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Contaminant Trace Element Loads at the Susquehanna River Fall Line during the Spring, 1993 High Flow Event

Addendum to the Fall Line Toxics 1992 Final Report

Chesapeake Bay Program

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prepared by: the Maryland Department of Environment
and: the U.S. Geological Survey, Department of the Interior
for the: USEPA Chesapeake Bay Program Office

INTRODUCTION

The largest freshwater discharge event on record to the Chesapeake Bay occurred in the spring of 1993 as a result of several climatological factors. In 1993, as much as 92 inches of snow was recorded for the winter in some parts of the upper Susquehanna River watershed. This snowpack was washed out by a single strong rainstorm that lasted approximately nine days. The average precipitation for this storm in the basin above Harrisburg was 7.5 inches. The total stormflow for the Susquehanna River from this storm exceeded that of the flow from Hurricane Agnes, a devastating storm that occurred in 1973. Peak flow measured at Conowingo Dam during the spring storm event of 1993 was 500,000 cubic feet per second (cfs), approximately half of peak flow measured for Hurricane Agnes (1,130,000 cfs). However, because of its longer duration and the larger residual of stored water in the watershed, the 1993 storm transported a total of 816 billion cubic feet of water through the Conowingo Dam, compared to Hurricane Agnes' total discharge of 521 billion cubic feet. During both storm events, a significant quantity of sediment material, including the associated trace element contaminants, was transported into the Bay from the watershed. In order to study the dynamics of contaminant transport and to calculate accurate loads during this period of high flow in 1993, the United States Geological Survey (USGS) conducted a short-term intensive water quality sampling study on the Susquehanna River at the Conowingo Dam in Maryland.

The Susquehanna River is the largest tributary to the Chesapeake Bay, contributing approximately 50% of the freshwater inflow to the Bay. It drains an area that is impacted heavily by agriculture, and coal and mineral mining industries. Additionally there is a significant number of municipalities that discharge effluents into the Susquehanna River. There are therefore significant sources of trace element contaminants from the Susquehanna watershed and mobilization of these to the Chesapeake Bay can be strongly enhanced during a large storm event. A second and also potentially important reservoir of trace element contaminants is stored in the sediments behind each of the three dams in the lower Susquehanna River. These are, in order of upstream to downstream, Safe Harbor, Holtwood, and Conowingo. During high discharge, scouring of stored sediments behind each dam can occur. According to Lloyd Reed of the U.S. Geological Survey, (personal communication, 1993), scouring occurs at the Conowingo Dam when discharge exceeds 200,000 cfs. This discharge level was exceeded during most of the storm event in March/April, 1993.

METHODS

Water samples were collected at the Conowingo Dam site during March 25 through May 4, 1993. Samples were collected using ultra-clean techniques two to three times per day for the nine day period of highest flow (March 25 - April 3, 1993), and an additional 11 times for the remaining 32 days of high flow. Samples were analyzed for suspended sediment, dissolved aluminum (Al), and total-recoverable and dissolved fractions of arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), nickel (Ni), lead (Pb), strontium (Sr), and zinc (Zn). Data for this study are in the Appendix to this Addendum, entitled 1993 Trace Element Data for the Susquehanna River at Conowingo Dam, MD. Loads of trace elements are calculated with a log-linear regression model that fits parameters for discharge, time, and seasonality to the concentration data. When there is not a significant relationship between the parameters of the regression model, loads are calculated by the Interpolation/Integration (II) model that interpolates concentration data, multiplies these by daily mean discharge measurements, and then integrates over the year. Methodologies for sampling and analysis are described in detail in the Fall Line Toxics Program 1992 Final Report.

RESULTS

Figure 1 presents a time series plot for discharge and suspended sediment measurements at Conowingo Dam, MD, for the period covering 1992 and 1993. The maximum discharge occurred in the spring of each year. However the plot also emphasizes that discharge was much higher in the spring 1993 than in 1992, and that storms which generate high discharges are an important mechanism for the mobilization of sediments. Concentration data for total-recoverable and dissolved Pb and Zn during this time period are presented in similar format in Figures 2 and 3, respectively. These two trace elements are normally associated with the particulate phase of surface water and therefore concentrations of total-recoverable Pb and Zn are correlated to discharge; particularly during the spring storm events. During base flow, total-recoverable concentrations of these 2 elements vary within a small range around the reporting limits of this study. Dissolved concentrations of Pb and Zn do not show a correlation to discharge or seasonality.

Figure 4 presents the time series plot for discharge and the concentrations of dissolved and total-recoverable Cr at Conowingo Dam in 1993. There appears to be no relation between discharge or seasonality with either phase of Cr.

Interestingly enough, the concentration of total-recoverable Cu exhibits a dual behavior at the Conowingo site. Figure 5(a) presents the time series plot for dissolved and total-recoverable Cu. During most of this time period, there was no more than a minimal correlation between discharge and total-recoverable Cu concentration (R=0.79 for the entire two year period). In fact there are several base flow concentration values that fall within the mid- to upper-range of stormflow data. However, during the storm event in late March and April, 1993, the behavior of Cu concentration changes and follows the discharge profile very closely. Figure 5(b), which is an expanded version of the 1993 storm event portion of the time series, emphasizes this point. The average total-recoverable Cu concentration was also slightly higher during this storm event than for base flow in 1993; 4.09 ± 1.97 (1 S.D.) as compared to 2.53 ± 1.51. The data suggest that total-recoverable Cu concentration is not related to discharge rates, except during abnormally high stormflows. There were no discernible relationships or trends for dissolved Cu during this study period.

Quality control data for all the trace elements presented in this addendum are given in the Fall Line Toxics Program 1992 Final Report. Briefly, all blank data for total-recoverable Cu, Pb, and Zn were less than the reporting limit. Dissolved blank data for these trace elements had measurable concentrations, but with values significantly less

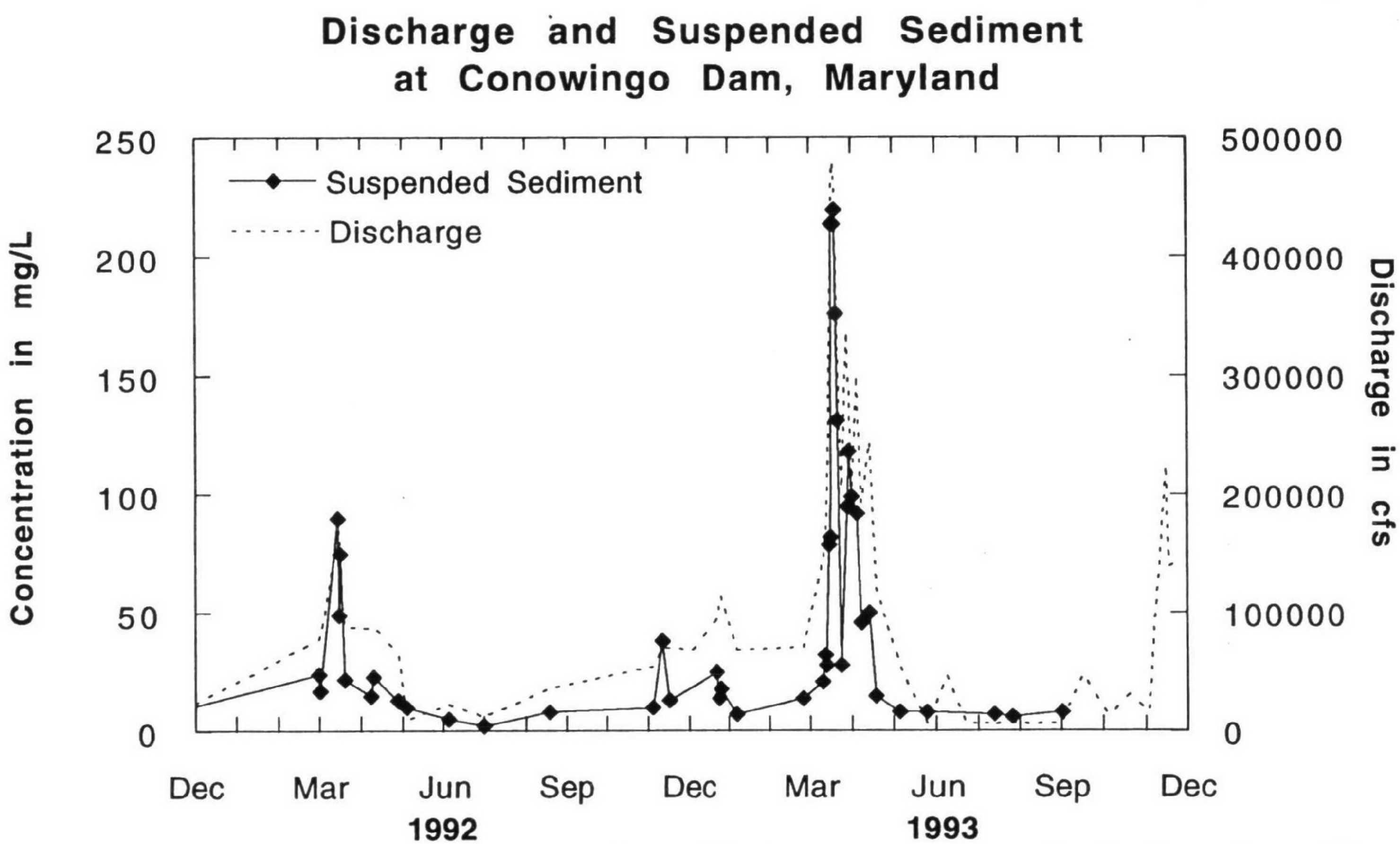


Figure 1. Time series of suspended sediment concentration and instantaneous discharge for the Susquehanna River at Conowingo Dam, MD for the time period from 1992 to 1993.

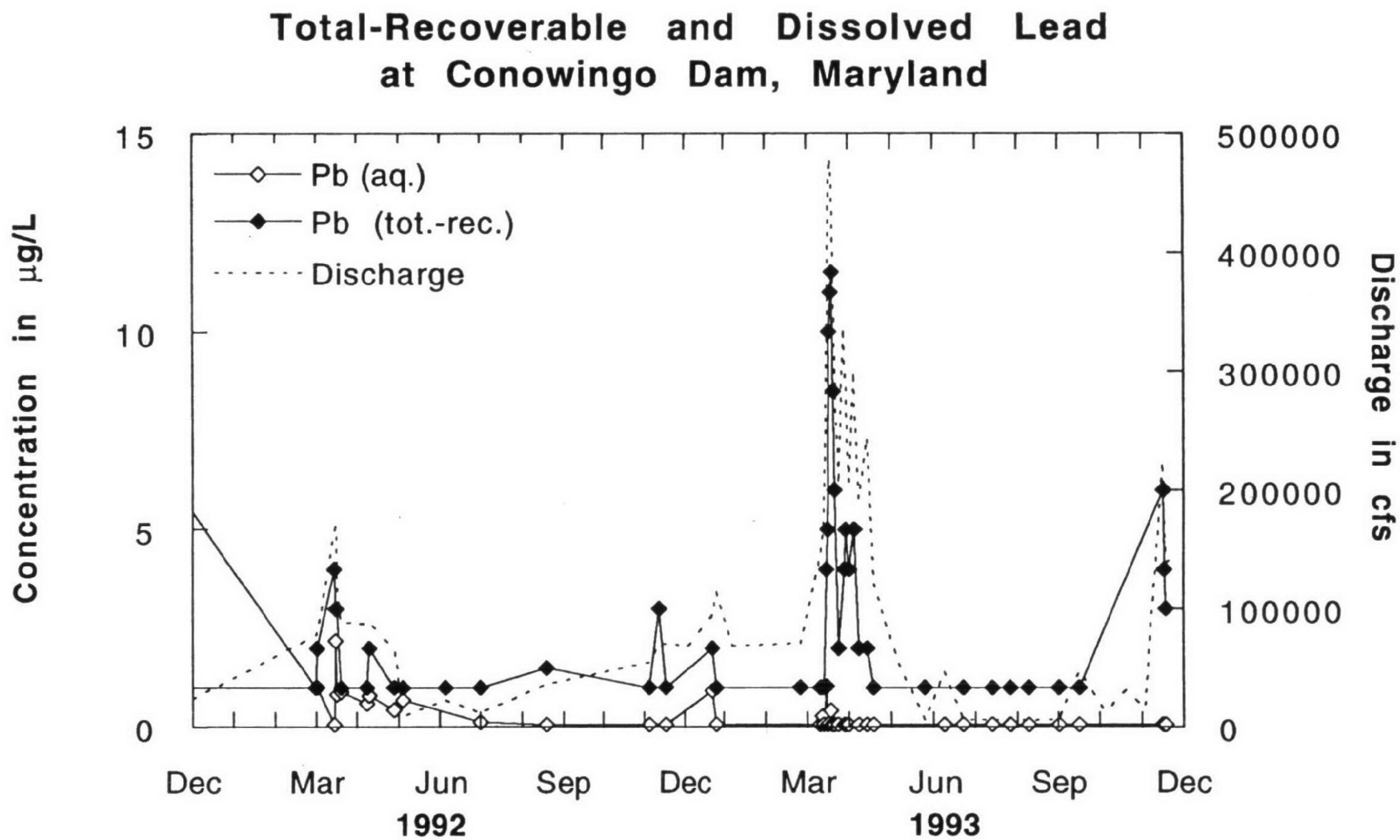


Figure 2. Time series of total-recoverable (tot.-rec.) and dissolved Pb (aq.) concentrations and instantaneous discharge for the Susquehanna River at Conowingo Dam, MD for the time period from 1992 to 1993. Reporting limits for total-recoverable and dissolved Pb are 1.0 and 0.06 µg/L, respectively.

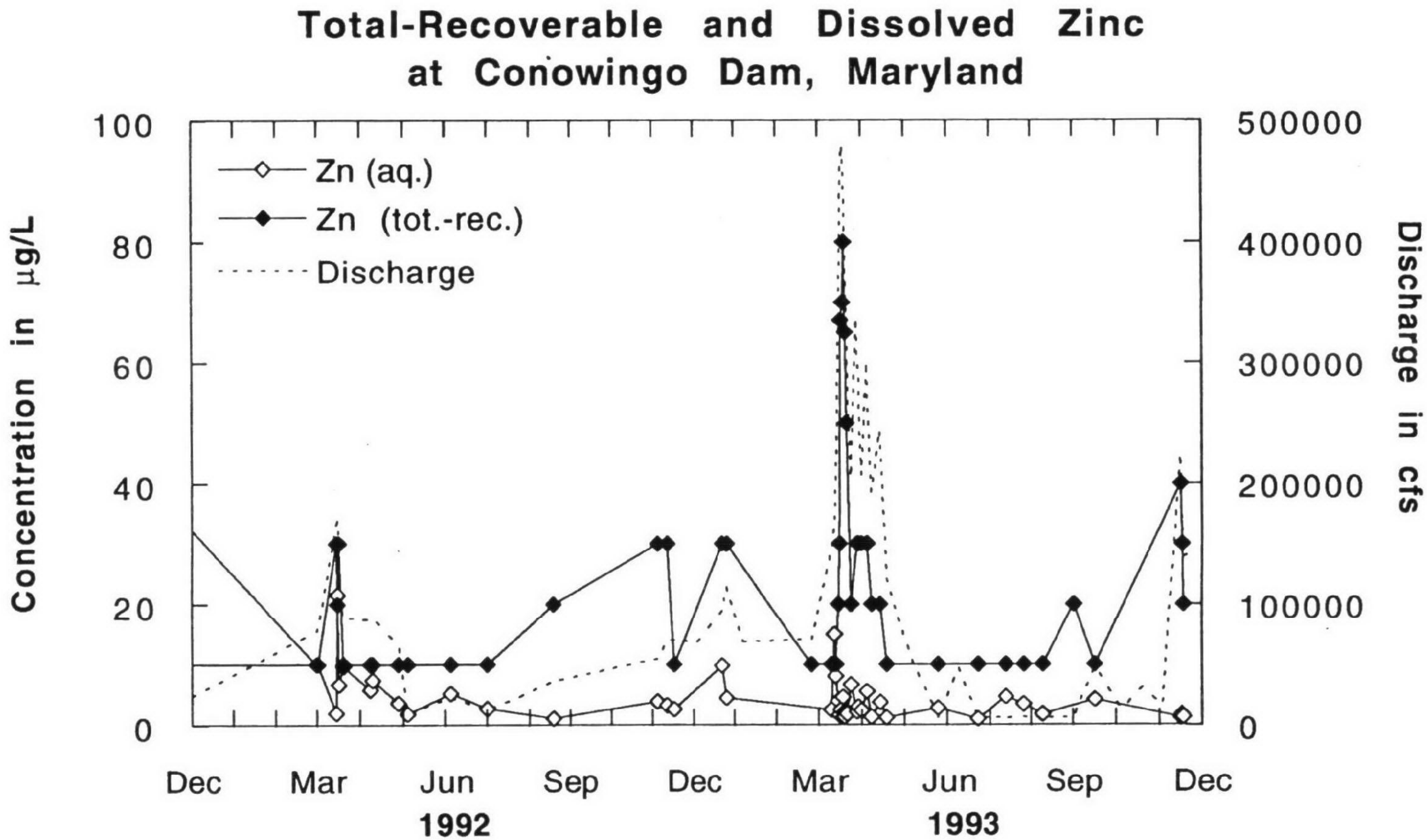


Figure 3. Time series of total-recoverable (tot.-rec.) and dissolved (aq.) Zn concentrations and instantaneous discharge for the Susquehanna River at Conowingo Dam, MD. Reporting limits for total-recoverable and dissolved Zn are 10 and 0.08 µg/L, respectively.

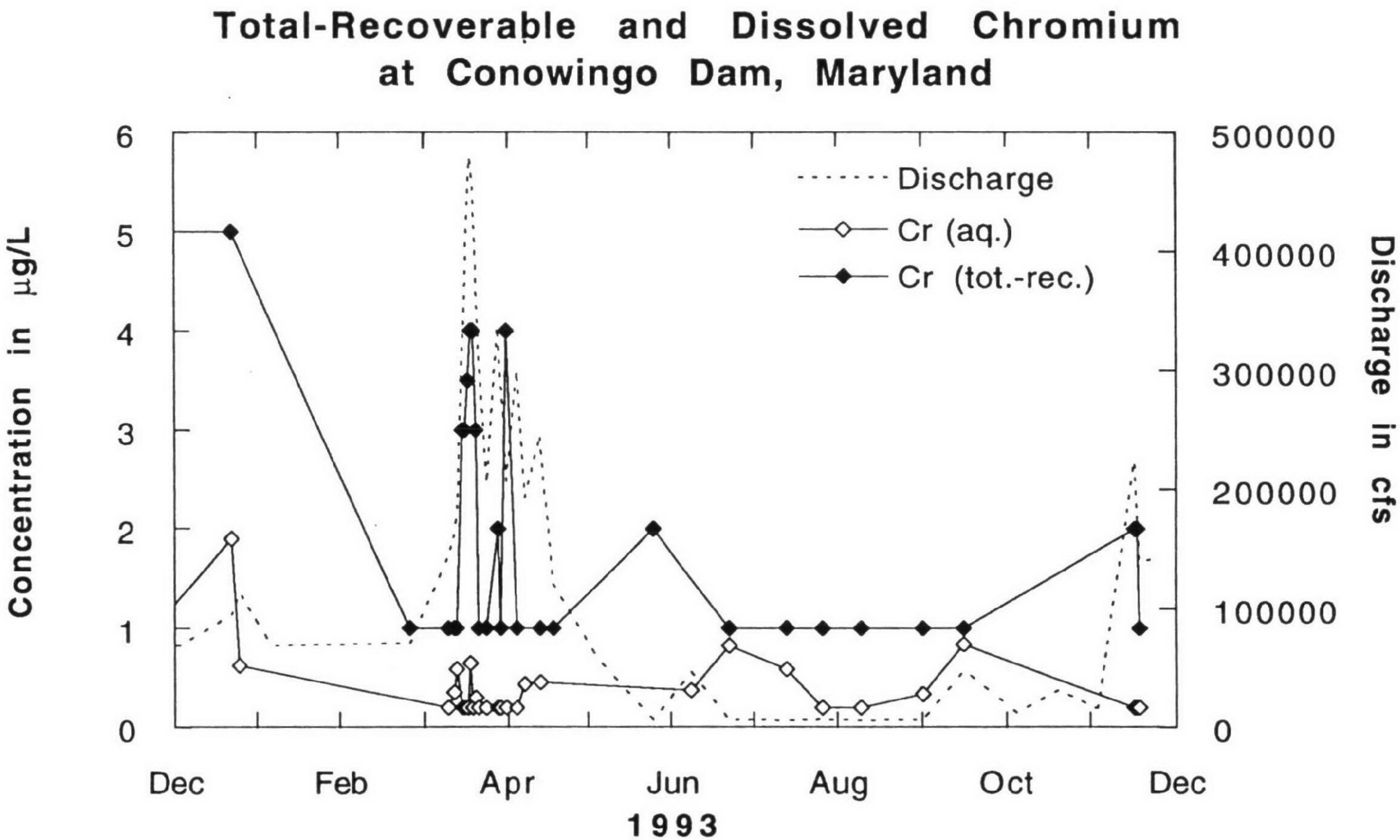
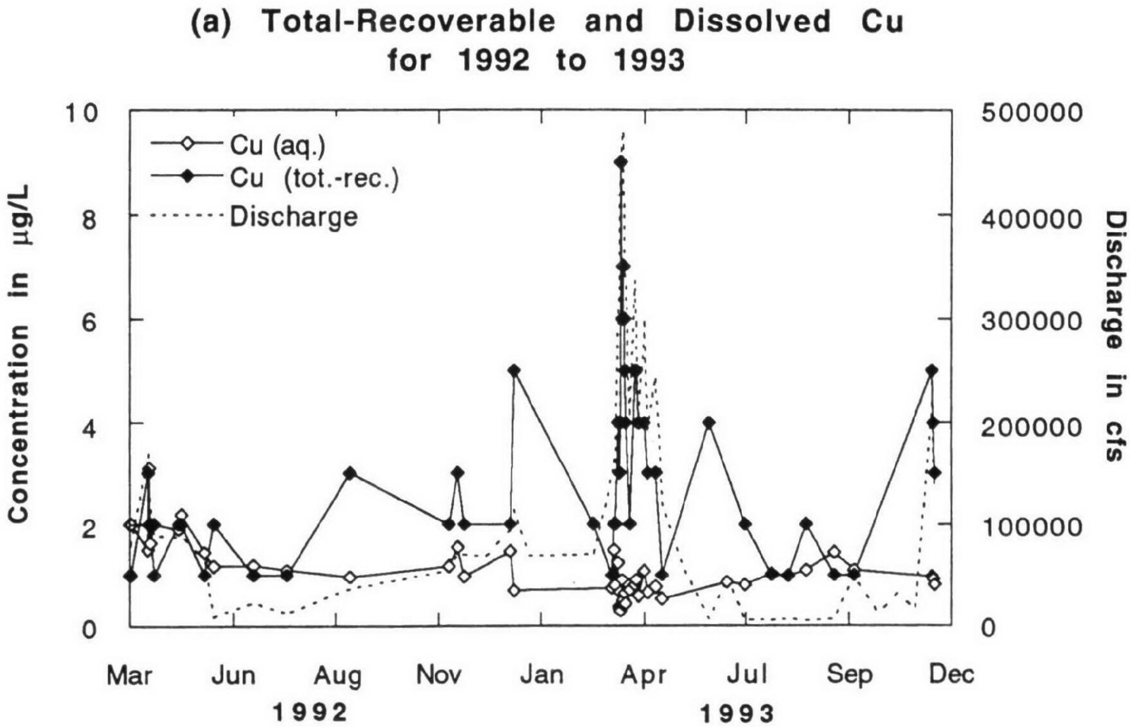


Figure 4. Time series of total-recoverable (tot.-rec.) and dissolved (aq.) Cr concentrations and instantaneous discharge for the Susquehanna River at Conowingo Dam, MD for 1993. Reporting limits for total-recoverable and dissolved Cr are 1 and 0.2 µg/L, respectively.



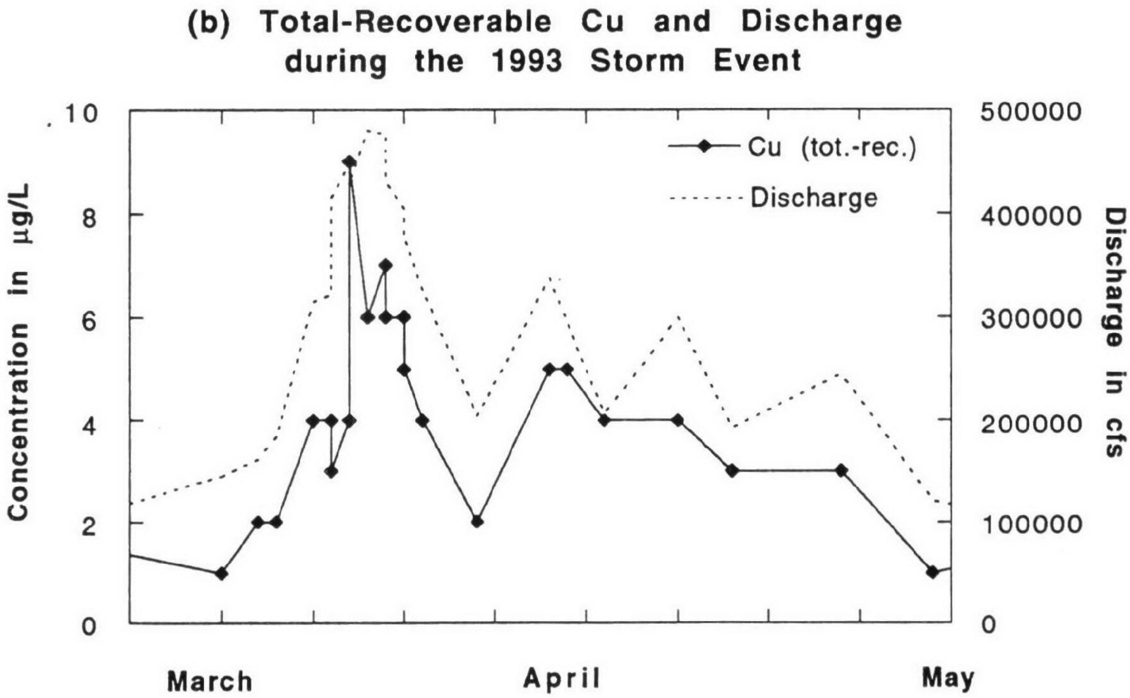


Figure 5. Time series of total-recoverable and dissolved Cu and instantaneous discharge for the Susquehanna River at Conowingo Dam for (a) 1992 to 1993 and (b) during the spring storm event of 1993. Reporting limits for total-recoverable and dissolved Cu are 1 and 0.02 µg/L, respectively.

than the environmental data. Quality control data for Cr indicated that contamination by this element may have occurred in 1992 and in part of 1993.

DISCUSSION

Trace Element Concentrations

Much of the trace element concentration data collected during the storm event of 1993 exhibited predictable behavior related to the elevated suspended sediment loads. The elements Pb and Zn are examples of soft-metal trace-element contaminants that are easily scavenged onto particulate surfaces. Sources of the contaminated suspended sediments during a storm event include runoff from the watershed as well as scouring of stored sediments from behind the dams of the lower Susquehanna River. During high flow, scouring is probably a significant source of sediment with trace elements sorbed to it. Data for Al and Fe concentrations, presented in the Appendix, also correlate well to suspended sediment loads.

The environmental geochemistry of Cr in this system is not obvious from the results of this study. Sources of Cr to the Susquehanna River are probably primarily industrial or atmospheric deposition. It is not obvious from the data that Cr is being stored in sediments behind the Conowingo Dam, or that storms in general have a major influence on the behavior of this trace element. More study is required for better understanding of the geochemical behavior of Cr.

The dual behavior of total-recoverable Cu in 1993 at Conowingo Dam suggests that there are multiple sources of this trace element in the Susquehanna watershed. During base flow, Cu sources may include drainage from active or abandoned coal and mineral mining operations, and industrial effluents such as from the steel and iron industries. During stormflow, it is possible that the Cu concentration is being augmented by sediments scoured from behind the dam, but if this were a significant source of Cu, one would expect to see elevated Cu concentrations whenever discharge was high enough to induce sediment scouring. While scouring occurred during almost the entire high stormflow period, from March 25 through April 28, most of the Cu concentrations for this period were within the range of base flow concentrations. There were five points that exceeded this range and these occurred only during the first three days, when peak flow occurred in 1993 storm event. The induction of a different source of Cu, other than sediment scouring, during abnormally high stormflow provides a better explanation for elevated concentrations and the unusual relationship to discharge during this storm event. The most likely alternate source is from municipal effluents.

Municipal effluents, contaminated from Cu plumbing used for water supplies, have been suggested as a general source of this trace element into river systems. However, since many of the sewage treatment plants in the Susquehanna River watershed have recently installed secondary treatment, municipal effluents are probably not a primary source of Cu during base flow. This is not necessarily the case for stormflow. Many of the municipal sewage treatment plants in the Susquehanna watershed have combined sewage treatment, in other words they combine storm drain effluents with municipal sewage. Treatment plants can become overwhelmed during unusually high flow, such as occurred in the spring of 1993, and be forced to discharge raw sewage directly into the Susquehanna River or its tributaries. Under very high flow regimes, Cu becomes correlated to discharge, and this may be related to the municipal overflows during storm surges. This would also explain the slightly higher Cu measurements that occurred at the peak flow of the storm event.

Concentration data for the other trace elements, As and Cd, were consistently below detection limit, so interpretation of their geochemical behavior during the 1993 storm event is not possible.

Load Estimates

Concentration data collected and mean daily discharges for river flow throughout 1993 were used to estimate annual loads of contaminant trace elements for that year. These load data are presented in Table 1.

Table 1. Annual loads of total-recoverable and dissolved trace elements for the Susquehanna River at Conowingo Dam, MD. Units are in metric tons per year. Load values in italics were calculated with the Integration/Interpolation model (II). For constituents using the II model with censored data (measured concentrations less than the reporting limit), the load estimates were calculated twice to determine a range in values. Censored data were assigned a value of zero for the calculation of a lower boundary or "minimum load," and a value of the analytical reporting limit for the calculation of an upper boundary, or "maximum load." All other load estimates (in normal print) are calculated with the log linear regression model (AMLE, Cohn) and ranges in loads are statistical estimates of variance (± 1 standard deviation) made by the model. Both models are described in detail in the Fall Line Toxics Program, 1992 Final Report.

	Al	As	Cd	Cr	Cu	Fe	Pb	Zn
Diss.	1,111 - 1,388	*3.09 - 28.7*	*0.286 - 4.70*	*12.5 - 17.5*	39.5 - 46.4	*962.0 - 964.0*	*3.327 - 5.760*	*160.3*
TR		*12.4 - 49.2*	*0 - 46.0*	*79.9 - 93.8*	111.3 - 135.2	76,448 - 90,363	119.0 - 162.6	992.5 - 1,314

The upper ranges of annual load estimates for total-recoverable Cr, Cu, Pb, and Zn are presented in bar graph format in Figure 6. For comparison, load estimates for 1992 are included in this graph. The spring portion (March, April, and May) of the annual load for each trace element is indicated as the stippled portion of each bar to evaluate the relative contribution of the large storm event to the annual load. Total loads for Cr, Cu, Pb, and Zn in the Susquehanna River at Conowingo Dam were consistently higher in 1993 than in 1992. The differences between the spring contributions of loads for each year are, however, more significant. For example, the spring contribution of the total annual Zn load delivered to the Chesapeake Bay in 1992 was 37% of the total annual load, while in 1993, a more significant 70% of the annual Zn load was transported in the spring. This same phenomenon was demonstrated for all of the other total-recoverable loads, and demonstrates the importance of stormflow to annual contaminant loads. The increased contaminant loads from the spring storm event of 1993 can be partially attributed to elevated concentrations of the contaminants, but more importantly to the large volume of water that was discharged from the watershed.

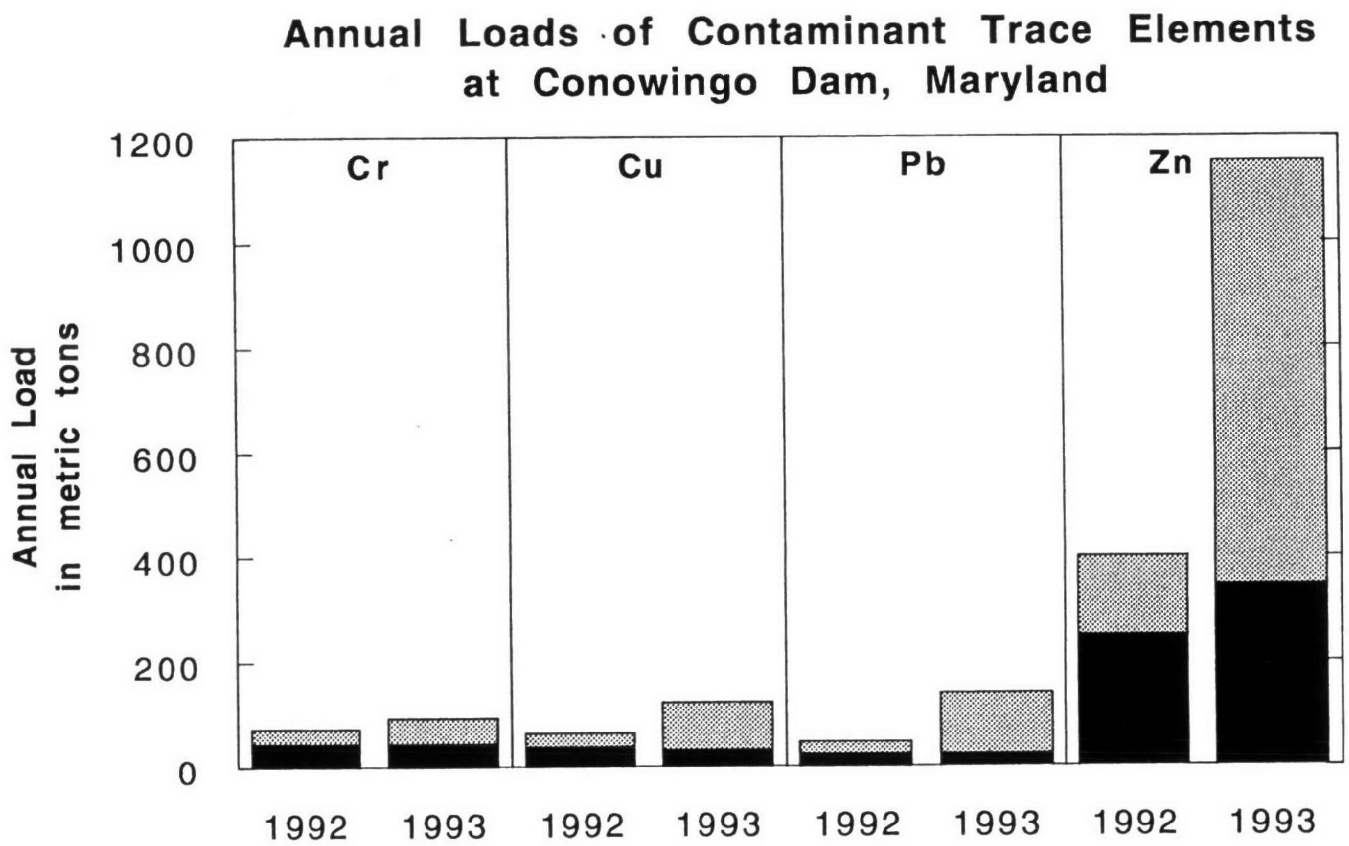


Figure 6. Annual load estimates of total-recoverable Cr, Cu, Pb, and Zn for the Susquehanna River at Conowingo Dam, MD. The spring contribution of each load (March, April, and May) is indicated as the stippled portion of each bar.

CONCLUSIONS

The results of this study suggest the following conclusions:

(1) Contaminant concentrations of trace elements that are associated with particulate phases, for example Pb and Zn, are correlated with discharge, particularly during very large storm events such as occurred in the spring of 1993.

(2) The concentration behavior of Cu is more complex than for some of the other trace elements, having multiple sources that are apparently similar in importance.

(3) Scouring of stored sediments from behind the Conowingo Dam may contribute significantly to the suspended sediment load, and hence contaminant trace element loads of Pb and Zn.

(4) All annual load estimates for 1993 were higher than had been observed in 1992. This was at least partially due to the large volume of water that was transported during the spring stormflow of 1993, and a disproportionately large fraction of the annual load was contributed during this storm event.

APPENDIX
1993 TRACE ELEMENT DATA FOR THE SUSQUEHANNA RIVER AT CONOWINGO DAM, MD

SUSQUEHANNA R AT CONOWINGO, MD

WATER-QUALITY DATA, CALENDAR YEAR JANUARY 1993 TO DECEMBER 1993

DATE	TIME	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	TEMPER-ATURE WATER (DEG C) (00010)	TEMPER-ATURE AIR (DEG C) (00020)	BARO-METRIC PRES-SURE (MM OF HG) (00025)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	SPE-CIFIC CON-DUCT-ANCE LAB (US/CM) (90095)	OXYGEN, DIS-SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	ALKA-LINITY WAT DIS TOT IT FIELD MG/L AS CACO3 (39086)	SEDI-MENT, SUS-PENDED (MG/L) (80154)
JAN											
05...	1430	95900	5.0	18.0	742	138	155	13.0	--	26	25
07...	1330	101000	5.0	13.0	769	171	150	13.3	7.4	27	14
08...	1300	114000	6.0	9.0	766	163	154	12.9	7.9	28	18
20...	1130	69200	5.5	7.0	774	219	201	13.9	7.8	31	7
MAR											
11...	1400	70900	4.0	10.0	763	290	255	12.5	7.3	--	14
25...	1130	145000	5.0	9.0	771	270	258	13.0	7.3	45	21
27...	1245	162000	6.0	11.0	766	225	207	13.2	7.5	25	32
28...	1330	184000	7.0	15.0	759	220	202	12.7	7.3	31	28
30...	1645	314000	7.0	16.0	757	160	154	--	7.3	17	79
31...	0145	321000	7.0	8.0	761	165	149	12.5	7.2	25	67
31...	1400	415000	8.0	15.0	759	146	132	12.3	7.2	20	97
APR											
01...	1230	448000	6.0	11.0	749	128	118	12.7	7.3	20	91
01...	2300	431000	7.0	14.0	749	120	116	12.5	7 2	12	338
02...	1315	480000	7.0	12.0	752	114	115	12.0	7.0	20	214
03...	1030	477000	7.0	12.0	762	119	109	12.6	7.0	17	251
03...	1715	461000	--	--	--	--	--	--	--	--	230
03...	1900	460000	6.0	6.0	763	116	111	11.7	7.1	19	234
03...	2230	430000	--	--	--	--	--	--	--	--	167
04...	1230	404000	7.0	10.0	765	220	111	13.2	7.2	19	175
04...	1945	378000	7.0	8.0	764	114	111	12.8	7.3	23	177
05...	1230	326000	7.0	15.0	766	124	116	13.3	7.4	21	131
08...	1500	190000	9.0	16.0	763	172	151	12.9	7.5	26	28
12...	1545	337000	8.0	14.0	753	196	147	12.5	7.3	29	95
13...	1415	295000	10.0	19.0	759	128	118	12.6	7 4	22	118
15...	1045	207000	9 0	16.0	760	133	129	10.8	7.4	23	99
19...	1515	300000	12.0	22.0	759	148	134	11.9	7.5	28	92
22...	1515	193000	12.0	8.0	747	--	150	11.1	--	--	46
28...	1115	244000	11.0	20.0	771	174	156	11.9	7.5	32	50
MAY											
03...	1215	121000	16.0	23.0	770	178	167	10.3	7 3	31	15
JUN											
09...	1130	6700	23.0	28.0	760	337	318	6.1	7.5	--	--
23	1330	46900	28.0	37.0	766	385	--	5.4	7.9	66	8
JUL											
07...	0915	6400	29.0	35.0	767	395	359	5.5	7.7	68	--
28	0945	5960	30.0	34.0	762	366	350	4.5	7.4	78	7

DATE	SEDI-MENT, DIS-CHARGE, SUS-PENDED (T/DAY) (80155)	SED SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)	ALUM-INUM, DIS-SOLVED (UG/L AS AL) (01106)	ARSENIC DIS-SOLVED (UG/L AS AS) (01000)	ARSENIC TOTAL (UG/L AS AS) (01002)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042)
JAN											
05...	6470	99	30	<0.60	<1	0.16	<1	1.90	5	1.47	2
07	3820	100	30	--	--	--	--	--	--	--	--
08...	5540	96	20	<0.60	<1	0.10	<1	0.63	--	0 69	5
20...	1310	94	30	--	--	--	--	--	--	--	--
MAR											
11...	2680	99	30	--	<1	--	<1	--	<1	--	2
25...	8220	96	30	<0.60	<1	0.10	<1	<0.20	<1	0 74	<1
27...	14000	96	<10	<0.60	<1	0.10	<1	0.36	1	1.49	2
28...	13900	98	20	<0.60	<1	0.10	<1	0 59	1	0.79	2
30...	67000	99	<10	<0.60	<1	0.10	<1	<0.20	3	1.24	4
31...	58100	99	<10	0.65	1	0.10	<1	<0.20	<1	0 36	4
31	109000	98	<10	<0.60	<1	0.10	<1	<0.20	5	0.39	3
APR											
01...	110000	98	<10	<0.60	1	0.10	<1	<0.20	1	0 30	4
01	393000	97	<10	<0.60	2	0.10	<1	<0.20	6	0.66	9
02...	277000	97	<10	<0.60	2	0.10	<1	0.65	4	0 90	6
03	323000	97	<10	0.88	2	0.10	<1	<0.20	3	0.42	7
03...	286000	97	--	--	--	--	--	--	--	--	--
03...	291000	97	20	1.03	2	0.10	<1	<0.20	5	0 50	6
03...	194000	98	--	--	--	--	--	--	--	--	--
04...	191000	95	40	<0.60	1	0.10	<1	<0.20	4	0 41	6
04...	181000	94	20	<0.60	2	0.10	<1	0 35	2	0 64	5
05...	115000	92	10	<0.60	1	0.10	<1	<0.20	1	0.44	4
08	14400	97	20	<0.60	<1	0.10	<1	<0.20	<1	0.70	2
12	86400	92	30	<0.60	<1	0.10	<1	<0.20	2	0.81	5
13...	94000	96	10	<0.60	1	0.10	<1	<0.20	1	0.90	5
15...	55300	99	40	<0.60	1	0.10	<1	<0.20	4	0.59	4
19...	74500	97	30	<0 60	<1	0.10	<1	<0.20	1	1.08	4
22...	24000	99	20	<0.60	<1	0.10	<1	0.44	--	0.66	3
28...	32900	96	20	<0.60	<1	0.10	<1	0.46	<1	0 76	3
MAY											
03	4900	94	20	<0.60	<1	0.10	<1	0.46	<1	0.53	<1
JUN											
09	--	--	--	<0.60	<1	0 10	<1	1.13	2	0.68	4
23	1010	99	--	<0.60	--	0.10	--	0.38	--	0.86	--
JUL											
07	--	--	20	<0 60	<1	0 10	<1	0.83	<1	0 81	2
28.	113	88	20	1.26	<1	0.15	<1	0.59	<1	1 03	1

SUSQUEHANNA R AT CONOWINGO, MD

WATER-QUALITY DATA, CALENDAR YEAR JANUARY 1993 TO DECEMBER 1993

DATE	IRON, DIS-SOLVED (UG/L AS FE) (01046)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)	NICKEL, DIS-SOLVED (UG/L AS NI) (01065)	NICKEL, TOTAL RECOV-ERABLE (UG/L AS NI) (01067)	STRON-TIUM, TOTAL RECOV-ERABLE (UG/L AS SR) (01082)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092)
JAN										
05...	12	--	0.92	2	<0.10	--	--	--	9 83	30
07...	--	--	--	--	--	--	--	--	--	--
08...	14	--	<0.06	1	<0.10	--	--	--	4.45	30
20...	--	--	--	--	--	--	--	--	--	--
MAR										
11...	13	--	--	1	<0.10	4	5	130	--	10
25...	17	650	<0.06	1	<0.10	4	5	100	2.59	<10
27...	11	800	0.28	1	<0.10	2	5	100	15.06	<10
28...	12	830	<0.06	1	<0.10	2	5	80	8.06	10
30...	17	2400	1.03	4	<0.10	3	9	70	4.00	20
31...	22	3000	<0.06	5	<0.10	3	12	60	1.72	30
31...	--	3000	<0.06	5	<0.10	3	12	60	1.55	30
APR										
01...	18	3100	<0.06	5	<0.10	3	12	40	2.11	30
01...	25	8600	0.15	15	<0.10	3	32	60	2.94	100
02...	33	6500	0.42	11	<0.10	4	21	40	4.62	70
03...	31	6600	<0.06	12	<0.10	4	21	40	1.94	80
03...	--	--	--	--	--	--	--	--	--	--
03...	34	6400	<0.06	11	<0.10	4	20	40	0.92	80
03...	--	--	--	--	--	--	--	--	--	--
04...	66	5800	<0 06	9	<0.10	4	19	40	2.36	70
04...	24	5200	<0.06	8	<0 10	4	17	40	2 19	60
05...	10	4100	<0.06	6	<0.10	3	15	40	1 94	50
08...	5	1100	<0 06	2	<0 10	4	8	60	6 63	20
12...	6	2700	<0 06	4	<0.10	3	9	70	2.26	30
13...	13	3600	<0.06	5	<0.10	3	9	40	3 09	30
15...	6	3900	<0 06	4	<0.10	3	8	60	2.45	30
19...	11	2600	--	5	<0.10	3	10	70	5.60	30
22...	24	1700	<0.06	2	<0.10	3	7	70	1.38	20
28...	14	1500	<0.06	2	<0.10	3	8	70	3.81	20
MAY										
03...	36	670	<0.06	1	<0.10	4	5	10	1 28	<10
JUN										
09...	8	480	<0.06	1	--	2	5	160	1.27	<10
23...	--	--	<0.06	--	<0.10	--	--	--	2.85	--
JUL										
07...	<3	330	<0.06	<1	<0.10	1	3	180	1.04	<10
28...	<3	200	<0.06	<1	<0.10	1	2	200	4.72	<10

SUSQUEHANNA R AT CONOWINGO, MD

WATER-QUALITY DATA, CALENDAR YEAR JANUARY 1993 TO DECEMBER 1993

DATE	TIME	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	TEMPER-ATURE WATER (DEG C) (00010)	TEMPER-ATURE AIR (DEG C) (00020)	BARO-METRIC PRES-SURE (MM OF HG) (00025)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	SPE-CIFIC CON-DUCT-ANCE LAB (US/CM) (90095)	OXYGEN, DIS-SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	ALKA-LINITY WAT DIS TOT IT FIELD MG/L AS CACO3 (39086)	SEDI-MENT, SUS-PENDED (MG/L) (80154)
AUG											
10...	1030	6750	28.0	28.0	770	404	376	4.3	7.6	78	6
24...	1000	5640	28.0	30.0	768	--	340	5.8	7.4	73	--
SEP											
15...	1000	6800	27.0	29.0	763	392	393	5.6	7.3	62	8
30...	1300	48300	21.0	17.0	767	354	356	6.5	7.3	56	10
NOV											
30...	1415	224000	8.0	6.0	776	134	141	12.0	7.0	29	127
DEC											
01...	1400	177000	7.0	8.0	780	128	126	12.8	6.5	20	78
02...	1315	139000	6.5	15.0	773	123	132	13.1	7.5	23	48

DATE	SEDI-MENT, DIS-CHARGE, SUS-PENDED (T/DAY) (80155)	SED. SUSP. SIEVE DIAM % FINER THAN .062 MM (70331)	ALUM-INUM, DIS-SOLVED (UG/L AS AL) (01106)	ARSENIC DIS-SOLVED (UG/L AS AS) (01000)	ARSENIC TOTAL (UG/L AS AS) (01002)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042)
AUG											
10...	109	99	40	1.29	<1	<0.10	<1	0 20	<1	0.98	1
24...	--	--	20	1.07	<1	0.15	<1	<0.20	<1	1.10	2
SEP											
15...	147	88	<10	1.20	<1	<0.10	<1	0.34	<1	1.44	1
30...	1300	--	10	<0.60	<1	<0.10	<1	0 84	<1	1.10	<1
NOV											
30...	76800	99	10	<0.60	<1	<0.10	<1	<0.20	2	0.97	5
DEC											
01...	37300	98	20	<0.60	<1	<0.10	<1	<0.20	2	0.92	4
02...	18000	98	20	<0.60	<1	<0.10	<1	<0.20	1	0 81	3

DATE	IRON, DIS-SOLVED (UG/L AS FE) (01046)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)	NICKEL, DIS-SOLVED (UG/L AS NI) (01065)	NICKEL, TOTAL RECOV-ERABLE (UG/L AS NI) (01067)	STRON--TIUM, TOTAL RECOV-ERABLE (UG/L AS SR) (01082)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092)
AUG											
10...	7	270	<0.06	<1	--	<0.10	2	3	210	3.46	<10
24...	7	180	<0.06	<1	--	--	2	2	250	1.76	<10
SEP											
15...	4	--	<0.06	<1	--	<0.10	2	2	220	20.38	20
30...	10	350	<0.06	<1	--	<0.10	3	4	220	4.14	<10
NOV											
30...	25	3300	<0.06	6	--	<0.10	3	13	70	1.23	40
DEC											
01...	21	2300	<0.06	4	--	<0.10	3	10	40	1.80	30
02...	25	1700	<0.06	3	--	<0.10	3	7	60	1 41	20