THE ROLE OF SEDIMENT IN NONPOINT POLLUTION IN THE POTOMAC RIVER BASIN

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Introduction

The agenda for Chesapeake Bay cleanup has focused more sharply in recent years on reduction of nonpoint source pollution. Sediment plays a central role in nonpoint pollution both as a transport mechanism for nutrients and toxic substances and as a primary cause of turbidity. Recent studies on sedimentation in the Chesapeake drainage basin, however, suggest that nonpoint control procedures which are based on reducing sediment erosion may be effective only over limited distances and over long time periods. This report examines the storage and transport characteristics of sediment and phosphorus in the Potomac River basin. This information is used to assess the time scales and spatial scales over which nonpoint source controls are effective in improving water quality in the Potomac estuary, a major arm of the Chesapeake Bay.

Review of Previous Studies

George Washington described the tidal Potomac River in 1793 as an "inexhaustible fund of rich mud which can be drawn as a manure, either to be used separately or in a compost, according to the judgement of the farmer". The Potomac River of Washington's era was most notably influenced by the product of one-crop tobacco farming; severe soil erosion. Mechanization of agriculture in the early 19th century lead to a marked increase in land clearance with a corresponding increase in basin-wide erosion rates. The period of maximum erosion in the Potomac River basin extended from approximately 1840 to 1920. Erosion has been reduced in the current century by improvements in land conservation and transformation of agricultural land to other uses. Sharp increases in erosion rates associated with construction activities have been observed in the Washington metropolitan area (Wark and Keller [1963] and Yorke and Herb [1978]). The effects of construction activiities on erosion are short-term. Once highways are paved and construction sites covered with grass erosion rates may drop below pre-construction levels (Wolman [1967]). The cycle of erosion in the mid-Atlantic region over the past three centuries has been summarized by Wolman [1967].

The decline in erosion rates in the upper Potomac River basin during the current century has not been matched by a corresponding decline in sediment yield to the Potomac estuary. (Babb [1893], Dole and Stabler [1909], USDA [1967], Meade and Trimble [1972] and Robinson [1977]). Meade [1982] notes that "although the period of intense regional soil erosion has passed in the Atlantic drainage, most of the sediment that was produced in that period has not been transported out of the source regions". The USDA [1967] estimates that 50 million tons of sediment are eroded each year in the upper Potomac River basin. The average annual sediment load to the Potomac estuary is less than 2 million tons. Meade suggests that the importance of channel and floodplain sediment storage has typically been underestimated. This conclusion has significant implications for nonpoint pollution control; it implies that the importance of "controllable" nonpoint sources (i.e., runoff from agricultural land and construction areas) has been overestimated.

Meade's conclusions are consistent with recent sedimentation studies in the Potomac estuary (Froomer [1978] and Brush and Defries [1982]), the Patuxent estuary (Fox [1975]), and the Maryland Piedmont (Costa [1975]). Brush and Defries use pollen counts as a technique for dating sections of sediment cores from the Potomac estuary. From the dated sections they are able to determine sedimentation rates for the time periods represented in the cores (usually between 140-400 years). Their results support Froomer's conclusions that recent short-term increases in sediment production due to construction activities have not affected sedimentation in the main body of the Potomac estuary; these effects are confined to the river channels and sub-estuaries immediately downstream of the sediment sources. Furthermore, the effects of rapid erosion during the nineteenth century on sedimentation in the Potomac estuary have been limited; the major effects have been the transformation of shoal areas to marshland and the transformation of marshland into floodplains in restricted areas of the upper estuary.

Brush and Defries note that hemlock pollen are found in very low concentrations in sediment cores from the Potomac estuary. Hemlock is a major component of forests in the Appalachian region of the Potomac basin but is not found in the Coastal Plain, which implies that there are no "local" sources of hemlock pollen to the Potomac estuary. Brush and Brush [1972] have shown that hemlock pollen is hydraulically equivalent to fine-grain sediment and consequently can be used as a tracer for transport of fine-grain sediment. Brush and Defries conclude that most of the fine-grain sediment eroded from the Appalachian portion of the Potomac basin is stored for very long time periods (measured in centuries) in the upper Potomac basin on floodplains.

The conclusions of Brush and Defries are supported by recent evidence from the Shenandoah River. The DuPont Company discovered high levels of mercury in the South Fork of the Shenandoah River downstream of its Waynesboro plant in 1977. Mercury was used in plant processes between 1929 and 1950. This period is assumed to be the period over which contamination of the river occurred. Adsorption of mercury to suspended solids has been well documented in laboratory and field investigations. It has been shown that mercury, like phosphorus, preferentially binds to fine-grain particles. The Virginia State Water ControlBoard and DuPont have performed floodplain and channel surveys to determine the fate of the mercury. Two of the major conclusions are 1) most of the mercury is contained within twenty river miles of the DuPont plant and 2) only 2 percent of the mercury mass is contained in river sediments; 98 percent is contained on floodplains.

The ultimate fate of Potomac River sediment is deposition in the Potomac estuary. Bennett [1983] notes that during the period 1979-1981 "all the sediment supplied plus a small contribution from Chesapeake Bay was trapped within the tidal Potomac". Furthermore, most of the fluvial sediment is deposited in the tidal river portion of the estuary.

Transport of phosphorus in stream channels is largely controlled by adsorption-desorption reactions with fine-grain sediment (Keup [1968], Edzwald et al. [1975]). Attempts to correlate dissolved phosphorus concentrations in the Potomac River with discharge (Jaworski [1969], Lang [1982]) and suspended sediment (this report) have not been successful. These approaches fail to account for the buffering effect of suspended sediment on dissolved phosphorus concentration. The buffering effect of suspended sediment on dissolved phosphorus has potentially significant implications for nonpoint source controls. Control procedures which reduce suspended sediment and total phosphorus loads to the same degree may have little impact on dissolved phosphorus concentration since dissolved phosphorus responds to the relative amounts of total phosphorus and suspended sediment. Fluctuations of dissolved phosphorus are of particular importance to water quality in the estuary because dissolved phosphorus is the primary form of phosphorus utilized by phytoplankton.

Bennett [1983a and 1983b] estimates that only 22% of the phosphorus which enters the Potomac estuary is transported to the Chesapeake Bay. The remaining 78% is adsorbed to suspended sediment or organic matter and deposited in the Potomac estuary. Because most of the phosphorus and all of the sediment which enters the Potomac estuary is trapped in the estuary, the effects of nonpoint source controls in the Potomac River basin can certainly extend no further than the Potomac estuary.

Due to the large fraction of total phosphorus which enters the Potomac estuary as particulate phosphorus and which is subsequently deposited in the estuary, flux of phosphorus from bottom sediment to the water column is a potentially important mechanism for phytoplankton growth. A detailed study of phosphorus flux from benthic sediments to the water column in the Potomac estuary has been performed by Callender (Callender [1982] and Callender and Hammond [1982]). Callender divides the Potomac estuary into three units; the tidal river, transition zone, and lower estuary. The lowest flux rates occur in the tidal river section; the flux rate of phosphorus to the water column over the entire tidal river portion of the estuary is one-third of the phosphorus input from the Blue Plains treatment plant. Callender notes that "the low fluxes of phosphate from tidal river sediments reflect the control benthic sediment exerts on phosphorus through sorption by sedimentary iron oxyhydroxides" (Callender and Hammond [1982]).

Phosphorus flux rates from tidal river sediments most closely parallel diffusive flux rates, i.e. flux rates that result from diffusion across the sediment-water column boundary in response to a concentration gradient (flux rates from transition zone sediments are much larger than diffusive rates). If phosphorus regeneration from benthic sediment is primarily dependent on a concentration gradient between sediment and water column then total phosphorus input is not the major control on phosphorus regeneration; the major control is the ratio of total phosphorus to total sediment. In this case nonpoint control procedures which reduce phosphorus and sediment loads correspondingly will have little impact on benthic phosphorus regeneration in the tidal river portion of the Potomac estuary. Furthermore, large flows are no more important than small flows in determining benthic phosphorus regeneration. In fact, large flows generally contain a smaller ratio of phosphorus to sediment than small flows due to the larger percent of sediment in the sand and silt class.

Marino [1983] relates long-term environmental changes in the Potomac estuary to historical changes in sediment and phosphorus availability. Her conclusions are based on a stratigraphic study of preserved diatom frustules in sediments of the Potomac estuary. Significant changes in the stratigraphic sequence of diatoms are described as follows: "The pre-1840 assemblage has high species diversity. The species found indicate that the estuarine water was clear, circumneutral to alkaline and abundant with aquatic plant life. Nutrients may have been somewhat limited. Concentrations of preserved diatoms drop dramatically after 1840. The most plausible explanation is that high turbidity and low phosphorus levels limited diatom growth. Large concentrations of preserved diatoms again appear in the sediments after about 1940, dominated by hypereutrophic species of the genus Cyclotella. This increase is attributed to higher phosphorus loadings to the Potomac estuary and reduced turbidity due to improved wastewater treatment."

Analysis of Sediment and Nutrient Data

The analyses in this section are based on daily suspended sediment data at three sites in the Potomac River basin (the Potomac River at Point of Rocks, the Monocacy River at Jug Bridge, and the Potomac River at Chain Bridge) and nutrient data collected at Chain Bridge during the USGS Potomac estuary study. Major conclusions from these analyses are summarized below.

1) The Piedmont section of the basin (including the Monocacy basin) contributes a disproportionately large portion of the total sediment load to the Potomac estuary (approximately 32% of the total sediment load from approximately 17% of the total drainage area; Tables 1 and 3). The mean annual sediment load of the Monocacy River in tons per square mile is twice the value for the Potomac River at Point of Rocks (231 tons/sq.mi. to 115 tons/sq.mi., Table 5).

2) Seneca pool, which is a depositional reach upstream of Great Falls, exerts a major influence on transport of sediment to the Potomac estuary (Tables 2 and 3).

3) Annual suspended sediment yields to the Potomac estuary appear to be increasing over the period 1961-1981 (Tables 5 and 7-11). Flow-corrected sediment yields, however, show no indication of increase (Table 11). Thus there is no evidence of trend in annual suspended sediment yield, independent of discharge. There appears to be an increasing trend in baseflow

suspended sediment concentration over the period 1961-1981 (Tables 12 and 13). The dependence of this "trend" on discharge is more difficult to assess (see item 6).

4) Most of the sediment delivered to the Potomac estuary is transported during only a few weeks of the year (Table 14). Approximately half the sediment is transported during 1% of the time (4 days per year on average).

5) Seasonal cycles are prominent in all aspects of sediment transport (Tables 6, 12, 13, 15, 16, and 17). The seasonal cycle of suspended sediment concentration (Tables 15 and 16) suggests that each Spring large amounts of sediment are available for transport. Low suspended sediment concentrations are most common in Fall and early Winter (Tables 12 and 13). Fall and Winter suspended sediment concentrations are also the least responsive to discharge (Table 17). This evidence points to the importance of freeze-thaw processes during late Winter and early Spring in determining the availability of sediment for transport. The seasonal cycle of suspended sediment load (Tables 15 and 16) is dominated by the effects of large Spring runoff. Large sediment loads in other seasons are associated with specific events. For example, hurricanes Agnes and David are largely responsible for the high values of mean daily sediment load during June and September for Point of Rocks (Table 16).

6) Suspended sediment concentration is strongly dependent on antecedent runoff. Several features of the relationship between antecedent runoff and suspended sediment are illustrated during water year 1977. In October of 1976 the annual peak discharge of 158,000 cfs at Point of Rocks is recorded; the peak suspended sediment concentration during this storm is 1140 mg/l. Within 30 days suspended sediment concentration drops to the minimum recording level of 1 mg/l; prior to the storm, baseflow suspended sediment concentrations were in the range of 20-40 mg/l. During the Summer of 1977 baseflow suspended sediment concentrations remain very high (40-80 mg/l) despite very low streamflow. High suspended sediment concentrations during the summer of 1977 are likely related to relatively low runoff during Spring and early Summer. The sequence of events from Fall 1976 to Summer 1977 supports the assumption in 6) above that large amounts of sediment become available for transport in early Spring. Furthermore, moderate to large runoff events are required to deplete channel storage of sediment which is available for transport during baseflow periods.

7) The occurrence of nuisance algal blooms in the Potomac estuary does not appear to be closely related to suspended sediment concentrations entering the Potomac estuary. The last major algal bloom in the Potomac estuary prior to 1983 (Summer of 1977) coincided with a period when suspended sediment concentrations were very high (40-80 mg/l). During the Summers of 1980 and 1981 suspended sediment concentrations frequently fell below 10 mg/l yet no major algal blooms occurred.

8) Total phosphorus concentration at Chain Bridge is strongly correlated with suspended sediment concentration (.86, see Table 18); the correlation of total phosphorus with discharge is

substantially smaller (.60). Dissolved phosphorus is weakly correlated with suspended sediment concentration (.28); the correlation of dissolved phosphorus with discharge is .19.
9) On average, 19% of the total phosphorus at Chain Bridge is in dissolved form (Table 19). The seasonal variability in the breakdown of total phosphorus into dissolved and particulate forms is rather small (Table 19). The seasonal cycles of both dissolved and total phosphorus concentrations (Table 20) are characterized by winter peaks in mean daily concentrations. From Table 20 it is also clear that dissolved and total phosphorus concentrations are highly variable; from the available data it is difficult to even estimate mean monthly concentrations.

Agenda Items for Further Work

1) Long-term Trend in Sediment Yield to the Potomac Estuary-
Long-term trends in sediment production and yield can be determined from suspended sediment records, reservoir sedimentation surveys, and stratigraphic evidence. Trends in sediment yield should be related to trends in land-use, determined from U. S. Bureau of Census data. The analysis of long-term trend in sediment yield to the estuary should be duplicated for phosphorus. The primary goals of this work are to estimate future trends in sediment and phosphorus loads to the Potomac estuary (in the absence of upstream nonpoint source controls) and to determine times scales over which nonpoint source controls can be effective in reducing sediment and nutrient loads to the estuary.
2) Dissolved Phosphorus Fluctuations in the Upper Potomac River-
The primary mechanisms of dissolved phosphorus fluctuation in the upper Potomac River should be determined. Emphasis should be placed on assessing the role of adsorption-desorption reactions with sediment. An important issue for assessing the impacts of nonpoint source controls on estuary water quality is determining the biological availability of particulate phosphorus that enters the Potomac estuary. This work should focus on downstream "transformations" of phosphorus.
3) Seneca Pool-
The role of Seneca Pool in regulating the nutrient and sediment load to the Potomac estuary should be determined. Nutrient work should focus on phosphorus exchange between water column and suspended and channel sediments. The role of Seneca Pool in regulating sediment transport can be determined by analysis of suspended sediment data and by stratigraphic analysis of channel, island, and floodplain sediment cores.
4) Transport of Fine-grain Sediment in the Potomac River-
Transport characteristics of fine-grain sediment in the Potomac River can be estimated from two "tracers"; hemlock pollen and mercury (from the DuPont spill). Using the mercury data and data obtained from analysis of sediment cores from a network of main-stem Potomac stations, residence times of fine-grain sediment in various storage zones (from field to estuary) can be estimated.
5) Nonpoint Source Monitoring-
Techniques should be developed to monitor trends in nutrient and sediment loads to the Potomac estuary, which are attributable to nonpoint source controls.

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Monocacy River-Jug Bridge	817	7%
Potomac River-Point of Rocks	9651	83%
Potomac River-Chain Bridge	11,570	100%

Table 1: Sub-basin Areas (in sq. mi.) and Percentages of Total Area.

Year	M+R	M	R
Average	90.	8.	82.
61	87.	8.	79.
62	89.	7.	83.
63	89.	7.	82.
64	90.	8.	82.
65	90.	6.	85.
66	92.	9.	83.
67	91.	8.	84.
68	92.	7.	85.
69	91.	8.	82.
70	93.	9.	84.
71	92.	7.	85.
72	93.	10.	83.
73	97.	8.	89.
74	93.	8.	85.
75	92.	11.	82.
76	88.	11.	78.
77	86.	9.	77.
78	87.	8.	79.
79	85.	9.	77.
80	85.	7.	78.
81	86.	8.	78.

M = Monocacy River at Jug Bridge gaging station
R = Potomac River at Point of Rocks gaging station
Average = 21 year average

Table 2. Percentage of Flow to Chain Bridge each Year from Monocacy River and Potomac River at Point of Rocks.

Year	Point of Rocks Mean Daily Flow	Monocacy Mean Daily Flow
1961	9338. (.97)	891. (1.09)
1962	9068. (.94)	735. (.90)
1963	7089. (.74)	562. (.69)
1964	7889. (.82)	761. (.93)
1965	7595. (.79)	529. (.65)
1966	4876. (.51)	523. (.64)
1967	8779. (.91)	800. (.98)
1968	8919. (.92)	731. (.90)
1969	4366. (.45)	448. (.55)
1970	9133. (.95)	1017. (1.24)
1971	11899. (1.23)	976. (1.19)
1972	15739. (1.63)	1827. (2.24)
1973	15682. (1.62)	1431. (1.75)
1974	10239. (1.06)	942. (1.15)
1975	11884. (1.23)	1539. (1.88)
1976	8152. (.85)	1106. (1.35)
1977	8565. (.89)	1008. (1.23)
1978	13212. (1.37)	1350. (1.65)
1979	12762. (1.32)	1443. (1.77)
1980	12779. (1.32)	1086. (1.33)
1981	5364. (.56)	540. (.66)
Ave.	9650. (1.00)	817. (1.17)

Table 3. Annual mean daily flow for the Potomac River at Point of Rocks and the Monocacy River at Jug Bridge in cfs. Mean daily flow in cfs/sq.mi. is given in parenthesis.

Table 4: Relative Percentage of Suspended Sediment Load from Point of Rocks and Monocacy Compared to Chain Bridge Loads.

	Monocacy + Point of Rocks	Point of Rocks	Monocacy	
OVER 3 YRS	81.	68.	13.	
1979	87.	76.	11.	
Oct	45.	31.	14.	+
Nov	57.	43.	14.	+
Dec	49.	37.	12.	+
Jan	58.	44.	14.	+
Feb	137.	127.	9.	-
Mar	88.	78.	10.	-
Apr	34.	25.	9.	+
May	77.	65.	12.	+
Jun	63.	60.	3.	+
Jul	138.	128.	10.	-
Aug	105.	39.	66.	-
Sep	66.	55.	11.	+
1980	65.	55.	11.	+
Oct	54.	45.	9.	+
Nov	38.	37.	1.	+
Dec	52.	50.	2.	+
Jan	75.	72.	3.	+
Feb	41.	39.	2.	+
Mar	69.	39.	30.	+
Apr	81.	74.	7.	
May	77.	70.	7.	+
Jun	70.	48.	22.	+
Jul	102.	78.	24.	-
Aug	110.	103.	6.	-
Sep	231.	205.	26.	--
1981	93.	61.	33.	
Oct	189.	96.	93.	-
Nov	132.	89.	44.	-
Dec	102.	98.	4.	-
Jan	51.	39.	12.	+
Feb	67.	32.	35.	+
Mar	65.	58.	7.	+
Apr	94.	76.	17.	-
May	106.	99.	7.	-
Jun	176.	90.	86.	-
Jul	157.	106.	51.	-
Aug	108.	86.	22.	-
Sep	151.	100.	50.	-

\+ Resuspension occuring above Chain Bridge
\- Deposition occuring above Chain Bridge

Year	Point of Rocks Sediment Load	Monocacy Sediment Load	Chain Bridge Sediment Load
1961	1.105 (114.)	.123 (151.)	
1962	.858 (89.)	.146 (179.)	
1963	1.107 (115.)	.113 (138.)	
1964	.892 (92.)	.129 (158.)	
1965	.676 (70.)	.107 (131.)	
1966	.444 (46.)	.114 (139.)	
1967	1.129 (117.)	.155 (190.)	
1968	.735 (76.)	.108 (132.)	
1969	.157 (16.)	.073 (89.)	
1970	1.271 (132.)	.315 (385.)	
1971	1.375 (142.)	.185 (227.)	
1972	2.436 (252.)	.455 (557.)	
1973	1.534 (159.)	.239 (293.)	
1974	1.037 (107.)	.139 (170.)	
1975	1.595 (165.)	.311 (381.)	
1976	.529 (55.)	.142 (174.)	
1977	1.333 (138.)	.222 (271.)	
1978	2.025 (210.)	.301 (368.)	
1979	2.031 (210.)	.303 (371.)	2.668 (196.)
1980	.788 (82.)	.151 (185.)	1.438 (124.)
1981	.248 (26.)	.132 (162.)	.407 (35.)
Ave.	1.110 (115.)	.189 (231.)	1.504 (130.)

Table 5. Annual Sediment Loads for the Potomac River at Point of Rocks, Monocacy River at Jug Bridge, and Potomac River at Chain Bridge in millions of tons. Sediment loads in tons/sq.mi. are given in parentheses.

Table 6: Fraction of Suspended Sediment Load from Monocacy River Relative to the Potomac River Loads at Point of Rocks. (October 1960 - September 1981)

	AVE	O	N	D	J	F	M	A	M	J	J	A	S
61	.100	.081	.163	.480	.506	.082	.096	.128	.068	.191	.242	.153	.920
62	.146	.004	.312	.093	.580	.337	.061	.191	.094	.225	.123	.055	.179
63	.093	.828	.247	.489	.073	.535	.079	.053	.143	.311	.134	.230	.247
64	.127	.260	.641	.305	.225	.400	.069	.161	.017	.193	.617	.656	.034
65	.137	.166	.180	.306	.027	.224	.129	.029	.082	.230	.160	.356	.281
66	.204	.591	.168	.364	.138	.136	.356	.064	.053	.100	.077	.266	.681
67	.121	.073	.466	.104	.695	.163	.063	.089	.049	.071	.716	.467	.160
68	.128	.135	.319	.086	.215	.022	.078	.081	.183	.244	.088	.336	.634
69	.316	.277	.328	.490	.210	.139	.251	.140	.123	.505	.714	.102	.644
70	.198	.335	.304	.510	.107	.144	.178	.130	.096	.538	.384	.170	.059
71	.119	.092	.072	.065	.066	.169	.077	.031	.047	.049	.178	.497	.245
72	.158	.151	.591	.068	.267	.094	.178	.227	.107	.158	.130	.066	.089
73	.135	.001	.259	.171	.573	.217	.159	.103	.086	.095	.261	.329	.495
74	.134	.017	.018	.095	.319	.168	.612	.227	.243	.019	.116	.052	.398
75	.163	.075	.051	.214	.354	.216	.045	.155	.292	.364	.314	.137	.236
76	.217	.103	.400	.640	.186	.286	.137	.628	.355	.266	.389	.155	.268
77	.143	.114	.168	.356	.053	.150	.222	.156	.043	.193	.069	.269	.075
78	.130	.171	.103	.427	.254	.111	.079	.059	.061	.148	.104	.019	.215
79	.130	.306	.251	.241	.245	.069	.117	.254	.154	.054	.072	.629	.170
80	.161	.167	.027	.048	.041	.054	.435	.085	.087	.313	.237	.056	.112
81	.348	.490	.331	.040	.236	.516	.103	.184	.062	.489	.323	.205	.335
AVE	.162	.211	.257	.266	.256	.202	.168	.151	.116	.227	.260	.248	.309

year	mean	minimum	median	max
1961	41.	1.	16.	884.
1962	37.	1.	8.	950.
1963	42.	1.	8.	1100.
1964	46.	1.	12.	1180.
1965	44.	1.	17.	1100.
1966	36.	1.	13.	1000.
1967	55.	1.	14.	1400.
1968	49.	2.	18.	948.
1969	60.	2.	22.	1510.
1970	79.	1.	27.	2000.
1971	74.	6.	31.	1100.
1972	66.	1.	23.	942.
1973	79.	6.	41.	647.
1974	57.	2.	29.	636.
1975	71.	1.	28.	1020.
1976	51.	4.	23.	836.
1977	61.	2.	29.	684.
1978	69.	9.	40.	1230.
1979	62.	5.	38.	923.
1980	39.	2.	21.	597.
1981	55.	3.	21.	1190.

Table 7- Yearly summary of Monocacy daily suspended sediment concentration. Units are mg/l.

year	mean	minimum	median	max
1961	338.	<1.	15.	16300.
1962	401.	<1.	6.	18200.
1963	310.	<1.	5.	20000.
1964	353.	<1.	10.	19400.
1965	293.	<1.	13.	29000.
1966	311.	<1.	5.	24000.
1967	424.	1.	21.	45000.
1968	294.	1.	16.	13900.
1969	199.	1.	17.	7210.
1970	862.	1.	36.	67900.
1971	508.	3.	38.	34500.
1972	1245.	1.	51.	134000.
1973	659.	4.	84.	16300.
1974	440.	3.	31.	26800.
1975	854.	2.	43.	43200.
1976	400.	7.	35.	22900.
1977	610.	3.	26.	43700.
1978	826.	9.	47.	42800.
1979	831.	5.	58.	43100.
1980	414.	3.	16.	30300.
1981	363.	2.	17.	22100.

Table 8- Yearly summary of Monocacy daily suspended sediment load. Units are tons/day.

year	mean	minimum	median	max
1961	27.	2.	10.	1180.
1962	23.	1.	9.	603.
1963	24.	1.	7.	808.
1964	26.	1.	8.	728.
1965	29.	1.	15.	670.
1966	21.	1.	10.	710.
1967	28.	1.	13.	950.
1968	32.	2.	18.	540.
1969	23.	2.	15.	241.
1970	53.	2.	23.	1160.
1971	68.	2.	38.	758.
1972	47.	2.	21.	878.
1973	52.	1.	27.	883.
1974	39.	2.	22.	870.
1975	53.	4.	37.	864.
1976	27.	3.	18.	602.
1977	59.	1.	53.	1140.
1978	53.	2.	25.	918.
1979	45.	3.	22.	876.
1980	28.	3.	14.	288.
1981	20.	1.	15.	338.

Table 9- Yearly summary of Point of Rocks daily suspended sediment concentration. Units are mg/l.

year	mean	minimum	median	max
1961	3027.	7.	102.	276000.
1962	2352.	3.	77.	183000.
1963	3033.	3.	66.	228000.
1964	2438.	2.	66.	150000.
1965	1851.	5.	140.	150000.
1966	1216.	2.	40.	110000.
1967	3093.	6.	180.	340000.
1968	2008.	15.	191.	106000.
1969	430.	9.	124.	12100.
1970	3482.	18.	290.	246000.
1971	3767.	26.	713.	150000.
1972	6655.	29.	447.	689000.
1973	4202.	21.	709.	132000.
1974	2840.	16.	294.	292000.
1975	4371.	42.	603.	385000.
1976	1445.	37.	211.	155000.
1977	3652.	15.	311.	262000.
1978	5549.	33.	408.	331000.
1979	5565.	14.	427.	400000.
1980	2153.	30.	239.	50000.
1981	680.	4.	121.	36900.

Table 10- Yearly summary of Point of Rocks daily suspended sediment load. Units are tons/day.

OF	WITH	CORRELATION	
		Point of Rocks	Monocacy
Annual Sediment Load	Annual Discharge	.83	.89
Annual Sediment Load	Time	.23	.40
Annual Discharge	Time	.36	.49
Flow-Corrected Sediment Load	Time	-.12	.06

Table 11. Correlation Analysis to Determine Trend over Time in Annual Sediment Load for Potomac River at Point of Rocks and the Monocacy River at Jug Bridge.

Year	O	N	D	J	F	M	A	M	J	J	A	S
1961	20.	1.	31.	26.	14.	0.	0.	1.	10.	29.	30.	30.
1962	23.	29.	15.	27.	23.	7.	0.	16.	12.	30.	25.	30.
1963	31.	12.	28.	19.	28.	6.	26.	11.	6.	12.	31.	30.
1964	31.	25.	27.	6.	17.	2.	0.	10.	30.	21.	31.	27.
1965	31.	26.	13.	10.	5.	0.	0.	0.	2.	4.	23.	24.
1966	19.	27.	31.	24.	15.	8.	7.	2.	2.	29.	30.	13.
1967	16.	25.	21.	26.	17.	5.	5.	4.	2.	1.	3.	17.
1968	10.	26.	14.	14.	17.	11.	7.	14.	0.	0.	0.	4.
1969	17.	12.	31.	29.	17.	19.	0.	3.	0.	0.	0.	2.
1970	11.	0.	12.	16.	4.	13.	0.	1.	1.	0.	0.	4.
1971	0.	6.	14.	1.	5.	6.	4.	0.	0.	0.	0.	0.
1972	5.	8.	12.	21.	10.	2.	9.	1.	0.	0.	0.	4.
1973	16.	4.	7.	21.	11.	13.	0.	0.	0.	0.	0.	0.
1974	11.	8.	5.	0.	26.	16.	4.	2.	0.	0.	0.	0.
1975	2.	0.	2.	7.	4.	8.	2.	0.	0.	0.	0.	0.
1976	4.	20.	28.	15.	9.	8.	7.	13.	0.	0.	0.	0.
1977	0.	25.	24.	31.	22.	0.	0.	0.	0.	0.	0.	0.
1978	0.	6.	6.	14.	9.	2.	1.	0.	14.	0.	0.	5.
1979	31.	29.	3.	1.	0.	0.	14.	8.	0.	0.	0.	0.
1980	9.	16.	22.	18.	25.	11.	0.	7.	6.	3.	7.	3.
1981	24.	24.	22.	29.	4.	23.	3.	0.	0.	0.	0.	8.
Ave.	15.	16.	18.	17.	13.	8.	4.	4.	4.	6.	9.	10.

Table 12. Number of Days on Which Suspended Sediment Concentrations Drop Below 10 mg/l for the Potomac River at Point of Rocks.

Year	O	N	D	J	F	M	A	M	J	J	A	S
1961	20.	8.	9.	8.	0.	3.	0.	14.	0.	17.	23.	20.
1962	31.	24.	24.	21.	18.	6.	9.	8.	2.	10.	29.	23.
1963	22.	13.	26.	11.	10.	8.	25.	12.	9.	25.	26.	28.
1964	17.	19.	24.	11.	17.	3.	9.	0.	9.	7.	15.	29.
1965	26.	26.	17.	15.	5.	8.	8.	1.	0.	4.	7.	5.
1966	10.	19.	20.	20.	15.	6.	12.	8.	3.	20.	14.	7.
1967	23.	19.	11.	19.	12.	8.	4.	6.	10.	0.	4.	1.
1968	2.	22.	15.	15.	14.	8.	0.	10.	1.	2.	10.	4.
1969	4.	6.	14.	21.	13.	2.	8.	3.	1.	4.	1.	0.
1970	12.	15.	11.	16.	1.	2.	0.	0.	0.	0.	0.	0.
1971	2.	3.	7.	9.	0.	5.	7.	1.	0.	2.	0.	0.
1972	4.	15.	11.	12.	3.	10.	10.	0.	0.	0.	1.	8.
1973	12.	0.	0.	0.	4.	3.	3.	4.	0.	0.	0.	0.
1974	2.	10.	4.	0.	12.	15.	0.	4.	0.	0.	0.	0.
1975	2.	11.	8.	12.	15.	6.	7.	0.	0.	0.	0.	0.
1976	4.	14.	7.	1.	4.	13.	4.	0.	2.	0.	0.	0.
1977	5.	12.	5.	31.	14.	0.	1.	0.	0.	0.	0.	0.
1978	0.	0.	0.	1.	0.	1.	0.	0.	0.	0.	0.	0.
1979	0.	0.	6.	0.	10.	0.	0.	0.	0.	0.	0.	4.
1980	12.	26.	25.	23.	28.	12.	0.	0.	0.	0.	1.	0.
1981	4.	13.	29.	26.	4.	9.	0.	0.	0.	0.	0.	0.
Ave.	10.	13.	13.	13.	9.	6.	5.	3.	2.	4.	6.	6.

Table 13. Number of Days on Which Suspended Sediment Concentrations Drop Below 10 mg/l for the Monocacy River at Jug Bridge.

	% of Suspended Sediment Discharge in			
	1% of time	2% of time	5% of time	10% of time
Potomac River-Point of Rocks	49	62	78	87
Monocacy River-Jug Bridge	46	62	82	90

Table 14. Frequency of Suspended Sediment Discharge for the Potomac River at Point of Rocks and the Monocacy River at Jug Bridge.

Monocacy Suspended Sediment Concentration (mg/l):

month	mean	st dev	cv	min	.10	median	.90	max
Oct	36.	65.	1.81	1.	2.	18.	75.	684.
Nov	36.	77.	2.14	1.	3.	12.	78.	823.
Dec	37.	83.	2.23	1.	4.	12.	81.	1010.
Jan	52.	122.	2.36	1.	5.	14.	105.	1230.
Feb	67.	143.	2.14	1.	6.	16.	190.	1100.
Mar	71.	134.	1.89	4.	8.	22.	155.	1100.
Apr	54.	106.	1.94	1.	8.	20.	114.	1060.
May	46.	71.	1.54	6.	10.	24.	95.	1020.
Jun	86.	144.	1.68	1.	12.	40.	200.	1240.
Jul	76.	173.	2.28	1.	9.	35.	136.	2000.
Aug	54.	98.	1.79	1.	5.	30.	105.	968.
Sep	56.	100.	1.79	1.	4.	30.	100.	948.

Monocacy Suspended Sediment Load (tons/day):

month	mean	st dev	cv	min	.10	median	.90	max
Oct	308.	2317.	7.53	.	1.	9.	144.	43700.
Nov	213.	1101.	5.18	.	1.	10.	290.	21100.
Dec	401.	1907.	4.76	.	3.	17.	424.	26800.
Jan	745.	3606.	4.84	.	3.	26.	698.	43100.
Feb	947.	3605.	3.81	1.	4.	34.	1300.	40400.
Mar	1054.	3662.	3.47	4.	13.	70.	1620.	45000.
Apr	688.	2821.	4.10	2.	13.	47.	1000.	37200.
May	275.	1114.	4.05	1.	10.	40.	355.	16200.
Jun	699.	6298.	9.01	1.	8.	41.	583.	134000.
Jul	359.	2977.	8.29	.	3.	23.	244.	67900.
Aug	139.	784.	5.62	.	1.	16.	110.	11400.
Sep	426.	2661.	6.25	.	1.	14.	176.	43200.

Table 15. Monthly Summary of Daily Suspended Sediment Concentration (in mg/l) and Load (in tons/day) for the Monocacy River at Jug Bridge. Entrees under the column '.10' represent daily concentrations (or loads) that are exceeded 90% of the time. Similarly entrees under '.90' represent daily concentrations that are exceeded 10% of the time.

Point of Rocks Suspended Sediment Load (mg/l):

month	mean	st dev	cv	min	.10	median	.90	max
Oct	32.	81.	2.51	1.	3.	12.	63.	1140.
Nov	22.	50.	2.26	1.	2.	10.	43.	673.
Dec	25.	59.	2.33	1.	2.	9.	58.	870.
Jan	30.	64.	2.17	1.	2.	10.	66.	630.
Feb	49.	120.	2.48	2.	4.	12.	103.	1180.
Mar	64.	121.	1.88	3.	7.	23.	142.	950.
Apr	47.	85.	1.81	2.	9.	22.	108.	1160.
May	41.	61.	1.49	1.	10.	22.	73.	728.
Jun	42.	75.	1.76	3.	10.	24.	78.	883.
Jul	34.	68.	1.97	1.	8.	23.	60.	1140.
Aug	29.	31.	1.06	1.	3.	22.	60.	319.
Sep	30.	48.	1.59	1.	3.	17.	69.	633.

Point of Rocks Suspended Sediment Load (tons/day):

month	mean	st dev	cv	min	.10	median	.90	max
Oct	2694.	17205.	6.39	3.	8.	75.	1710.	262000.
Nov	982.	5529.	5.63	3.	12.	115.	1190.	84100.
Dec	2143.	13334.	6.22	3.	11.	117.	2910.	292000.
Jan	2503.	11836.	4.73	4.	20.	178.	3910.	187000.
Feb	6153.	29775.	4.84	20.	55.	260.	8800.	400000.
Mar	9670.	34780.	3.60	38.	120.	920.	14400.	385000.
Apr	4103.	14513.	3.54	29.	159.	691.	7910.	246000.
May	2554.	8902.	3.49	34.	124.	518.	4300.	150000.
Jun	3479.	32068.	9.22	22.	80.	326.	2370.	689000.
Jul	772.	4245.	5.50	2.	39.	202.	904.	68000.
Aug	474.	1542.	3.26	2.	13.	166.	890.	25000.
Sep	1139.	9154.	8.04	2.	9.	107.	752.	161000.

Table 16 Monthly summary of Daily Suspended Sediment Concentration (mg/l) and Load (tons/day) for the Potomac River at Point of Rocks.

	Correlation	
	Monocacy	Point of Rocks
October	.47	.64
November	.59	.53
December	.72	.84
January	.76	.71
February	.76	.74
March	.83	.88
April	.79	.74
May	.62	.61
June	.62	.56
July	.68	.55
August	.66	.67
September	.61	.62

Table 17. Log-log Correlation of Daily Suspended Sediment Concentration with Discharge, by Month, for the Monocacy River and the Potomac River at Point of Rocks.

	Correlation	
	Suspended Sediment Concentration	Discharge
Phosphorus Total	.86	.60
Phosphorus Dissolved	.28	.19
Ammonia + Org N Total	.70	.50
Ammonia + Org N Dissolved	.35	.16
Nitrite + Nitrate Dissolve	.06	.13

Table 18. Correlation Analysis of Nutrients with Suspended Sediment Concentration and Discharge at Chain Bridge.

	% of Monthly P Load in Dissolved Form	% of Monthly P Load in Particulate Form
January	.16	.84
February	.16	.84
March	.20	.80
April	.23	.77
May	.18	.82
June	.28	.72
July	.19	.81
August	.28	.72
September	.16	.84
October	.35	.65
November	.23	.77
December	.33	.68
Annual Average	.19	.81

Table 19. Monthly Breakdown of Phosphorus Loads at Chain Bridge estimated from USGS Potomac Estuary Study data.

Dissolved Phosphorus (mg/l as P)

month	mean	st. dev.	cv	# of obs.
Jan	.044	.018	.42	37
Feb	.052	.029	.56	36
Mar	.037	.015	.41	40
Apr	.024	.017	.68	31
May	.027	.016	.59	35
Jun	.029	.024	.83	34
Jul	.023	.017	.73	28
Aug	.045	.029	.65	28
Sep	.034	.025	.72	27
Oct	.029	.025	.86	20
Nov	.033	.028	.83	19
Dec	.047	.043	.91	25

Total Phosphorus (mg/l as P)

month	mean	st. dev.	cv	# of obs.
Jan	.135	.135	1.00	37
Feb	.150	.139	.93	36
Mar	.112	.088	.78	40
Apr	.075	.061	.81	31
May	.087	.101	1.16	35
Jun	.075	.045	.60	34
Jul	.078	.072	.92	28
Aug	.101	.066	.66	28
Sep	.116	.148	1.28	27
Oct	.059	.045	.77	20
Nov	.092	.108	1.17	19
Dec	.087	.086	.98	25

Table 20. Monthly Summary of Dissolved Phosphorus and Total Phosphorus Concentrations at Chain Bridge.