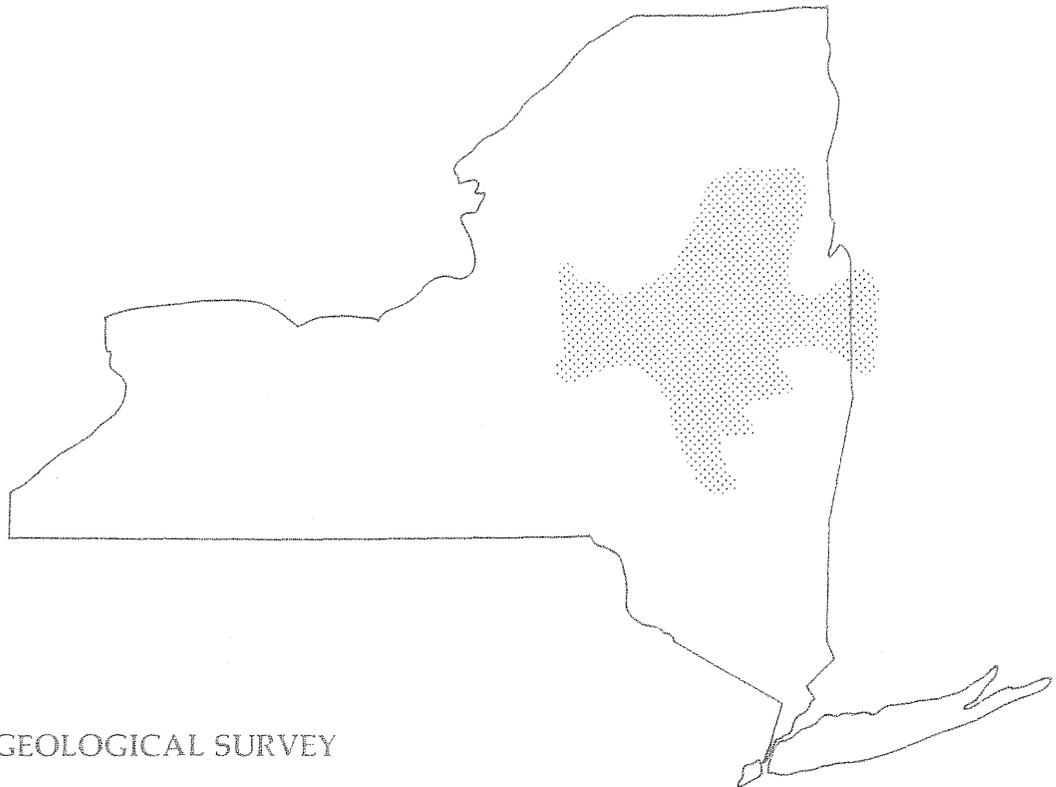


Relationship of Water Quality of Hudson River, New York,  
During Peak Discharges to Geologic Characteristics  
of Contributing Subbasins



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 80-108

Prepared in cooperation with the  
BOARD OF WATER COMMISSIONERS OF  
THE TOWN OF WATERFORD, and  
NEW YORK STATE DEPARTMENT OF  
ENVIRONMENTAL CONSERVATION



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<b>16. Abstract (Limit: 200 words)</b> Water samples from two Hudson River floods in 1977--one originating mainly in shale subbasins that produce high sediment loads, the other in soil-poor, crystalline rock terrane that yields little sediment--were analyzed to evaluate the relationship of iron, manganese, lead, phosphorus, and polychlorinated biphenyls (PCB's) to suspended-sediment concentration. During the flood of high sediment discharge, ratios for all substances studied except PCB's reflected their concentration within the basin regolith. During the flood of smaller magnitude, from the low-sediment crystalline terrane, however, only the ratio for iron correlated with predicted concentrations in the basin, which suggests that the chemical constituents studied were contributed principally from other sources, possibly anthropogenic sources. High lead concentrations in the low-sediment flood were derived from an unidentified, basinwide source whose contribution was relatively insignificant during the flood from the shale area.			
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Albany, New York

1981

UNITED STATES DEPARTMENT OF THE INTERIOR

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## CONVERSION FACTORS AND ABBREVIATIONS

<u>Multiply SI units</u>	<u>By</u>	<u>To obtain inch-pound units</u>
square kilometer (km <sup>2</sup> )	0.3861	square mile (mi <sup>2</sup> )
cubic meter per second per square kilometer (m <sup>3</sup> /s)/km <sup>2</sup> )	91.45	cubic foot per second per square mile (ft <sup>3</sup> /s)/mi <sup>2</sup> )
cubic meter (m <sup>3</sup> )	35.31	cubic foot (ft <sup>3</sup> )
gram (g)	0.03527	ounce, avoirdupois (oz)
degree Celsius (°C)	(°F-32)/1.8	degree Fahrenheit (°F)

Abbreviations used in the text of this report include:

μg/L, micrograms per liter  
mg/L, milligrams per liter  
μg/g, micrograms per gram

**RELATIONSHIP OF WATER QUALITY OF HUDSON RIVER, NEW YORK,  
DURING PEAK DISCHARGES TO GEOLOGIC CHARACTERISTICS  
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By

John T. Turk and David E. Troutman

**ABSTRACT**

Water samples from the Hudson River during a flood in March 1977 that originated in a subbasin underlain by shale and yielding high sediment loads indicate a high correlation between suspended-sediment concentration and concentration of iron, manganese, lead, phosphorus, and polychlorinated biphenyls (PCB's). The slope of first-order linear regressions on iron, manganese, lead, and phosphorus was generally within a factor of 2 of their concentration within the regolith as predicted from the bedrock composition. Agreement between predicted concentration of these substances (except PCB's) in the regolith and suspended-sediment regression coefficients is interpreted to indicate a lack of significant contributions from anthropogenic sources. In contrast, water samples collected during a flood in April 1977, which originated in a crystalline-rock subbasin yielding less suspended sediment, showed a significant correlation only between suspended sediment and iron.

Calculations indicate that the regression slopes for iron, manganese, and phosphorus differed between the two floods because water sources differed. During the flood from the crystalline subbasin, manganese and phosphorus concentrations were higher than predicted from suspended-sediment concentration, which suggests sources in addition to the regolith during that event.

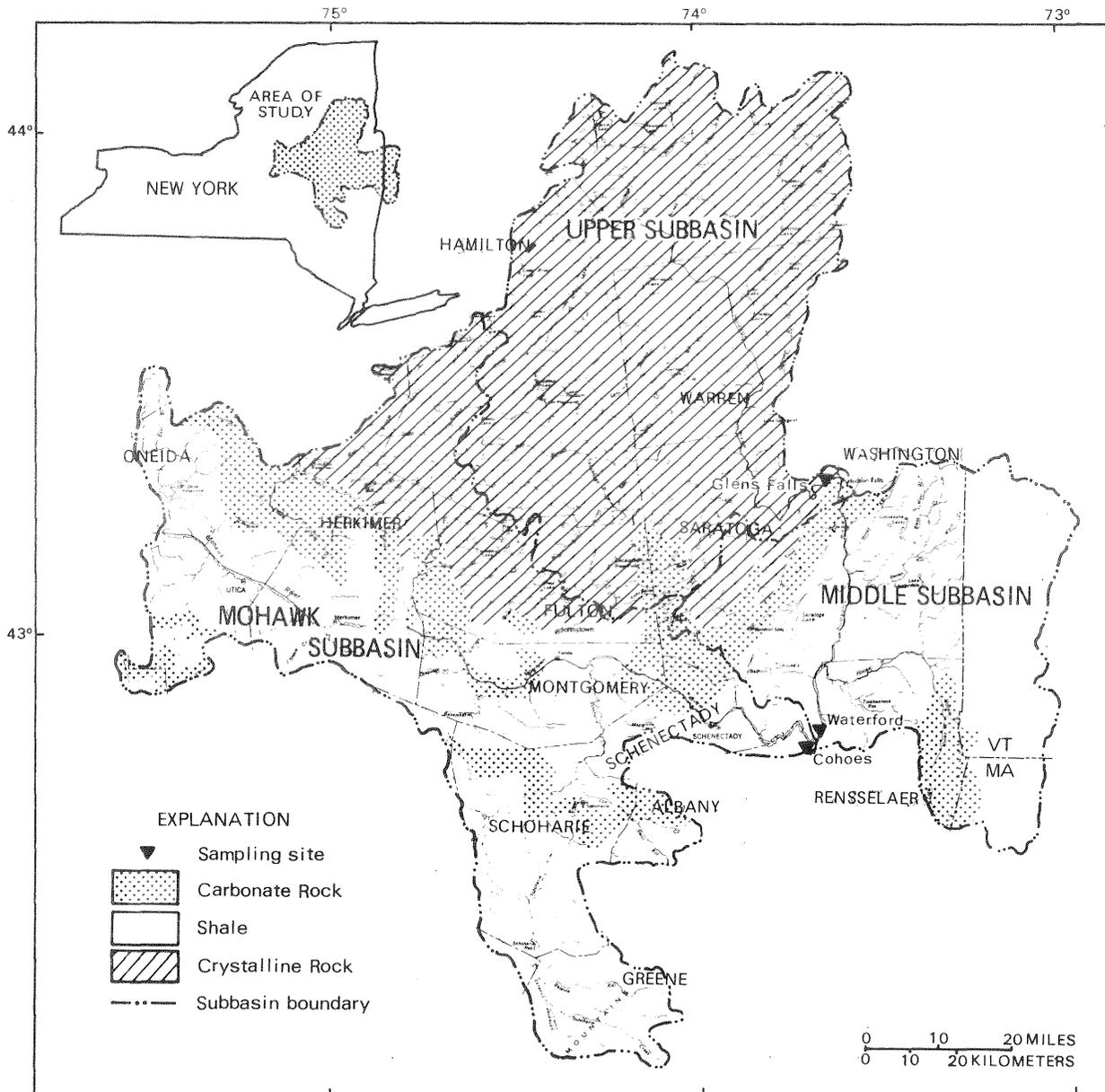
The basin regolith is not always the major source of lead in the river. Lead concentrations in the flood water from the crystalline basin were contributed from a basinwide source whose effect was masked during the flood from the shale basin. Although this source has not been identified, it was probably neither atmospheric precipitation nor dry fallout.

High PCB concentrations are probably caused by resuspension of river-bottom deposits containing PCB's.

**INTRODUCTION**

The discharge of polychlorinated biphenyls (PCB's) and heavy metals into the upper Hudson River (fig. 1) has caused regional concern over the possibility of environmental damage and threat to human health.

Although several agencies routinely collect data on heavy-metals concentrations in the Hudson River basin, none of the programs involve sampling at a frequency high enough to accurately identify heavy-metals transport during periods of high discharge. This is also true of constituents such as phosphorous, many pesticides, and certain industrial organic compounds that tend to be sediment related.



Base from U.S. Geological Survey  
State base map  
Shaded relief, 1:500,000, 1956

Figure 1.--Major geographic and geologic features of Hudson River basin, New York.

Attempts are being made by local, State, and Federal agencies to assess and quantitatively model the transport of both types of pollutants as an aid in formulation of river-basin-management decisions. The U.S. Geological Survey, in cooperation with the New York State Department of Environmental Conservation and the Board of Water Commissioners of the Town of Waterford, began a study in 1976 to gather and interpret data on the transport of lead and PCB's as well as other constituents with similar transport properties.

Although iron, manganese, lead, phosphorus, and PCB's (the five chemical constituents considered in this study) are all transported as suspended sediment during periods of high discharge, geologic differences among the areas contributing runoff, and differences in type and extent of anthropogenic sources, could cause inconsistent relationships among these constituents within the basin. Through evaluation of the factors that control these relationships, the quantitative transport models can be improved. To evaluate trends, it is necessary to determine whether the temporal variations in the concentrations of these substances are caused by long-term changes in water quality or are simply related to differences in the sources of the water.

### **Purpose and Scope**

As part of a long-term series of investigations of transport patterns of sediment-borne chemicals in the upper Hudson River basin, this study was conducted from 1976-77 to compare the contributions of selected chemicals from different sources. Constituents studied that are derived mainly from natural sources are iron and manganese. PCB's are derived from anthropogenic sources, and lead and phosphorous are contributed from both sources. Water samples were collected during two periods of high discharge at three sites representing different types of geologic terrane and industrial activity within the basin.

### **Physiographic Setting**

For the purposes of this study, the Hudson River basin is divided into the Mohawk River basin, the middle Hudson River basin (that part from the confluence with the Mohawk River to Glens Falls), and the Hudson River upstream from Glens Falls (fig. 1). The Mohawk River basin, which drains 8,951 km<sup>2</sup>, consists of 62 percent shale, 15 percent carbonate rock, 16 percent crystalline rock, and 7 percent miscellaneous or unidentified rock types. The middle Hudson River basin, which drains 4,688 km<sup>2</sup>, is composed almost entirely of shale and contains less than 10 percent carbonate or crystalline rocks. In contrast, virtually all of the 7,278-km<sup>2</sup> drainage area upstream from Glens Falls is crystalline rock--primarily gneiss and anorthosite (New York State Museum and Science Service, 1970). Less than 10 percent of the basin above Glens Falls contains carbonate rock and shale; these occur primarily near Glens Falls. All of the study area has been glaciated and is mantled with varying thicknesses of drift. Most industry is within the Mohawk and Middle Hudson basins.

## Data Collection and Analysis

All data were collected during two 1977 floods, one from March 11-18, the other from April 24-28, as part of a continuing study. Methods of collection were those described in Guy and Norman (1970). All parts of the depth-integrating samplers in contact with the sample were Teflon<sup>1</sup> or stainless steel. Samplers were cleaned immediately before collection with laboratory-grade detergent and hexane, rinsed with distilled water, and prerinsed with river water. Samples for the metals analyses were transferred to acid-rinsed polyethylene bottles and were acidified with nitric acid to pH less than 1. Samples for PCB analysis were transferred to glass containers that were precleaned by heating to 500°C.

All chemical analyses were done by the U.S. Geological Survey Central Laboratory in Doraville, Ga.

## Data Transformations

Data from the Mohawk River at Cohoes (representing a predominantly shale source) and from the Hudson River at Glens Falls (crystalline source) and Waterford (shale and crystalline source) during the two floods are summarized in table 1. To facilitate interpretation, the data were treated in two ways: (a) the ratio of the concentration of each constituent to the concentration of suspended sediment was calculated (table 2), and (b) a linear least-squares regression equation of each constituent as a function of the suspended-sediment concentration was determined for the individual floods at each site (table 3). The data in tables 4-6 are based on regressions of the form:

$$y = mx + b$$

where  $y$  = concentration of the constituent (dependent variable),  
in micrograms per liter;

$m$  = slope of the regression line, in micrograms  
per gram;

$x$  = concentration of suspended sediment (the independent  
variable), in grams per liter.

$b$  = intercept of the regression line with the  $y$ -axis,  
in micrograms per liter.

Also tabulated are (a) the number of data pairs; that is, values of the dependent and independent variables used to derive the regression equation for each flood-site configuration  $n$ ; (b) the correlation coefficient  $r$ ; and (c) the probability,  $P$ , that  $r$  will be equaled or exceeded in  $n$  pairs of randomly selected data pairs for unrelated variables.

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<sup>1</sup> Use of brand name is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Table 1.--Concentrations of selected constituents during floods of March-April 1977<sup>1</sup>

[Analyses by U.S. Geological Survey, Doraville, Ga.]

Date	Average discharge (m <sup>3</sup> /s)	Constituent					
		Suspended sediment (mg/L)	Iron (µg/L)	Manganese (µg/L)	Lead (µg/L)	Phosphorus (µg/L)	PCB (µg/L)
0135 MOHAWK RIVER AT COHOES (03157500) - MARCH 1977							
03-11-77	864	136	4,600	180	13	--	0.0
03-13-77	1,120	149	4,800	160	10	--	.0
03-14-77	3,060	1,220	35,000	980	45	--	.3
03-15-77	2,060	501	15,000	440	28	--	.2
03-18-77	626	53	1,900	70	6	--	.0
HUDSON RIVER AT WATERFORD (01335770) - MARCH 1977							
03-11-77	450	107	3,500	180	9	13	0.0
03-13-77	691	162	4,800	210	20	15	.0
03-14-77	1,850	948	25,000	1,000	62	65	.9
03-14-77	1,910	791	26,000	860	46	--	.8
03-15-77	2,000	401	11,000	430	28	29	1.4
03-15-77	1,560	189	6,300	250	15	--	.4
03-16-77	1,180	*116	3,200	--	12	--	.4
03-17-77	1,100	70	2,000	100	14	6	.0
HUDSON RIVER AT WATERFORD (01335770) - APRIL 1977							
04-24-77	685	*44	1,800	80	8	7	0.1
04-25-77	1,090	*62	1,400	70	8	3	.5
04-26-77	1,120	*50	1,100	60	12	6	1.2
04-27-77	1,010	*31	790	50	11	6	.5
04-28-77	943	*20	580	40	16	5	.4
HUDSON RIVER AT GLENS FALLS (01327600) - APRIL 1977							
04-25-77	821	*19	520	50	6	6	0.0
04-26-77	793	*14	390	50	15	4	.0
04-27-77	680	* 8	230	30	5	4	.0
04-28-77	623	* 7	250	30	15	2	.0

<sup>1</sup> March flood originated in shale subbasin, April flood in crystalline-rock terrane.

\* Mean suspended-sediment concentration for the day; all others are at the time of collection.

Table 2.--Ratio of selected constituents to suspended sediment during floods of March-April 1977<sup>1</sup>

[All values are in micrograms per gram sediment]

Date	Iron	Manganese	Lead	Phosphorus	PCB
MOHAWK RIVER AT COHOES (01357500) - MARCH 1977					
03-11-77	34,000	1,300	96	--	0.0
03-13-77	32,000	1,100	67	--	.0
03-14-77	29,000	800	37	--	.2
03-15-77	30,000	880	56	--	.4
03-18-77	36,000	1,300	110	--	.0
Mean	32,000	1,100	73	--	0.1
Standard dev.	2,900	200	30	--	.2
HUDSON RIVER AT WATERFORD (01335770) - MARCH 1977					
03-11-77	33,000	1,700	84	1,200	0.0
03-13-77	30,000	1,300	120	930	.0
03-14-77	26,000	1,100	65	690	1
03-14-77	33,000	1,100	58	--	1
03-15-77	27,000	1,100	70	720	3.5
03-15-77	33,000	1,300	79	--	2
03-16-77	28,000	--	100	--	3
03-17-77	29,000	1,400	200	860	.0
Mean	30,000	1,300	97	880	1
Standard dev.	2,900	200	46	200	1
HUDSON RIVER AT WATERFORD (01335770) - APRIL 1977					
04-24-77	41,000	1,800	200	1,600	2
04-25-77	23,000	1,100	100	480	8
04-26-77	22,000	1,200	240	100	24
04-27-77	25,000	1,600	350	190	20
04-28-77	29,000	2,000	800	2,500	20
Mean	28,000	1,500	340	970	15
Standard dev.	7,700	400	270	1,000	9
HUDSON RIVER AT GLENS FALLS (01327600) - APRIL 1977					
04-25-77	27,000	2,600	300	3,200	0.0
04-26-77	28,000	3,600	1,100	2,900	.0
04-27-77	29,000	3,800	600	5,000	.0
04-28-77	36,000	4,300	2,100	2,900	.0
Mean	30,000	3,600	700	3,500	.0
Standard dev.	4,100	700	900	1,000	.0

<sup>1</sup> March flood originated in shale subbasin; April flood in crystalline-rock terrane.

Table 3.--Linear least-squares regression relationship for selected constituents during floods of March-April 1977<sup>1</sup>

<i>y</i>	<i>m</i> (micrograms per gram)	<i>b</i> (micrograms per gram)	<i>n</i>	<i>r</i>	<i>P</i>
MOHAWK RIVER AT COHOES (01357500) - MARCH 1977					
Iron	28,200	627	5	1.00	<0.001
Manganese	760	51	5	1.00	< .001
Lead	33	7	5	.98	< .01
PCB	0.28	-0.01	5	.95	< .02
HUDSON RIVER AT WATERFORD (01335770) - MARCH 1977					
Iron	28,500	293	8	0.99	<0.001
Manganese	1,010	48	7	1.00	< .001
Lead	55	7	8	.98	< .001
Phosphorus	640	39	5	1.00	< .001
PCB	1.0	0.14	8	.67	< .1
HUDSON RIVER AT WATERFORD (01335770) - APRIL 1977					
Iron	20,900	270	5	0.70	>0.1
Manganese	740	29	5	.76	> .1
Lead	-160	17	5	-.77	> .1
Phosphorus	-350	69	5	-.38	> .1
PCB	6.6	0.26	5	.27	> .1
HUDSON RIVER AT GLENS FALLS (01327600) - APRIL 1977					
Iron	23,900	60	4	0.99	<0.01
Manganese	1,910	17	4	.93	< .1
Lead	-250	13	4	-.25	< .1
Phosphorus	2,600	9	4	.88	< .1

<sup>1</sup> March flood originated in shale subbasin, April flood in crystalline-rock terrane.

*y* = Dependent variable  
*m* = slope of regression line (µg/g)  
*b* = intercept of regression line with *y*-axis (µg/L)

*n* = number of data pairs for each flood at each site  
*r* = correlation coefficient  
*P* = Probability that *r* will be equaled or exceeded in *n* pairs of randomly selected data pairs for unrelated variables

## RELATIONSHIP BETWEEN CHEMICAL CONSTITUENTS AND SUSPENDED SEDIMENT

In periods of low suspended-sediment concentration (low discharge), iron (Fe), manganese (Mn), lead (Pb), phosphorus (P), and polychlorinated biphenyls (PCB's) are transported primarily as dissolved constituents. During high flows, sediments entering the river carry additional amounts of these constituents so that the eroded soils and resulting river sediment become the principal source of these substances. If a chemical constituent such as iron, for example, is present in relatively uniform concentrations throughout the regolith and if the amount contributed from anthropogenic and other nonregolith sources is small compared with the amount contributed by sediment transport, the following should occur:

- 1 The concentration of iron should show a high correlation with the concentration of suspended sediment in all samples.
- 2 The spatial variation in mean ratio of iron concentration to suspended-sediment concentration in waters draining the basin should not differ significantly (greater than two standard deviations) from the within-site temporal variation at some reference site;
- 3 The slope of the regression equation of constituent concentration to suspended-sediment concentration should approximate the average concentration of that constituent throughout the regolith.

### Correlations

All five dependent variables were significantly correlated with suspended-sediment concentration for at least one site during one flood (item 1 above). Iron correlated closely with suspended sediment on three of the four sampling occasions (table 3); manganese and lead correlated with suspended sediment on two of the four occasions, and phosphorus and PCB's correlated with suspended sediment on one of three occasions.

### Ratios

In the evaluation of spatial and temporal trends (item 2 above), the data on the March 1977 flood at Waterford (table 1) were used as a base for comparison of ratios of other chemicals to sediment because this set contained the largest number of samples and because all five chemical constituents were evaluated in each sample.

Iron.--The mean ratio of iron to suspended sediment in this data set was within one standard deviation of the mean ratio for the other three sampling occasions.

Manganese.--For manganese, two of the three sites (March at Cohoes and April at Waterford) were within one standard deviation of the base data. The Glens

Falls (crystalline source) mean was almost twice as high as that of the base-data set.

Lead.--For lead, the Cohoes mean ratio was within one standard deviation of the base set, but the mean ratios for the other Waterford set and the Glens Falls set were several times greater.

Phosphorus.--This element, which was not determined in the Cohoes data set, was similar in the two Waterford data sets only because of the fortuitous average of the individual ratios in the Waterford data for April, which ranged over more than an order of magnitude. The phosphorus ratio for the Glens Falls site showed no correlation with the base set.

PCB.--The ratios of PCB's to suspended sediment at Cohoes was within one standard deviation of the base-data set only because of the large standard deviation for this ratio.

### Regression Slopes

A comparison of regression slopes (item 3 above) assumes a uniform concentration of chemical constituents in the fractions of the regolith; in other words, the material transported as suspended sediment is similar in chemical composition to the regolith from which it originated. Because this assumption may not always be true, and because actual quantitative concentrations of the constituents in the regolith are not known, differences can be expected between regression slopes and estimated chemical concentrations within the regolith. A comparison of (a) regression slopes determined in this study for the statistically significant regressions with (b) independent data on the composition of average shales and granites (Krauskopf, 1976) is given in table 4. The values given by Krauskopf for shale should approximate those of shale in this study area. The chemical constituents showed agreement between the regression slopes and the estimated concentrations in the regolith. In general, the observed data and the data from Krauskopf (1967) agree within a factor of 2 even though Krauskopf's data are based on world averages rather than on bedrock of the Hudson basin.

No comparison is made in table 4 for the regression slope and regolith concentration of PCB's. It is assumed that PCB's are supplied primarily from resuspension of river-bottom materials rather than from the regolith because they are known to have been discharged to the river system by industry since the 1950's. Because PCB concentrations in bottom materials of streams in the subbasins of the Hudson River basin have been shown to vary by at least three orders of magnitude (New York State Department of Environmental Conservation, 1976), a highly variable PCB concentration in the suspended-sediment load of the Hudson River should be expected, depending upon discharge and proximity to the former point sources.

To summarize the relationship between chemical constituents and suspended sediment, the regolith of the basin was the likely major source of iron during both floods at all sites except Glens Falls (crystalline source), as indicated by (a) its high correlation with suspended-sediment concentration, (b) the

lack of significant spatial and temporal variation in the ratios of iron to suspended sediment, and (c) the agreement between the regression slope and the assumed concentration of iron in the regolith. By similar considerations, the regolith was also the predominant source of manganese and lead during the March 1977 flood at all sites and possibly manganese and phosphorus during the April 1977 flood at Waterford. However, only in the March flood at Waterford was it the predominant source of phosphorus, and in no instance was it a source of PCB's.

Table 4.--Comparison of regression slopes with estimated concentrations in shales and granites<sup>1</sup>

[All values are in micrograms per gram]

Element	Slope value	Shale	Granite
Iron	28,200	47,000	27,000
	28,500		
	23,900		
Manganese	760	850	400
	1,010		
Lead	33	20	20
	55		
Phosphorus	640	770	700

<sup>1</sup> Data from Krauskopf (1967).

### Effect of Terrane on Sediment Yields

The periodic lack of close correlation between regolith composition and stream chemistry can be explained partly by variations in sediment yield, which in turn results from differences in terrane.

As shown in figure 1, both Waterford and Cohoes are downstream from basins containing a large percentage of shale, which is more rapidly eroded by alternate freezing and thawing and from abrasion by surface runoff than the crystalline rocks. Thus, the yield of suspended sediment and associated chemical constituents should be larger from the subbasins underlain by shale than from those underlain by crystalline rock. This effect is reflected in table 1. In a later section, this difference in sediment yield is shown to be a probable explanation for the inconsistencies and temporal changes in the stream-chemistry data.

If the suspended-sediment concentration is divided by discharge, the following average ratios are obtained, in arbitrary units:

<u>Flood and site</u>	<u>Source</u>	<u>Sediment:discharge ratio</u>	<u>Discharge: drainage-area ratio</u>
March-Cohoes	Shale	0.20	0.17
March-Waterford	Shale & crystalline rock	.23	.11
April-Waterford	Shale & crystalline rock	.04	.08
April-Glens Falls	Crystalline rock	.01	.10

Note that the two March floods, in which the main source of the chemical constituents studied was the regolith, have the highest concentration of suspended sediment per unit of discharge but do not correlate with ratios of discharge cubic meters per second ( $m^3/s$ ) to drainage area square kilometers ( $km^2$ )--a measure of runoff intensity.

The above data indicate that the ratios for the April Waterford data set (flood from the crystalline subbasin) and the Glens Falls set are much lower than the ratio for Cohoes. Floods from the predominantly shale Mohawk subbasin may yield as much as 20 times more sediment per unit of discharge than subbasins that are predominantly crystalline (U.S. Geological Survey, 1978).

The lack of consistency between suspended-sediment concentration and runoff intensity is easily explained from the differences in geology and distribution of runoff within a basin. Streamflow sampled at Waterford during the March flood was primarily runoff from the shale-rich subbasin between Glens Falls and Waterford, and only 40 percent of the total flow was from the crystalline subbasin upstream. In contrast, 72 percent of the total flow during the April flood was runoff from the crystalline subbasin (U.S. Geological Survey, 1978).

### **Effect of Sediment Yield on Water Quality**

Sediment yields from differing terranes contribute different types of chemical loads to streams. In the study area, principal sources of chemical load in the streams are dissolved and suspended constituents from the regolith and those introduced by man. If the supply of sediment and associated chemical species from the regolith is low, those species will have originated from other sources, which will cause a lack of correlation with the suspended-sediment concentration. The magnitude of this effect can be evaluated from the data in table 1. If the flow represented by the April (crystalline basin) data is hypothetically rerouted to originate on a shale subbasin (table 5), the ratios of suspended-sediment to discharge for March suggest that loads would increase to 0.2 mg/L of sediment for each cubic meter per second of discharge, which would contribute chemical constituents in the proportions indicated by Krauskopf's (1967) data for average shale. The concentrations of the chemical constituents in table 5 were calculated as follows: (a) The difference between the observed suspended-sediment concentration and that predicted from the discharge was multiplied by the assumed concentration of the chemical constituent in shale; and (b) this concentration was then added to the observed concentration of that constituent.

Table 5.--Chemical characteristics of a hypothetical data set resulting from discharges similar to those of April 1977 but originating from a shale subbasin

Date	Discharge (m <sup>3</sup> /s)	Concentration				
		Suspended sediment (mg/L)	Iron (µg/L)	Manganese (µg/L)	Lead (µg/L)	Phosphorus (µg/L)
04/27/77	685	137	7,500	160	10	79
04/25/77	1,090	218	9,700	200	11	123
04/26/77	1,120	224	10,000	210	15	140
04/27/77	1,010	202	9,400	200	14	140
04/28/77	943	189	8,900	180	19	140
04/25/77	821	164	7,700	170	9	120
04/26/77	793	159	7,500	170	18	120
04/27/77	680	136	6,400	140	8	100
04/28/77	623	125	5,900	130	17	93

### Comparison of Bedrock to Other Sources

Linear regressions of chemical concentrations against suspended-sediment concentrations, from table 5, are significant in five of the eight cases if a probability of 0.05 or less is used as the criterion. All regressions (table 6) except lead compare closely with those shown in table 3 for March 1977 samples, which suggests that the nonregolith sources that caused a lack of correlation of iron, manganese, and phosphorus with suspended sediment in the April flood could also have been present during the March flood, but their effect would have been obscured by the larger suspended-sediment contribution from the regolith.

### Discrepancies in Lead Data

Although differences in sediment yield among basin types are sufficient to confirm the regolith as the predominant source of iron, manganese, and phosphorus in the March flood and its nonpredominance in the April flood, these differences do not explain the higher ratio of lead to suspended sediment during the April floods (table 2). The differences in ratios of lead to suspended-sediment concentration between the two floods would require a much larger nonregolith source of lead in the April flood than in the March flood. Such a source might be expected to result from increased industrial discharges or increased nonpoint contributions of dissolved lead. Either

source would presumably be controlled by geography; for example, periodic industrial discharges would be expected downstream from Glens Falls, which is also the point at which terranes of differing composition meet. The regolith sources of lead were not clearly restricted to either type of subbasin during the April flood; approximately 60 percent of the lead transported past Waterford during the April flood was also transported past Glens Falls, and the relative contributions of lead at Waterford and Glens Falls are in direct proportion to the drainage areas of the two sites despite the large differences in geology and population distribution of these two subbasins. Therefore, the large fraction of lead derived from sources other than the regolith cannot be attributed to a localized geologic or anthropogenic source; therefore, the source must be variable because it seems to have had no effect at either of the two sites sampled during the March flood. Precipitation would be a suspected source, but changes in the lead content in precipitation in this region (U.S. Geological Survey, 1978) indicate that less lead was contributed during the April flood than during the March flood. At this time it is not possible to attribute the anomalous lead data to any particular cause.

Table 6.--Linear, least-squares regression relationships for hypothetical data sets shown in table 5

<i>y</i>	<i>m</i> (micrograms per gram)	<i>b</i> (micrograms per liter)	<i>n</i>	<i>r</i>	<i>P</i>
Iron	28,200	3,600	5	1.00	<0.001
Manganese	557	82	5	.97	< .01
Lead	33	7	5	.33	> .1
Phosphorus	640	0.7	5	.84	< .1
Iron	46,600	69	4	1.00	<0.001
Manganese	990	-8.5	4	.99	< .01
Lead	-40	19	4	-.14	> .1
Phosphorus	740	-0.05	4	.99	< .01

*y* = dependent variable

*m* = slope of regression line  
( $\mu\text{g/g}$ )

*b* = intercept of regression line  
with *y*-axis ( $\mu\text{g/L}$ )

*n* = number of data sets for each  
flood at each site

*r* = correlation coefficient

*P* = probability that *r* will be equaled  
or exceeded in *n* pairs of randomly  
selected data pairs for unrelated  
variables

## CONCLUSIONS

Runoff from precipitation or snowmelt varies in intensity and originates from subbasins of various rock types within the Hudson River basin; therefore, water during high flows varies in chemical composition from flood to flood. Areas containing shale bedrock may contribute as much as 20 times more suspended sediment per given runoff intensity than crystalline subbasins. Sediment yields that originate mainly in the shale subbasins contain concentrations of iron, manganese, and phosphorus that can be predicted from the suspended-sediment concentrations of the Hudson river. In contrast, river discharges originating from crystalline subbasins contain less suspended sediment and therefore show little correlation between these elements and suspended-sediment concentration.

Lead and PCB concentrations cannot be consistently predicted from suspended-sediment concentrations of water from shale subbasins because these substances are also contributed from sources other than the basin regolith. PCB concentrations may be related to the inhomogeneous distribution of PCB's in the bottom materials of the river as a result of former point discharges. The various basin sources of lead are not known.

Samples collected from two different floods at the same sites, 1 month apart, and during comparable discharges, differed greatly in chemical composition. These differences result either from obvious natural causes or man-induced causes. Additionally, these short-term variations may be larger than the changes expected from many current pollution-abatement programs. Therefore, if a program for sampling during periods of high discharge is used to develop a data base for evaluating long-term changes in water quality, only data sets in which the water has originated from areas of similar geography or geologic terrane should be compared.

Results of this study suggest that comparison of chemical concentration in river water with suspended-sediment concentrations and with natural concentrations within the regolith may be a useful technique in river-basin reconnaissance. Basins in which such indices are comparable are those relatively unaffected by anthropogenic sources of substances such as those studied here, at least during periods of high discharge. Lack of agreement among these indices should be interpreted as an indication of additional supply processes within the basin.

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