59.00	B	52.47	6.36	5.05	275	1414	26.1	121.2	38.3	0.21
"	C	52.55	7.63	6.88	358	1936	25.7	146.2	35.4	0.17
"	R	48.37	9.46	8.97	455	2152	32.9	182.7	44.4	0.28
"	$\overline{X}$	51.13	7.82	6.97	363	1834	28.2	150.0	39.4	0.22
59.50	B	41.08	9.33	7.50	330	1790	30.2	164.0	39.7	0.17
"	C	48.91	8.37	7.56	684	1844	24.7	141.3	38.5	0.31
"	R	56.38	6.94	6.50	379	1320	19.8	117.2	30.1	0.04
"	$\overline{X}$	48.79	8.21	7.19	464	1653	24.9	140.8	36.1	0.17

Appendix B

James River

Surface Sediments < 63μ

Post Agnes

James River Surface Sediments
<63µ - Fall 1972

River Mile		Copper (ppm)			Zinc (ppm)			Lead (ppm)		
		Total	Inorganic	Organic	Total	Inorganic	Organic	Total	Inorganic	Organic
24.75	B	32.3	21.9	10.4	202.6	118.7	83.9	52.1	41.1	11.0
	C	33.0	22.0	11.0	206.0	117.0	89.0	46.6	37.8	8.8
	R	-	-	-	-	-	-	-	-	-
	$\bar{X}$	32.6	21.9	10.7	204.3	117.8	86.4	49.3	39.4	9.9
25.00	B	31.3	21.9	9.4	208.3	132.2	76.1	54.5	45.4	9.1
	C	31.8	20.9	10.9	180.6	95.5	85.1	50.3	35.4	14.9
	R	75.3	56.4	18.9	204.3	100.9	103.4	50.6	35.8	14.8
	$\bar{X}$	46.1	33.1	13.0	192.4	109.5	88.2	51.8	38.9	12.9
25.25	B	32.7	22.7	10.0	204.0	133.0	71.0	46.2	40.6	5.6
	C	30.9	21.5	9.4	185.0	100.8	84.2	51.6	37.6	14.0
	R	30.4	20.8	9.5	196.2	109.5	86.7	50.2	37.7	12.5
	$\bar{X}$	31.3	21.7	9.6	195.0	114.4	80.6	49.3	38.6	10.7
25.50	B	34.0	23.4	10.5	207.4	141.9	65.5	55.9	50.9	5.0
	C	40.3	22.9	17.3	204.3	112.8	91.5	54.7	38.2	16.5
	R	28.1	20.4	7.7	266.1	218.2	47.9	50.4	45.3	5.1
	$\bar{X}$	34.1	22.2	11.8	225.9	157.6	68.3	53.7	44.8	8.9
25.75	B	38.9	22.1	16.8	199.0	136.0	63.0	47.0	38.1	8.8
	C	31.4	24.9	6.5	200.0	143.0	57.0	47.2	43.4	3.7
	R	90.4	81.3	9.0	221.4	167.7	53.7	44.3	41.5	2.8
	$\bar{X}$	53.6	42.8	10.8	206.8	148.9	57.9	46.2	41.0	5.1
26.00	B	16.3	11.1	5.2	162.0	42.2	119.8	13.8	11.7	2.0
	C	47.7	33.7	14.1	200.7	107.1	93.6	53.2	35.8	17.4
	R	29.0	21.1	7.9	335.1	258.3	76.8	50.5	43.8	6.7
	$\bar{X}$	31.0	22.0	9.0	232.6	135.9	96.7	39.2	30.4	8.7

River Mile		Copper (ppm)			Zinc (ppm)			Lead (ppm)		
		Total	Inorganic	Organic	Total	Inorganic	Organic	Total	Inorganic	Organic
26.25	B	13.9	8.3	5.6	73.6	29.9	43.7	18.1	10.7	7.4
	C	21.6	12.8	8.7	102.6	44.5	58.1	40.0	27.6	12.4
	R	-	-	-	-	-	-	-	-	-
	$\bar{X}$	17.7	10.6	7.2	88.1	37.2	50.9	29.0	19.1	9.9
26.50	B	13.7	8.8	4.9	69.4	20.6	48.8	16.7	8.6	8.1
	C	24.7	19.5	5.2	224.5	176.2	48.3	40.8	32.2	18.6
	R	24.1	15.6	8.5	105.7	49.7	56.0	35.8	25.5	10.3
	$\bar{X}$	20.8	14.6	6.2	133.2	82.2	51.0	31.1	22.1	12.3
26.75	B	31.8	23.6	8.2	213.6	144.7	68.9	54.8	46.0	8.8
	C	29.7	21.2	8.5	239.2	184.7	54.5	45.2	38.0	7.1
	R	28.3	20.0	8.3	294.9	202.1	92.8	50.4	36.9	13.5
	$\bar{X}$	29.9	21.6	8.3	249.2	177.2	72.1	50.1	40.3	9.8
27.00	B	25.0	12.7	12.3	111.0	41.1	69.9	43.9	23.4	20.5
	C	47.5	34.7	12.8	84.8	29.8	55.0	23.4	14.6	8.8
	R	61.4	52.0	9.4	79.2	27.1	52.6	20.8	13.7	7.1
	$\bar{X}$	44.6	33.1	11.5	91.7	32.7	59.0	29.4	17.2	12.1
27.25	B	33.4	18.4	15.0	258.3	162.2	96.1	50.8	34.1	16.7
	C	37.6	23.9	13.7	206.0	108.8	97.2	52.9	36.9	16.0
	R	62.8	45.5	17.3	180.6	102.4	78.2	46.8	33.1	13.7
	$\bar{X}$	44.6	29.3	15.3	215.0	124.5	90.5	50.2	34.7	15.5
27.50	B	34.5	25.4	9.1	207.9	140.9	67.0	54.5	48.9	5.6
	C	-	-	-	-	-	-	-	-	-
	R	25.8	17.2	8.6	123.9	70.0	53.9	32.5	24.1	8.4
	$\bar{X}$	30.1	21.3	8.8	165.9	105.4	60.4	43.5	36.5	7.0

River Mile		Copper (ppm) Total	Copper (ppm) Inorganic	Copper (ppm) Organic	Zinc (ppm) Total	Zinc (ppm) Inorganic	Zinc (ppm) Organic	Lead (ppm) Total	Lead (ppm) Inorganic	Lead (ppm) Organic
27.75	B	31.8	25.0	6.8	202.9	133.3	69.6	50.0	47.5	2.5
	C	54.5	40.6	13.8	181.2	110.5	70.7	48.4	34.6	13.8
	R	92.8	65.6	27.2	243.5	150.6	92.9	42.3	28.8	12.5
	$\bar{X}$	59.7	43.8	15.9	209.2	131.5	77.7	46.9	37.0	9.6
28.00	B	49.1	34.4	14.6	204.5	104.9	99.7	53.0	35.6	17.4
	C	65.1	46.6	18.5	218.8	120.4	98.4	58.2	40.6	17.6
	R	30.7	16.2	14.5	214.0	142.0	72.0	42.8	32.4	10.4
	$\bar{X}$	48.3	32.4	15.9	212.4	122.4	90.0	51.3	36.2	15.1
28.25	B	42.9	35.0	7.9	208.9	132.2	76.7	53.0	45.4	7.6
	C	56.0	46.7	9.3	307.0	248.0	59.0	44.8	40.6	4.2
	R	44.2	27.8	16.4	244.2	192.3	51.9	57.9	50.9	7.0
	$\bar{X}$	47.7	36.5	11.2	253.4	190.8	62.5	51.9	45.6	6.3
28.50	B	34.3	23.7	10.6	198.4	106.7	91.7	54.0	38.2	15.8
	C	101.6	86.4	15.2	303.7	237.1	66.6	50.3	44.8	5.5
	R	-	-	-	-	-	-	-	-	-
	$\bar{X}$	45.3	55.0	12.9	251.0	171.9	79.1	52.1	41.5	10.6
28.75	B	49.9	29.9	20.0	206.0	104.0	102.0	56.8	36.0	20.8
	C	37.8	23.3	14.6	200.9	106.3	94.6	56.6	38.8	17.8
	R	34.5	25.0	9.5	220.4	153.3	67.1	54.6	47.5	7.1
	$\bar{X}$	40.7	26.0	14.7	209.1	121.2	87.9	56.0	40.8	15.2
29.00	B	33.3	23.7	9.6	199.7	102.9	96.8	52.6	33.7	18.9
	C	29.2	20.3	8.9	194.8	125.6	69.2	43.3	36.5	6.8
	R	37.4	27.6	9.8	214.4	145.3	69.1	57.6	50.4	7.2
	$\bar{X}$	33.3	23.8	9.4	203.0	124.6	78.3	51.2	40.2	11.0

James River Surface Sediments (continued)

River Mile		Copper (ppm)			Zinc (ppm)			Lead (ppm)		
		Total	Inorganic	Organic	Total	Inorganic	Organic	Total	Inorganic	Organic
29.25	B	37.2	22.6	14.7	201.4	96.0	105.4	51.0	34.1	16.9
	C	90.1	70.2	19.9	206.0	121.0	85.0	45.2	34.6	10.6
	R	32.9	25.0	7.9	202.9	123.9	79.0	50.8	43.4	7.4
	$\bar{X}$	53.4	39.2	14.2	203.4	113.6	89.8	49.0	37.3	11.7
30.00	B	31.9	23.1	8.9	176.1	91.6	84.5	44.7	31.0	13.6
	C	-	-	-	-	-	-	-	-	-
	R	31.4	25.0	6.4	231.2	178.5	52.7	44.0	37.5	6.5
	$\bar{X}$	31.6	24.1	7.6	203.7	135.0	68.6	44.3	34.3	10.1
30.50	B	39.7	25.6	14.1	206.1	101.4	104.7	52.8	33.8	19.0
	C	36.3	28.1	8.2	204.0	126.0	78.0	44.7	38.0	6.7
	R	32.6	24.4	8.2	182.3	110.6	71.7	49.2	35.3	13.8
	$\bar{X}$	36.2	26.0	10.2	197.5	112.7	84.8	48.9	35.7	13.2
31.00	B	39.7	29.2	10.5	204.0	124.0	80.0	39.4	38.1	12.0
	C	59.7	34.9	24.9	201.5	101.8	99.7	52.6	31.8	20.8
	R	42.0	31.9	10.1	214.0	129.0	85.0	48.4	37.4	11.0
	$\bar{X}$	47.1	32.0	15.1	206.5	118.3	88.2	46.8	35.8	14.6
31.50	B	34.3	24.5	9.9	199.8	102.4	97.4	49.5	33.5	16.0
	C	34.6	28.0	6.6	196.0	138.0	58.0	46.2	42.2	4.0
	R	78.0	22.7	55.2	196.1	94.3	101.8	48.6	31.6	17.0
	$\bar{X}$	49.0	25.1	23.9	197.3	111.6	85.7	48.1	35.8	12.3
32.00	B	-	-	-	-	-	-	-	-	-
	C	36.7	23.1	13.6	205.5	116.6	88.9	51.3	34.8	16.6
	R	33.2	25.4	7.8	208.4	133.4	75.0	52.9	45.8	7.1
	$\bar{X}$	34.9	24.2	10.7	206.9	125.0	81.9	52.1	40.3	11.8

River Mile		Copper (ppm) Total	Copper (ppm) Inorganic	Copper (ppm) Organic	Zinc (ppm) Total	Zinc (ppm) Inorganic	Zinc (ppm) Organic	Lead (ppm) Total	Lead (ppm) Inorganic	Lead (ppm) Organic
32.50	B	34.9	29.2	5.7	219.8	139.2	80.6	55.2	46.9	8.2
	C	32.7	26.4	6.3	191.2	129.3	61.9	48.2	40.6	7.6
	R	35.2	25.1	10.1	204.0	114.0	90.0	57.6	40.3	17.3
	$\bar{X}$	34.3	26.9	7.4	205.0	127.5	77.5	53.7	42.6	11.0
33.00	B	36.9	24.8	12.0	198.4	98.5	99.9	51.6	34.8	17.1
	C	-	-	-	-	-	-	-	-	-
	R	40.1	27.2	12.9	217.9	104.8	113.1	52.4	31.4	21.0
	$\bar{X}$	38.5	26.0	12.5	208.1	101.6	106.5	52.0	33.1	19.0
33.50	B	-	-	-	-	-	-	-	-	-
	C	36.9	24.2	12.7	413.0	110.0	303.0	56.1	38.8	17.3
	R	42.0	27.5	14.5	206.0	99.9	106.2	50.6	31.8	18.8
	$\bar{X}$	39.4	25.9	13.6	309.5	104.9	204.6	53.3	35.3	18.0
36.50	B	32.9	25.2	7.7	204.0	136.0	68.0	46.5	42.5	4.0
	C	33.3	25.3	8.0	192.2	124.1	68.1	51.3	43.9	7.4
	R	34.0	21.9	12.1	204.0	105.3	98.7	54.2	34.9	19.3
	$\bar{X}$	33.4	24.1	9.3	200.1	121.8	78.3	50.7	40.4	10.2
36.75	B	37.2	30.3	6.9	207.9	139.7	68.2	54.4	46.6	7.8
	C	33.9	21.6	12.3	210.0	110.0	100.0	54.7	36.0	18.7
	R	31.5	23.7	7.9	194.3	105.2	89.1	50.6	31.6	19.0
	$\bar{X}$	34.2	25.2	9.0	204.1	118.3	85.8	53.2	38.1	15.2
37.00	B	38.9	30.0	8.9	210.0	132.0	78.0	48.4	40.7	7.6
	C	31.1	23.5	7.6	195.2	119.6	75.6	55.9	47.5	8.4
	R	9.8	9.1	0.7	23.3	23.3	10.5	6.2	4.2	2.0
	$\bar{X}$	26.6	20.9	5.7	142.8	88.1	54.7	36.8	30.8	6.0

James River Surface Sediments (continued)

River Mile		Copper (ppm) Total	Copper (ppm) Inorganic	Copper (ppm) Organic	Zinc (ppm) Total	Zinc (ppm) Inorganic	Zinc (ppm) Organic	Lead (ppm) Total	Lead (ppm) Inorganic	Lead (ppm) Organic
37.25	B	39.2	25.6	13.6	216.0	123.0	93.0	50.2	35.8	14.4
	C	38.2	26.6	11.6	199.3	99.9	99.4	52.3	34.8	17.5
	R	55.3	49.5	5.8	197.4	122.2	75.2	48.4	37.7	10.7
	$\bar{X}$	44.2	33.9	10.3	204.2	115.0	89.2	50.3	36.1	14.2
37.50	B	30.0	25.8	4.2	188.7	113.1	75.6	46.4	40.9	5.4
	C	40.2	30.1	10.1	226.0	129.0	97.0	51.6	42.3	9.2
	R	34.1	25.1	9.0	210.0	117.0	93.0	42.5	35.0	7.5
	$\bar{X}$	34.8	27.0	7.8	208.2	119.7	88.5	46.8	39.4	7.4
37.75	B	34.4	28.7	5.7	210.0	131.0	79.0	48.8	40.4	8.4
	C	36.9	24.9	12.0	206.0	101.0	105.0	53.9	35.1	18.8
	R	36.2	24.3	11.9	230.0	122.0	108.0	52.6	39.4	13.2
	$\bar{X}$	35.8	26.0	9.9	215.3	118.0	97.3	51.8	38.3	13.5
38.00	B	35.8	8.9	26.9	79.0	23.5	55.5	17.7	8.7	9.0
	C	38.5	25.6	12.9	220.0	105.0	115.0	55.7	36.4	19.3
	R	33.0	27.6	5.3	206.1	115.2	90.9	50.2	36.2	14.0
	$\bar{X}$	35.8	20.7	15.4	168.3	81.2	87.1	41.2	27.1	14.1
38.25	B	17.2	10.6	6.6	82.8	24.9	57.9	19.7	10.9	8.8
	C	39.1	25.3	13.8	216.0	101.0	115.0	59.3	33.8	25.5
	R	34.0	23.5	10.5	212.0	122.0	90.0	56.4	40.8	15.6
	$\bar{X}$	30.1	19.8	10.3	170.3	82.6	87.6	45.1	28.5	16.6
38.50	B	19.6	10.4	9.2	77.0	18.1	58.9	23.3	10.3	13.0
	C	31.1	23.8	7.2	176.1	114.2	78.2	43.5	35.7	7.8
	R	31.0	25.4	5.6	228.0	171.0	57.0	43.8	42.9	2.8
	$\bar{X}$	27.2	19.9	7.3	160.4	101.1	64.7	36.9	29.6	7.9

River Mile		Copper (ppm) Total	Inorganic	Organic	Zinc (ppm) Total	Inorganic	Organic	Lead (ppm) Total	Inorganic	Organic
38.75	B	20.5	15.5	5.0	84.3	33.8	50.5	25.1	20.2	4.9
	C	26.4	16.2	10.2	125.0	46.4	78.6	34.4	20.5	13.9
	R	92.7	86.2	6.5	226.0	144.0	82.0	49.2	45.3	3.9
	X̄	46.5	39.3	7.2	145.1	74.7	70.4	36.2	28.6	7.6
39.00	B	32.6	19.6	13.0	310.0	171.0	139.0	46.4	30.2	16.2
	C	25.8	15.0	10.9	88.9	34.4	54.5	32.5	19.7	12.8
	R	31.2	23.2	8.0	256.0	181.0	75.0	44.0	35.2	8.8
	X̄	29.9	19.2	10.6	218.3	128.8	89.5	41.0	28.4	12.6
39.25	B	32.5	21.8	10.7	420.0	115.0	265.0	47.4	40.6	6.8
	C	47.1	40.8	6.4	280.7	202.0	78.7	46.8	38.0	8.7
	R	36.2	25.6	10.6	714.0	178.0	536.0	58.1	41.1	17.0
	X̄	38.6	29.4	9.2	471.6	165.0	293.0	50.8	39.9	10.8
39.50	B	45.5	38.0	7.5	313.0	234.0	79.0	51.1	43.6	7.5
	C	36.6	33.5	3.1	252.1	188.5	63.6	55.7	50.7	5.0
	R	37.5	25.7	11.8	212.0	105.0	107.0	50.5	35.4	15.1
	X̄	39.9	32.4	7.5	259.0	175.8	83.2	52.4	43.2	9.2
39.75	B	37.5	25.6	11.9	242.0	132.0	110.0	49.6	38.8	10.8
	C	37.0	29.7	7.4	210.1	133.7	76.4	53.0	42.7	10.3
	R	35.4	26.7	8.7	185.4	107.3	78.1	48.4	36.1	9.2
	X̄	36.6	27.3	9.3	212.5	124.3	88.2	50.3	39.2	10.1
40.00	B	34.6	21.8	12.8	185.0	88.5	96.5	57.7	35.1	22.6
	C	38.3	27.7	10.6	234.0	112.0	122.0	53.1	39.4	13.7
	R	32.1	26.5	5.6	181.0	121.0	60.0	45.4	40.2	5.2
	X̄	35.0	25.3	9.7	200.0	107.0	92.8	52.1	38.3	13.8

James River Surface Sediments (continued)

River Mile		Copper (ppm)			Zinc (ppm)			Lead (ppm)		
		Total	Inorganic	Organic	Total	Inorganic	Organic	Total	Inorganic	Organic
40.25	B	34.5	23.5	11.0	188.0	91.4	96.6	51.4	31.8	19.6
	C	38.0	29.4	8.6	228.0	136.0	92.0	51.0	41.4	9.6
	R	39.5	22.2	17.3	190.0	86.3	103.7	50.9	34.2	16.7
	$\bar{X}$	37.3	25.0	12.3	202.0	104.6	97.4	51.1	35.8	14.3
40.50	B	34.2	28.7	5.5	209.5	136.2	73.3	52.5	44.7	7.8
	C	37.6	27.0	10.6	220.0	119.0	101.0	49.2	39.4	9.8
	R	33.6	21.4	12.2	182.0	88.6	93.4	49.9	35.7	14.2
	$\bar{X}$	35.1	25.7	9.4	203.8	114.6	89.2	50.6	39.9	10.6
40.75	B	35.7	28.6	7.1	215.3	138.0	77.3	50.4	41.1	9.2
	C	37.7	26.6	11.1	224.0	121.8	102.2	57.5	41.1	16.4
	R	34.4	25.5	8.9	187.4	116.9	70.5	51.0	39.4	11.6
	$\bar{X}$	35.9	26.9	9.0	208.9	125.6	83.3	53.0	40.5	12.4
57.00	B	16.3	12.0	4.3	83.2	34.6	48.6	12.5	10.2	2.3
	C	55.7	51.9	3.8	204.0	133.0	71.0	48.4	43.6	4.7
	R	12.4	5.0	7.4	58.0	18.3	39.7	17.7	7.4	10.3
	$\bar{X}$	28.1	23.0	5.2	115.1	62.0	53.1	26.2	20.4	5.8
57.50	B	38.6	25.6	13.0	194.0	117.0	77.0	45.0	40.2	4.7
	C	58.3	39.9	18.4	187.0	92.1	94.9	52.0	38.9	13.1
	R	34.8	24.5	10.3	189.0	98.7	90.3	50.3	35.4	14.9
	$\bar{X}$	43.9	30.0	13.9	190.0	102.6	87.4	49.1	38.2	10.9
58.00	B	68.4	57.9	10.5	182.0	93.3	88.7	57.4	38.2	19.2
	C	37.5	26.3	11.2	193.0	99.7	93.3	52.3	34.5	12.8
	R	28.6	23.0	5.6	163.0	95.8	67.2	45.8	36.4	9.4
	$\bar{X}$	44.8	35.7	9.1	179.3	96.3	83.1	51.9	36.3	13.8

James River Surface Sediments (continued)

River Mile		Copper (ppm)			Zinc (ppm)			Lead (ppm)		
		Total	Inorganic	Organic	Total	Inorganic	Organic	Total	Inorganic	Organic
58.50	B	78.3	74.0	4.2	170.4	103.3	67.1	46.8	33.8	13.0
	C	125.8	125.3	0.5	183.4	106.3	77.1	54.7	42.6	12.1
	R	286.7	287.3	- 0.4	273.4	173.2	100.2	92.4	84.3	8.1
	$\overline{X}$	163.6	162.2	1.6	209.1	127.6	81.5	64.6	53.5	11.1
59.00	B	34.5	24.8	9.7	182.0	93.0	89.0	41.4	31.4	10.0
	C	41.2	32.0	9.2	206.0	127.5	78.5	57.0	38.5	18.5
	R	72.6	61.9	10.7	407.0	117.0	290.0	55.1	38.6	16.5
	$\overline{X}$	49.4	39.6	9.9	265.0	112.5	152.5	51.2	36.2	15.0
59.50	B	67.4	66.4	1.0	167.0	112.0	55.0	38.0	35.2	2.8
	C	43.5	40.4	3.1	196.5	130.9	65.6	50.4	46.6	3.8
	R	35.0	25.3	9.7	174.0	97.3	76.7	48.9	35.7	13.2
	$\overline{X}$	48.6	44.0	4.6	179.2	113.4	65.8	45.8	39.2	6.6