Appraisal of Stream Sedimentation in the Susquehanna River Basin

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1532-F

Prepared in cooperation with the Pennsylvania Department of Forests and Waters, Pennsylvania Department of Agriculture, State Soil and Water Conservation Commission, and the U.S. Army Corps of Engineers, Baltimore District

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By KENNETH F. WILLIAMS *and* LLOYD A. REED

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1972

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

W. A. Radlinski, *Acting Director*

Library of Congress catalog-card No. 77-184626

For sale by the Superintendent of Documents, U.S. Government Printing Office
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Stock Number 2401-1228

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By Kenneth F. Williams and Lloyd A. Reed

ABSTRACT

The Susquehanna River presently transports about 3.0 million tons of sediment annually (110 tons per square mile). Only about 1.8 million tons of sediment enters the head of Chesapeake Bay annually because some sediment is trapped behind the power dams on the lower Susquehanna. Measured annual sediment yields from subbasins in the Susquehanna range from 40 to 440 tons per square mile. The highest yields are from parts of the glaciated section of the basin, in the anthracite coal region, and the Piedmont province. The lowest yields are from parts of the glaciated section of the basin and the Appalachian high plateau.

Available data indicate that there has been a downward trend of sediment discharge in recent years. In the future, the high sediment yields associated with urbanization may offset this present downward trend.

INTRODUCTION

The Pennsylvania Department of Forests and Waters, the Baltimore District of the U.S. Army Corps of Engineers, and the Pennsylvania Department of Agriculture cooperated with the U.S. Geological Survey in a reconnaissance study of fluvial sedimentation in the Susquehanna River basin. The project is part of a study by State and Federal agencies to provide a comprehensive plan for the development and conservation of the water and related land resources of the Susquehanna River basin.

Adequate stream-sedimentation information is one of the many requirements for proper utilization of water and related land resources. Stream-sedimentation information is used to predict the usable life of on-stream reservoirs, to aid design of future domestic and industrial water supplies, to guide the selection of good water-recreation sites, and to help define the suitability of the aquatic environment for fish.

This report describes the sediment yields throughout the basin, the variability and characteristics of sediment, the suspended-sediment concentrations, potential reservoir-sedimentation problems that may occur in the basin, and trends in sediment discharge. The report also points out potential problem areas where extensive sediment studies may be required.

Geologic, hydrologic, and other environmental controls over stream sedimentation are considered. Each physiographic province in the basin is considered as a separate entity which has unique erosion and resultant stream-sedimentation characteristics.

Much of the data used was collected between 1962 and 1967 at long-term U.S. Geological Survey stream-gaging stations having drainage areas of 100–800 square miles. In addition, data from independent studies in the basin were used to supplement data obtained during the reconnaissance study.

PREVIOUS SEDIMENT INVESTIGATIONS

The results of stream-sedimentation studies conducted in terrains similar to the Susquehanna River basin are included in reports on the Potomac and Delaware River basins by Wark, Keller, and Feltz (1961) and Wark and Hall (1959) respectively. The Potomac and Delaware River basin reports discussed average-annual sediment yield of streams, some of the variables causing excess stream sedimentation, and the particle-size distribution of suspended sediment.

Reservoir-sedimentation surveys for 16 reservoirs (U.S. Department of Agriculture, 1969) are included in this report to show storage-capacity losses in reservoirs in and near the Susquehanna basin.

Culbertson (1957) and Jones (1964 and 1966) reported on the sedimentation characteristics of several small agricultural basins in the central and north-central parts of the Susquehanna River basin. These studies evaluated the effects of conservation practices on hydrology and sedimentation in these basins.

McCarren, Wark, and George (1964) presented evidence of the effects of coal mining and processing on sediment yields from a small area in the upper Swatara Creek basin. That report describes the long-term changes in stream-sediment concentration that took place as coal mining and processing decreased in the early 1950's.

Schuleen and Higgins (1953) reported sedimentation rates in the Safe Harbor Reservoir and discussed the quantity and nature of sediment transported by the Susquehanna River into the reservoir during the period from 1948 to 1953.

Williams and George (1968) presented a progress report on sedimentation in the Susquehanna River basin using data collected through September 1965.

Measurements of suspended-sediment discharge obtained during other studies were available for several sites in the Susquehanna River basin. The longest continuous record was for the Juniata River at Newport, Pa., where daily measurements of suspended-sediment discharge were begun in January 1951. These data were collected as a part of the U.S. Geological Survey program to define the long-term variation of stream sedimentation in selected river basins throughout the United States. All available suspended-sediment data for the Susquehanna River basin appear in the annual series of U.S. Geological Survey water-supply papers entitled "Quality of Surface Water of the United States" or in "Water Resources Data for Pennsylvania—Part 2, Water Quality Records," (available from U.S. Geol. Survey, Harrisburg, Pa.) which replaced the water-supply papers in 1964.

DEFINITION OF TERMS

Bedload. Sediment that moves along in almost continuous contact with the streambed. Individual particles move by sliding, rolling, or skipping.

Bed material. The sediment mixture of which the streambed is composed.

Clay. Sediment particles with a mean diameter smaller than 0.004 mm (millimeter).

Fluvial sediment. Fragmentary material that originates from the weathering of rocks and is transported by, suspended in, or deposited from water.

Sand. Sediment particles with a mean diameter between 0.062 and 2.0 mm.

Sediment discharge. The quantity of sediment, expressed as dry weight, that is carried past a stream cross section in a unit of time. The unit of time may be a short measurement interval, a day, a month, a year, or some other period. Although some sediment is not sampled in the zone near the bed, the unmeasured component of the total sediment discharge is assumed to be small.

Sediment load. The sediment that is being moved by a stream. Load refers to the material itself and not to the quantity being moved.

Sediment yield. The sediment outflow from a drainage basin at a given location in a specified period of time. The sediment yield is the average-annual sediment discharge from the drainage basin, expressed in tons per square mile per year.

Silt. Sediment particles with a mean diameter between 0.004 and 0.062 mm.

Specific weight. The ovendry weight of sediment per unit volume of deposit in place.

Suspended-sediment concentration. A ratio of the sediment to the water-sediment mixture, expressed as milligrams per liter.

Trap efficiency. The percentage of inflowing sediment that is retained in a reservoir.

THE BASIN

The Susquehanna River, which empties into the Chesapeake Bay, drains the largest basin along the east coast of the United States. The river drains an area of 27,500 sq mi (square miles) in the States of New York, Pennsylvania, and Maryland.

Four physiographic provinces lie within the Susquehanna River basin (fig. 1): (1) the Appalachian Plateaus, (2) the Valley and Ridge, (3) the Blue Ridge, and (4) the Piedmont (Fenneman, 1938). The Appalachian Plateaus can be divided into a low section in the northeast and a high section in the southwest. Continental glaciation on the northeastern section (the low plateau) of the Appalachian Plateaus has produced well-rounded hills and broad flat valleys. Much of the southwestern section (the high plateau) was not glaciated and is characterized by flat-topped mountains having deeply incised narrow stream valleys. The plateau is underlain by horizontal strata, as only minor folding and faulting occurred in the area. The Valley and Ridge province, which encompasses most of the middle third of the basin, is characterized by steep mountains and ridges separated by broad valleys. The structure in the Valley and Ridge province is the result of extensive folding, faulting, and crushing of the formations, followed by erosion that cut valleys in the soft formations and left the hard strata as mountains.

Only a very small part of the mountainous Blue Ridge province lies within the Susquehanna River basin. The Piedmont province, which begins about 10 mi south of Harrisburg, Pa., contains terrain that is gently rolling to hilly. It consists of both upland and lowland. The lowland is underlain by limestone, sandstone, and shale, and the upland is underlain by crystalline rocks.

CLIMATE AND PRECIPITATION

The climate in the Susquehanna River basin is considered to be moderate. The length of the growing season ranges from about 120 to 200 days, and the average is about 150 days. The growing season

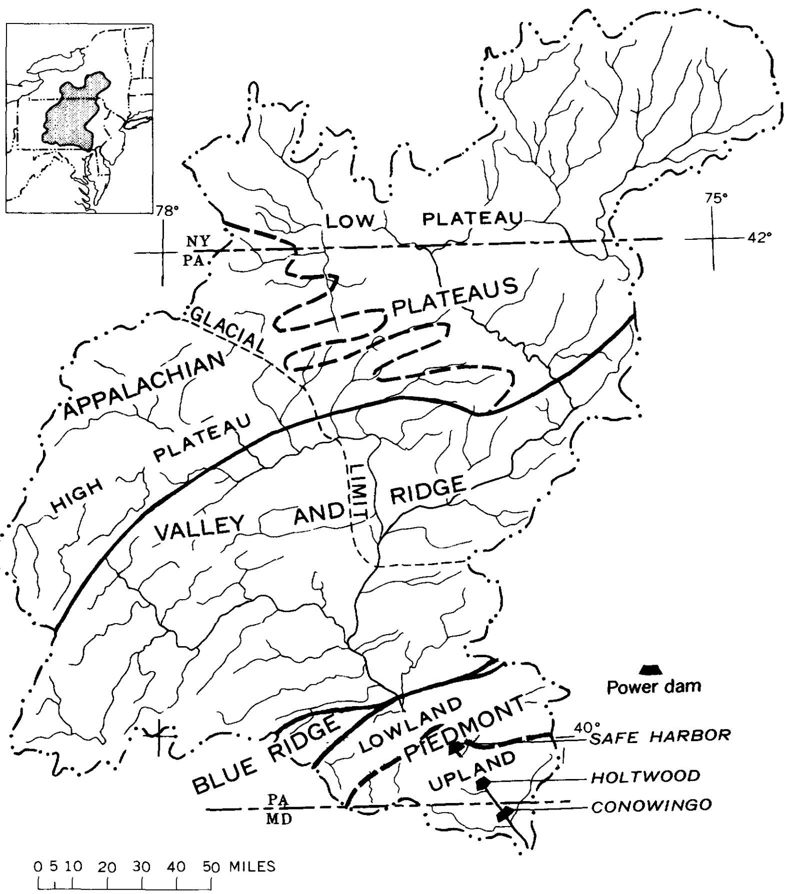

FIGURE 1.—Physiographic provinces of the Susquehanna River basin. (From Fenneman, 1938.)

is shortest in parts of the Appalachian Plateaus and is longest near the mouth of the Susquehanna (Johnson, 1960; Kauffman, 1960).

Average annual precipitation ranges from 32 inches in the northwestern part of the basin to 44 inches in the southern and east-central parts. The basin as a whole receives approximately 40 inches of precipitation in an average year. About half of the annual precipitation eventually returns to the ocean as streamflow. The remaining water provides moisture for vegetal growth and is transpired or evaporates directly to the atmosphere. Relatively little water is consumed by industrial processes in the basin.

LAND USE

In the Eastern United States, climate, parent material, and topography have influenced the soil and the use of the land for many decades. Where the soils were productive, the flat to rolling countryside was cleared and cultivated. Forests occupy most of the areas where the soils are unproductive or the topography is too steep for cultivation.

Land use in the different physiographic provinces within the Susquehanna River basin in 1967 is summarized in table 1. The small part of the Blue Ridge province within the basin is included with the Valley and Ridge province.

The major bituminous coal fields within the Susquehanna basin are in the unglaciated section of the Appalachian high plateau. The major fields are in the southwestern part of this plateau, although some coal is mined in the headwaters of the Tioga River basin and along the southern section of the Juniata River basin.

The anthracite coal fields in the basin are in the Valley and Ridge province east of the Susquehanna River and north of Blue Mountain. Spoil banks, old mine-waste piles, and the wastes of old abandoned anthracite coal-processing plants provide a source of fine sediments.

AVERAGE-ANNUAL SEDIMENT YIELD

Sediment yields have been calculated for 42 stations in the Susquehanna River basin. Data at 33 of the stations were obtained for this study. The measuring stations and the corresponding average-annual sediment yields are shown in figure 2 and are summarized in table 2.

Figure 3 indicates the generalized average-annual sediment yields from subbasins larger than 100 sq mi in the Susquehanna basin. The ranges shown were developed from the measured sediment yields and from sediment-yield data for river basins adjacent to the Susquehanna. The generalized sediment yields shown in figure 3 are discussed in the following text by physiographic provinces, starting with the northernmost province, the Appalachian Plateaus.

APPALACHIAN PLATEAUS

The province having the widest range of sediment yields is the Appalachian low plateau province, where yields range from 40 tons

TABLE 1.—*Land use in the Susquehanna River basin, 1967*

Physiographic province	Percentage of basin	Land use (percentage of land area)			
		Forest[1]	Grass[2]	Cultivated[2]	Urban[2]
Piedmont	7	25	33	34	8
Valley and Ridge	37	57	19	18	6
Appalachian high plateau	56	76	12	9	3
Appalachian low plateau		46	29	21	4

[1] U.S. Forest Service (written commun., 1966).
[2] U.S. Soil Conservation Service (written commun., 1966).

TABLE 2.—*Summary of average-annual sediment yields in the Susquehanna River basin*

Map reference No.	Station	Drainage area (sq mi)		Physiographic province	Land use (percentage of land area)				Average-annual sediment yield	
		Total	Contributing[1]		Forest[2]	Cultivated[3]	Grass[3]	Urban[3]	Tons	Tons per sq mi
1	Susquehanna River at Unadilla, N.Y.	984	907	Appalachian low plateau	41	30	24	5	60,000	66
2	Unadilla River at Rockdale, N.Y.	518	518	do	39	29	27	5	21,000	40
3	Susquehanna River at Conklin, N.Y.	2,240	2,160	do	42	25	28	5	170,000	79
4	Chenango River at Greene, N.Y.	598	598	do	46	9	42	3	30,000	50
5	Owego Creek near Owego, N.Y.	186	186	do	45	16	34	5	13,000	70
6	Susquehanna River near Waverly, N.Y.	4,780	4,500	do	43	18	34	5	680,000	150
7	Corey Creek near Mainesburg, Pa.	12.2	12.2	do	27	6	66	1	1,580	130
8	Elk Run near Mainesburg, Pa.	10.2	10.2	do	33	7	59	1	1,340	130
9	Tioga River at Tioga, Pa.	282	282	Appalachian low and high plateaus	64	9	19	8	40,000	140
10	Crooked Creek at Tioga, Pa.	122	122	Appalachian high plateau	54	14	28	4	14,000	110
11	Tioga River at Lindley, N.Y.	770	770	Appalachian low and high plateaus	61	13	21	5	92,000	120
12	Canisteo River at West Cameron, N.Y.	342	320	Appalachian low plateau	48	27	23	2	140,000	440
13	Tioga River near Erwins, N.Y.	1,370	1,320	do	54	20	22	4	250,000	190
14	Cohocton River near Campbell, N.Y.	472	440	do	42	27	29	2	61,000	140
15	Chemung River at Chemung, N.Y.	2,530	2,450	do	48	25	23	4	370,000	150
16	Susquehanna River at Towanda, Pa.	7,797	7,440	do	--	--	--	--	1,100,000	150
17	Tunkhannock Creek near Tunkhannock, Pa.	383	383	do	53	25	19	2	39,000	100
18	Fishing Creek near Bloomsburg, Pa.	274	274	Valley and Ridge	54	23	19	4	26,500	97
19	Susquehanna River at Danville, Pa.	11,220	10,840	Appalachian Plateaus and Valley and Ridge	--	--	--	--	1,500,000	140
20	West Branch Susquehanna River at Bower, Pa.[4]	315	315	Appalachian high plateau	77	10	10	3	38,000	120

See footnotes at end of table.

TABLE 2.—*Summary of average-annual sediment yields in the Susquehanna River basin*—Continued

Map reference No.	Station	Drainage area (sq mi) Total	Drainage area (sq mi) Contributing[1]	Physiographic province	Land use (percentage of land area) Forest[2]	Cultivated[3]	Grass[3]	Urban[3]	Average-annual sediment yield Tons	Tons per sq mi
21	Driftwood Branch Sinnemahoning Creek at Sterling Run, Pa.	272	272	Appalachiain high plateau	96	1	2	1	18,000	66
22	Spring Creek near Axemann, Pa.	87.2	87.2	Valley and Ridge	33	--	--	--	9,600	110
23	Bald Eagle Creek at Milesburg, Pa.	265	265	do	--	--	--	--	24,000	91
24	Bald Eagle Creek at Blanchard, Pa.	339	339	do	44	26	21	9	27,000	80
25	Marsh Creek at Blanchard, Pa.	44.1	44.1	do	59	--	--	--	4,000	91
26	Pine Creek at Cedar Run, Pa.	604	604	Appalachian high plateau	75	8	15	2	45,000	75
27	West Branch Susquehanna River at Lewisburg, Pa.	6,847	6,510	Appalachian high plateau and Valley and Ridge	--	--	--	--	500,000	77
28	Penns Creek at Penns Creek, Pa.	301	301	Valley and Ridge	65	15	17	3	23,000	76
29	East Mahantango Creek near Dalmatia, Pa.	162	162	do	33	26	35	6	45,000	280
30	Juniata River at Huntingdon, Pa.	816	816	do	71	10	12	7	51,000	62
31	Dunning Creek at Belden, Pa.	172	172	do	65	--	--	--	10,000	58
32	Raystown Branch Juniata River at Saxton, Pa.	756	756	do	69	14	14	3	68,000	90
33	Kishacoquillas Creek at Reedsville, Pa.	164	164	do	59	--	--	--	10,000	61
34	Juniata River at Newport, Pa.	3,354	3,354	do	66	14	17	3	264,000	79
35	Bixler Run near Loysville, Pa.	15.0	15.0	do	52	16	29	3	1,000	67
36	Sherman Creek at Shermans Dale, Pa.	200	200	do	57	19	20	4	17,000	85
37	Susquehanna River at Harrisburg, Pa.	24,100	23,400	Appalachian Plateaus and Valley and Ridge	--	--	--	--	2,600,000	110
38	Yellow Breeches Creek near Camp Hill, Pa.	216	216	Valley and Ridge and Blue Ridge	31	30	32	7	28,000	130

39	Swatara Creek at Harper Tavern, Pa.[5]	337	337	Valley and Ridge	35	23	32	10	73,000	220
40	West Conewago Creek near Manchester, Pa.	510	510	Piedmont Lowland	22	34	41	3	110,000	220
41	South Branch Codorus Creek near York, Pa.	117	74	Piedmont Upland	20	40	37	3	26,000	350
42	Conestoga Creek at Lancaster, Pa.	324	324	Piedmont Lowland	27	34	28	11	57,000	180

[1] Excluding drainage above large lakes.
[2] U.S. Forest Service (written commun., 1966).
[3] U.S. Soil Conservation Service (written commun., 1966).
[4] Bituminous coal mining in basin.
[5] Anthracite coal mining and processing in upper basin.

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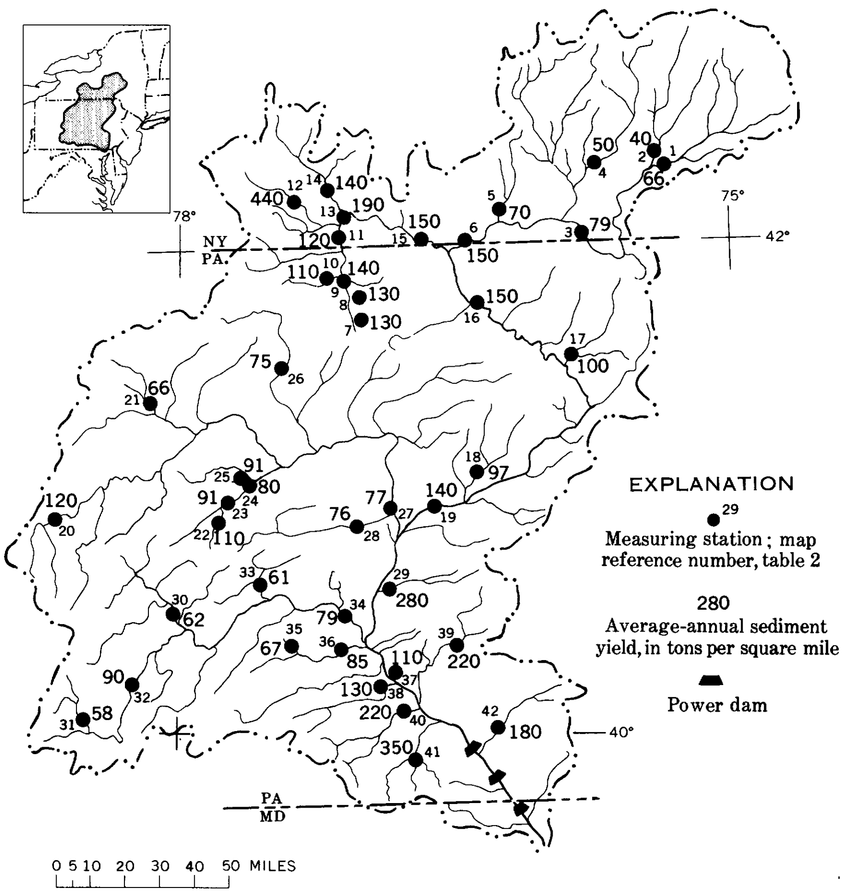

Figure 2.—Average-annual sediment yields at stations in the Susquehanna River basin.

per sq mi for the Unadilla River at Rockdale, N.Y., to 440 tons per sq mi for the Canisteo River at West Cameron, N.Y. In areas where the glacial advance and retreat left broad flat valleys, sediment yields are low; where the glacial activity was low and the stream valleys are narrow and steep, sediment yields are high.

Three different sediment-yielding areas are found in the Appalachian low plateau province (fig. 3): (1) a low-yielding area where sediment yields range from 40 to 100 tons per sq mi, (2) an area where sediment yields range from 100 to 200 tons per sq mi, and (3) a high-yielding area where sediment yields are greater than 200 tons per sq mi.

Sediment yields were measured at three stations in the Appalachian high plateau. Measured sediment yields range from 66 tons per sq mi

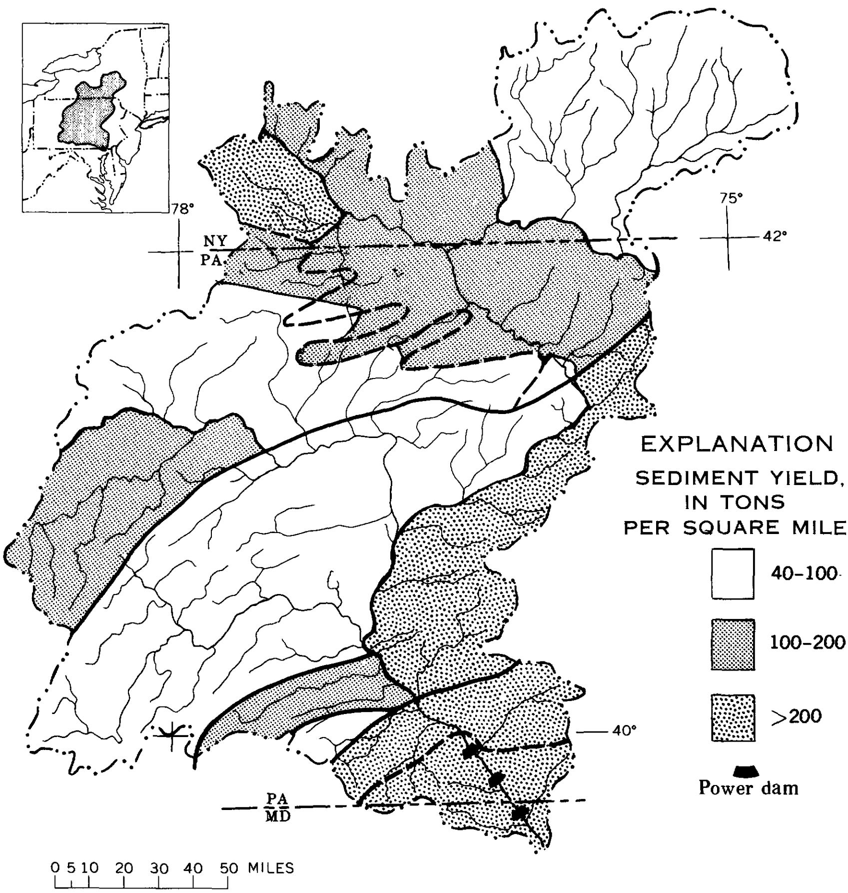

FIGURE 3.—Generalized average-annual sediment yields of drainage areas larger than 100 sq mi in the Susquehanna River basin.

for the Driftwood Branch Sinnemahoning Creek at Sterling Run, Pa., to 120 tons per sq mi for the West Branch Susquehanna River at Bower, Pa. The extensive forest cover and soils derived from the sandstones in this province limit the amount of fine material available to streams.

Sediment yields do not seem to be high even in areas of the high plateau where strip mining has exposed large quantities of material in the bituminous coal fields. They probably do not exceed 200 tons per sq mi, as indicated by data for the West Branch Susquehanna River at Bower. Apparently much of the erodible exposed material is carried into strip pits and other internal drainage and never reaches the stream.

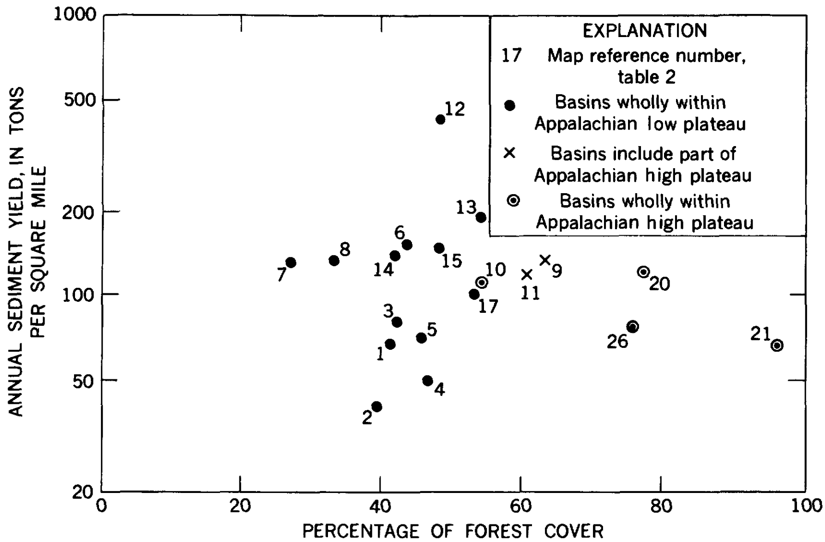

FIGURE 4.—Effect of forest cover on sediment yields in the Appalachian Plateaus.

No good correlation between sediment yield and land use, expressed as percentage of forest cover (fig. 4), exists for the Appalachian Plateaus section of the Susquehanna River basin. Geology and topography appear to be the major factors controlling the sediment yield, but they are difficult to define quantitatively; thus, sediment-yield predictions beyond the generalized predictions shown in figure 3 are difficult to make for subbasins in this part of the Susquehanna. If sediment could significantly affect a water-resources project in this area, a thorough sediment study should be undertaken.

VALLEY AND RIDGE

Sediment yields were measured at 15 stations in the Valley and Ridge province. Measured annual sediment yields range from 58 tons per sq mi for Dunning Creek near Belden, Pa., to 280 tons per sq mi for East Mahantango Creek near Dalmatia, Pa. The Valley and Ridge province can be divided into three sediment-yielding areas—one having low sediment yields, one having moderate yields, and one having high yields (fig. 3). In the low-yielding area, which comprises most of the Valley and Ridge, sediment yields are generally less than 100 tons per sq mi. The high-yielding area is east of the Susquehanna River and extends from the Scranton and Wilkes-Barre area south to the southern limit of the Valley and Ridge. Here sediment yields are influenced by the coal-processing activities and average greater than 200 tons per sq mi. In the moderate area, which includes

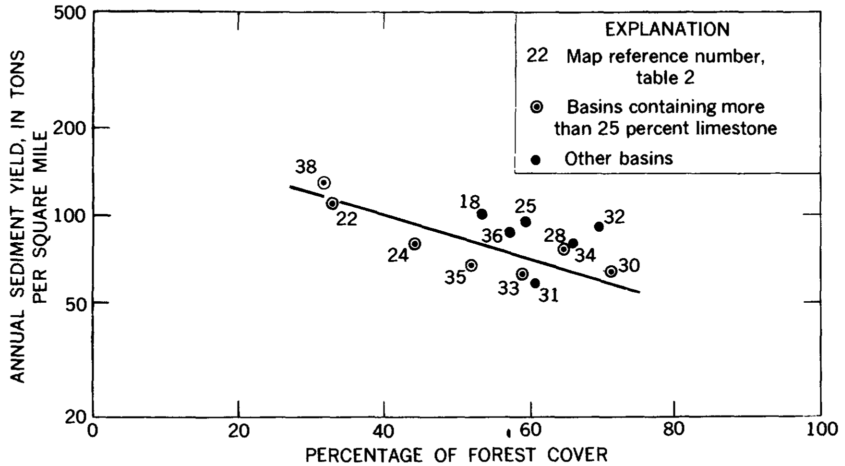

Figure 5.—Significance of forest cover and geology on sediment yields in the Valley and Ridge province.

parts of the Conodoguinet and Yellow Breeches Creek basins, sediment yields range from 100 to 200 tons per sq mi (fig. 3).

Analysis of the Valley and Ridge data suggests that the sediment yields from basins having 25 percent or more limestone terrane are considerably lower than yields from other areas in this province that are similar with respect to land use (fig. 5). The lower slopes characteristic of limestone terrane may result in less erosion; however, the most significant factor contributing to the lower yields is internal drainage, which is characteristic of limestone terrane.

Figure 5 applies only to areas unaffected by anthracite coal mining and processing. Sediment yields from basins affected by mining depend on the amount of coal processed in the basin and on the methods used to dispose of the fine material. Thorough sediment studies should be undertaken in areas where sediment from anthracite mining could be a significant problem to a planned water-resources project.

BLUE RIDGE

No sediment-yield data are available for the very small part of the Blue Ridge province within the Susquehanna River basin. However, sediment yields from this heavily forested part of the basin are probably similar to those of the Appalachian high plateaus.

PIEDMONT

Measured sediment yields in the Piedmont Lowland range from 180 to 220 tons per sq mi. Sediment yields in the Piedmont Upland probably average less than the yield of 350 tons per sq mi reported for the South Branch Codorus Creek near York, which was the only sediment station established in the area. The estimated average sediment yield is about 300 tons per sq mi, as most of the upland is somewhat less subject to erosion than the Codorus Creek basin. The upland yields are significantly greater than lowland yields because the slopes generally are steeper, and the soils developed on the crystalline rocks are more erodible. Consideration should be given to sediment accumulation when designing water-resources projects in this area, especially in planning reservoirs having a small capacity-inflow ratio.

SUSPENDED-SEDIMENT CONCENTRATION

The presence of suspended sediment often creates problems for water users and water-resources planners. It increases water-treatment costs and may limit the recreational potential of a stream. Therefore, knowledge of the frequency distribution of suspended-sediment concentrations should be useful to water users and water-resources planners.

The frequency distribution of suspended-sediment concentrations at stations having sufficient data is summarized in table 3. Since most water users withdraw a fairly constant amount of water throughout the year, they are interested in prevalent sediment concentrations.

The data presented in table 3 indicate that two Piedmont streams, the South Branch Codorus Creek and the Conestoga Creek, characteristically have higher suspended-sediment concentrations during

TABLE 3.—*Frequency distribution of suspended-sediment concentrations in Pennsylvania*

Station	Period of record	Mean daily concentration, in milligrams per liter, that was equaled or exceeded for indicated percentage of time												
		2	5	10	20	30	40	50	60	70	80	90	95	98
Fishing Creek near Bloomsburg	Oct. 1, 1966–Sept. 30, 1967	50	27	14	7	5	5	4	3	3	2	2	2	1
Juniata River at Newport	Oct. 1, 1951–Sept. 30, 1967	180	90	45	25	15	11	8	6	4	3	2	2	1
Bixler Run near Loysville	Oct. 1, 1954–Sept. 30, 1967	110	45	24	14	11	8	7	6	5	4	3	2	2
Susquehanna River at Harrisburg	Oct. 1, 1963–Sept. 30, 1967	140	76	46	27	18	11	7	5	4	3	2	1	1
South Branch Cordorus Creek near York	Oct. 1, 1966–Sept. 30, 1967	400	180	55	34	27	22	18	16	13	11	8	6	5
Conestoga Creek at Lancaster[1]	Jan. 1962–Sept. 1964	250	160	120	85	60	45	40	30	20	15	10	9	6

[1] Synthesized from periodic data.

periods of low flow than the streams in the Valley and Ridge. Observations suggest that higher concentrations during low flow also occur in the other Piedmont streams within the Susquehanna basin as well as in the main stems of the Conodoguinet and Yellow Breeches Creeks.

The main stem of the Susquehanna River is known to have lateral variations of chemical constituents (Anderson, 1963). There are also variations in the suspended-sediment concentrations in the cross section, as summarized in table 4. Sediment concentrations, according to the data, generally are highest on the east side of the river, a fact reflecting the high sediment discharge of the North Branch Susquehanna River and East Mahantango Creek. This knowledge may permit a water user to establish fixed intakes so that he can, on the average, withdraw water that has the least suspended-sediment concentration. Of course, variations of the other constituents within the cross section will also have to be evaluated so that the optimum withdrawal point can be established.

PARTICLE SIZE OF SUSPENDED SEDIMENTS

The particle size of suspended-sediment samples was determined for most streams sampled in the Susquehanna River basin. Figure 6 summarizes the range in particle size of sediments transported by streams in each physiographic province. Because of the variation of the particle-size composition as sediment concentration and streamflow vary, only data collected during periods of peak discharge are used in the figure. Generally, from 50 to 75 percent of the annual sediment load is transported during the periods of peak stream discharge; the results shown in the figure represent a reasonable approximation of the average sediment-weighted particle-size composition. The average composition of suspended sediment is fairly consistent, being approximately 10 percent sand, 50 percent silt, and 40 percent clay.

TABLE 4.—*Variation of suspended-sediment concentrations in the cross section of the Susquehanna River at Harrisburg, Pa., October 1, 1963, to September 30, 1967*

Station	Mean daily concentration, in milligrams per liter, that was equaled or exceeded for indicated percentage of time												
	2	5	10	20	30	40	50	60	70	80	90	95	98
East channel:													
Station 300 (east bank)	210	110	60	38	25	15	10	6	4	4	3	1	1
Station 1,000	160	80	50	27	17	11	7	5	4	3	2	1	1
West channel:													
Station 400	110	60	38	22	14	9	5	4	3	2	1	1	1
Station 1,000 (west bank)	100	56	35	20	14	10	7	4	3	3	2	1	1

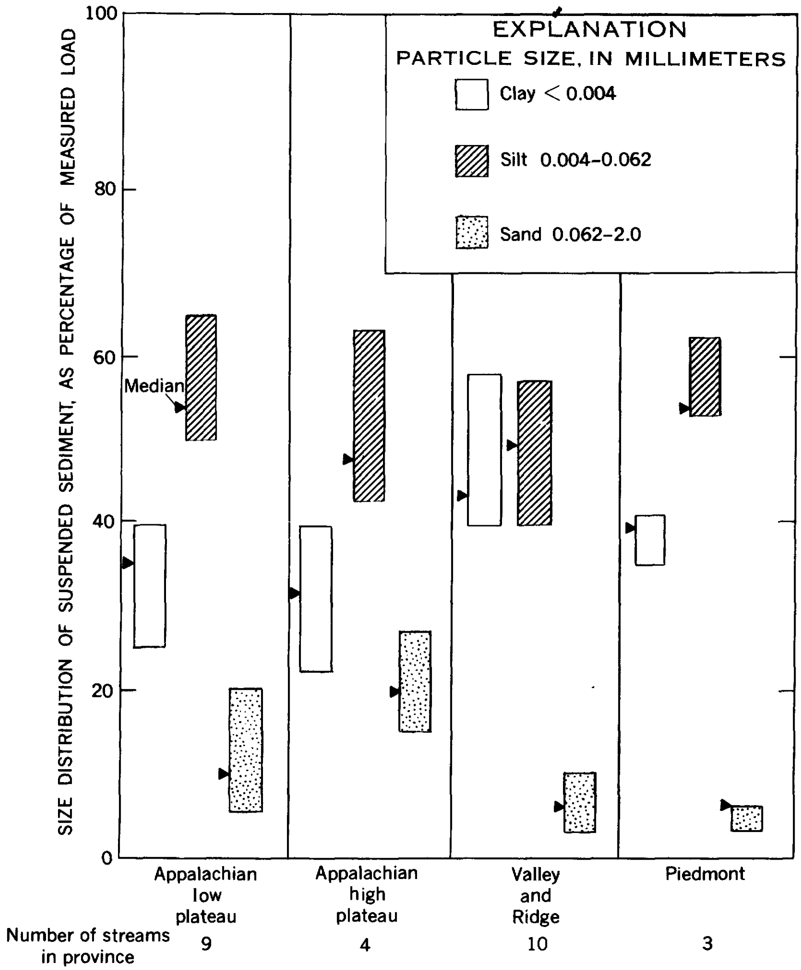

FIGURE 6.—Range in size distribution of suspended sediment transported by streams in each physiographic province.

RESERVOIR SEDIMENTATION

Although reservoir sedimentation is not a serious problem in the Susquehanna River basin, sedimentation problems can occur, and construction agencies generally allow for sediment deposition during the design life of their structures. Design curves are presented here (fig. 7) so that sediment-deposition rates in reservoirs can be predicted. These curves were developed from the relation (Brune, 1953) between trap efficiency and capacity-inflow ratio (reservoir capacity divided by average annual inflow). Sediment yields for basins larger than 100 sq mi can be estimated from figure 3.

A summary of storage-depletion rates for selected reservoirs in and adjacent to the Susquehanna River basin is given in table 5. Reservoirs were selected on the basis of the accuracy of the reservoir surveys and length of time between surveys. These data indicate that rapid depletion of the total storage capacity is not a serious problem for reservoirs having comparatively large capacity-inflow ratios; however, for reservoirs having fairly small capacity-inflow ratios, the rate of storage depletion could prove significant.

Reservoir-sedimentation problems can occur without a noticeable loss of storage capacity. As Bondurant and Livesey (1965) indicated, fairly small quantities of sediments can deplete the useful life of boat docks and other inlet facilities if inflowing sediment settles readily and fine sediments that stay suspended for long periods of time give the water a turbid appearance and make the reservoir esthetically undesirable.

SEDIMENT DISCHARGE INTO THE CHESAPEAKE BAY

Three major power dams span the Susquehanna River before it flows into the Chesapeake Bay (fig. 1). The Safe Harbor Dam,

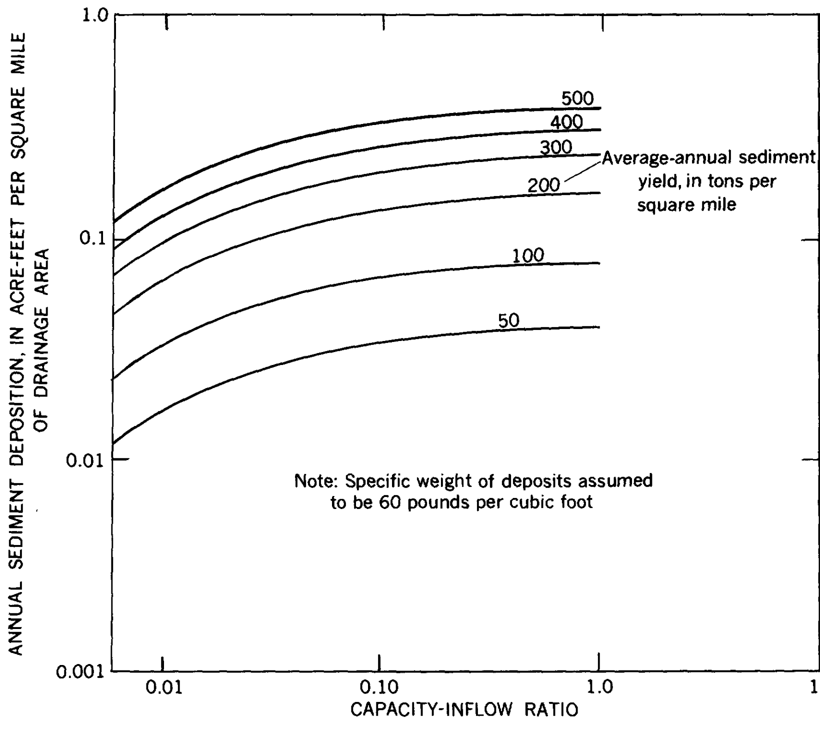

FIGURE 7.—Design curves for predicting rates of sediment deposition in reservoirs.

TABLE 5.—*Summary of selected reservoir- sedimentation surveys in and adjacent to the Susquehanna River basin*

Reservoir	Location	Sediment-contributing drainage area (sq mi)	Date of reservoir surveys	Storage capacity at spillway elevation (acre-ft)	Average annual inflow (acre-ft)	Average capacity-inflow ratio	Trap efficiency (percent)[1]	Average-annual sediment accumulation per square mile: Acre-ft	Average-annual sediment accumulation per square mile: Tons[2]	Average-annual sediment yield (tons per sq mi)	Depletion of storage capacity (percentage per 10 yr)
Susquehanna River basin											
Lake Williams	York, Pa.	42.6	1912 Apr. 1939	2,686 2,232	[3]30,400	0.08	85	0.394	421	500	6.2
Chesapeake Bay area											
Prettyboy Reservoir	Hereford, Md	77.5	Oct. 1943 Sept. 1961	60,410 59,864	[3]66,500	0.91	97	0.391	547	560	0.5
Loch Raven Reservoir	Towson, Md	219	Oct. 1943 June 1961	64,813 64,072	[3]188,000	.34	96	.187	233	240	.6
Atkisson Reservoir	Belair, Md	45.4	May 1942 May 1954	896 705	36,300	.022	62	.351	495	---	18
Delaware River basin											
Columbia Dam	Columbia, N.J.	171	July 1937 July 1957	312 244	[3]141,000	0.0022	3	0.02	28	---	11
Icedale Reservoir	Coatesville, Pa	20.0	1900 July 1951	137 106	[3]10,600	.011	45	.03	33	---	4.9
Coatesville Reservoir	Coatesville, Pa	5.0	1916 July 1951	1,019 970	2,200	.45	97	.28	305	---	1.4
Potomac River basin											
Tridelphia Lake	Ashton, Md	80.1	June 1942 Sept. 1958	20,222 19,633	[3]63,600	0.31	95	0.44	479	505	1.7

Ohio River basin											
Quemahoning Reservoir	Johnstown, Pa	90.7	Jan. 1912 Sept. 1937	35,295 34,413	[3]109,000	0.32	96	0.377	490	510	1.0
Loyalhanna Reservoir	Saltsburg, Pa.	285	June 1942 Apr. 1962	95,300 93,500	348,300	.30	95	.319	306	320	1.0
Crooked Creek Reservoir	Ford City, Pa	274	Apr. 1940 Aug. 1964	93,900 92,376	303,600	.31	95	.229	254	270	.7
Tygart River Reservoir	Grafton, W. Va	1,179	Oct. 1937 Mar. 1959	289,600 287,700	1,609,800	.18	92	.075	106	115	.3
Hudson River basin											
Schoharie Reservoir	Prattsville, N.Y.	312	Aug. 1926 May 1950	63,821 62,702	[3]442,000	0.14	90	0.166	217	240	0.8
Genesee River basin											
Lake Rushford	Caneadea, N.Y	60.7	1925 Oct. 1951	28,000 27,426	[3]62,100	0.45	97	0.37	484	500	0.8
Mount Morris Reservoir	Mount Morris, N.Y	1,011	Nov. 1951 May 1963	338,010 335,393	912,000	.37	96	.23	386	400	.7
Raritan River basin											
Carnegie Lake	Princeton, N.J	47.8	Dec. 1907 Apr. 1959	1,256 822	[3]43,500	0.024	65	0.20	[4]240	370	7.6

[1] Computed from Brune, 1953, p. 414.
[2] Density of deposited sediments assumed or reported by U.S. Department of Agriculture, 1969.
[3] Computed from nearby stream-gaging records.
[4] U.S. Geological Survey bottom samples, April 1959.

completed in 1931, is 33 miles upstream from the mouth of the Susquehanna; the Holtwood Dam, completed in 1910, is 25 miles upstream; and the Conowingo Dam, completed in 1928, is 10 miles upstream.

Using the 45-year average-annual river flow of 26,500,000 acre-ft at Holtwood, the capacity-inflow ratios (Brune, 1953) were computed for each of the reservoirs created by the power dams.

Dam	*Head*	*Approximate total storage (acre-ft)*	*Capacity-inflow ratio*	*Combined capacity-inflow ratio*
Safe Harbor	55	150,000	0.006	0.006
Holtwood	50.6	60,000	.0023	.008
Conowingo	89	300,000	.011	.019

Because the reservoirs operate in series, the combined capacity-inflow ratio for the three is 0.019 (based on a combined capacity of 510,000 acre-ft), and the combined trap efficiency (Brune, 1953) is 55 percent. In series, the individual trap efficiency for the three reservoirs is 30 percent for Safe Harbor, 8 percent for Holtwood, and 17 percent for Conowingo.

As part of a coal-recovery operation, the Pennsylvania Power & Light Co. annually dredges 1 million tons of coal-laden deposits (Levin and Smith, 1954) from the reservoir formed by Safe Harbor Dam. Reservoir-sediment surveys by the Pennsylvania Power & Light Co. indicate that 1 million tons of incoming river sediments is deposited annually, replacing the dredged material. The surveys indicate that the reservoir is in a man-induced state of dynamic equilibrium (Schuleen and Higgins, 1953). Pennsylvania Power & Light Co. surveys indicate that the reservoir formed by the Holtwood Dam has been in a state of dynamic equilibrium since the late 1940's.

The reservoir formed by the Conowingo Dam has not been surveyed; however, the trap efficiency of 17 percent would indicate that 0.2 million tons is being trapped annually. This makes the total sediment deposition in the three reservoirs 1.2 million tons per year. The remaining 1.8 million tons passes into the Chesapeake Bay.

TRENDS IN SEDIMENT DISCHARGE

There is evidence of changing sediment-discharge rates in and near the Susquehanna River basin. O'Bryan and McAvoy (1966) described a pattern of decreasing sediment loads in the basin of the Gun Powder Falls River, a tributary to the Potomac River. The long-term sediment records for Juniata River at Newport, Pa., a tributary to the Susquehanna, show a decline in the sediment-discharge rate (fig. 8). Figure 8 shows that, beginning about 1955 or 1956, a 31-

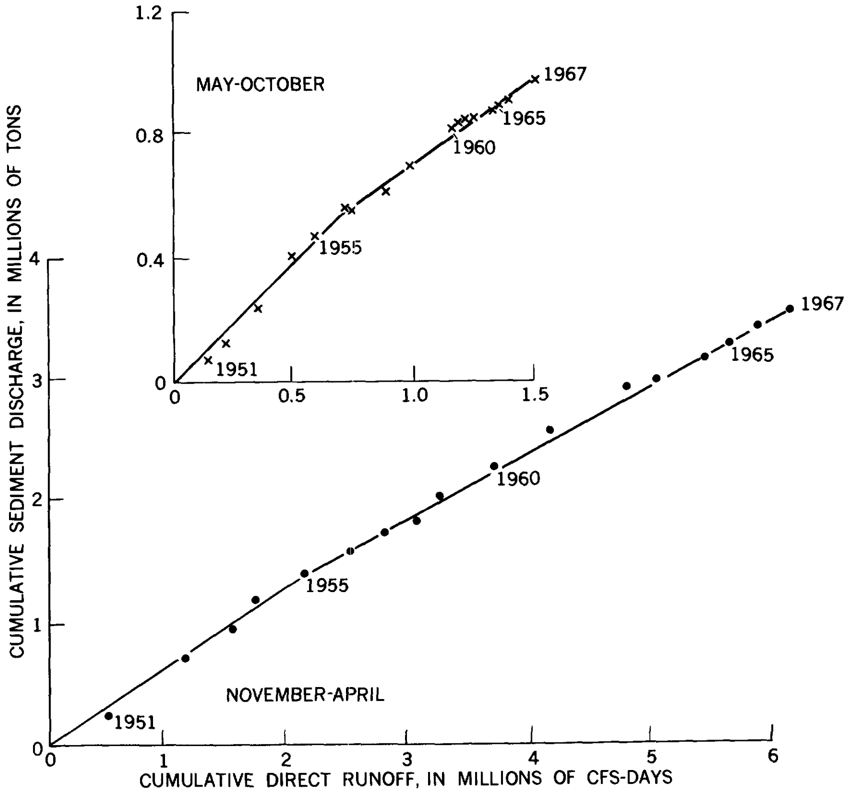

FIGURE 8.—Double-mass comparison of sediment discharge and direct runoff for Juniata River at Newport, Pa., showing decrease in sediment discharge after 1955.

percent reduction in the sediment discharge occurred in the period from May through October, and a 24-percent reduction occurred in the period from November through April. These seasonal changes amount to a 25-percent reduction in the average-annual sediment discharge. Analyses of reservoir-survey data (Schuleen and Higgins, 1953) for Lake Clarke, the lake formed by Safe Harbor Dam on the main stem of the Susquehanna south of Harrisburg, indicate that the amount of sediment discharged annually in the middle and late 1930's was at least three to four times its present level.

Several investigators (McCarren, Wark, and George, 1964; Biesecker, Lescinsky, and Wood, 1968) have noted that, as a result of decreased mining activity and stricter waste-disposal laws, sediment discharges in tributaries of the Susquehanna River from areas producing anthracite coal have decreased. Other investigators (Wolman and Schick, 1967; Vice, Guy, and Ferguson, 1969) have shown that highway and urban construction increases the sediment discharge of streams. Guy and Ferguson (1963) have shown, for example, that 1 sq mi of urbanization can contribute a sediment discharge equivalent to that from 100 sq mi of rural land in the Piedmont terrain of the Potomac River basin.

In the Susquehanna basin, problems of excessive sedimentation from urban and highway construction occur locally. However, the area affected is generally small when compared with the drainage area of the main tributaries. The decreasing sediment yields observed in the Susquehanna and some of its tributaries could be offset in the future by the high yields associated with urban and highway construction.

SUMMARY AND CONCLUSIONS

Under existing land-use and average-runoff conditions, the Susquehanna River transports about 3.0 million tons of sediment annually (110 tons per sq mi). However, only about 1.8 million tons of sediment enters the head of the Chesapeake Bay, because some sediment is trapped behind the power dams of the lower Susquehanna. Measured sediment yields range from 40 tons per sq mi to 440 tons per sq mi. The lowest sediment yields in the basin are from the Susquehanna main stem in the glaciated part of the Appalachian low plateau, the Valley and Ridge, and parts of the heavily forested Appalachian high plateaus. The highest yields are from parts of the Chemung River basin in the glaciated section of the Appalachian low plateau, the anthracite coal region, and the Piedmont. If sediment could significantly affect a water-resources project in the Appalachian low plateau, in the anthracite coal region, or in the Piedmont, thorough sediment studies should be undertaken.

Geology in the Valley and Ridge appears to be a variable that affects sediment yields, because basins containing more than 25 percent limestone have significantly lower sediment yields than basins having identical land use but containing less or no limestone. No relations were developed for the relatively small area of the Piedmont within the Susquehanna because sufficient sites were not available.

The Piedmont streams, as well as the main stems of Conodoquinet and Yellow Breeches Creeks, have significant suspended-sediment concentrations most of the time. Generally, other streams in the Susquehanna basin have such concentrations only during, and for a few days after, storm-runoff events.

The average particle-size composition of sediments transported by streams in each physiographic province is fairly consistent, being about 10 percent sand, 50 percent silt, and 40 percent clay.

Generally, reservoir sedimentation is a minor problem for all reservoirs. A few severe problems occur in reservoirs having low capacity-inflow ratios, in reservoirs constructed in areas having high sediment yields, and in reservoirs subjected to temporarily excessive sedimentation from urban and highway construction.

Continuous sediment records for Juniata River at Newport, Pa., indicate that there has been a 25-percent reduction in the sediment discharge from the Juniata River basin between 1951 and 1967. Considerable evidence exists to show that, owing to the decline of anthracite coal mining and processing, there has also been a downward trend of sediment discharge for the main stem of the Susquehanna River. In the future, the high sediment yields associated with urbanization may offset this present downward trend in sediment discharge.

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U.S. GOVERNMENT PRINTING OFFICE: 1972 O—443-561