Sediment Characteristics of Five Streams Near Harrisburg, Pennsylvania, Before Highway Construction

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1798-M

Prepared in cooperation with the Pennsylvania Department of Transportation and the State Conservation Commission, Pennsylvania Department of Environmental Resources

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By LLOYD A. REED

SEDIMENTATION IN SMALL DRAINAGE BASINS

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Multiply English units	*By*	*To obtain (SI) units*
Inch (in)	25.4	Millimetre (mm)
Foot (ft)	.3048	Metre (m)
Mile (mi)	1.609	Kilometre (km)
Acre	.4047	Square hectometre (hm^2)
Square mile (mi^2)	2.590	Square kilometre (km^2)
Ton (short)	.9072	Tonne (t)
Ton per square mile (ton/mi^2)	.3502	Tonne per square kilometre (t/km^2)
Acre-foot	1,233	Cubic metre (m^3)
Cubic foot per second (ft^3/s)	.02832	Cubic metre per second (m^3/s)
Cubic foot per second per square mile [$(ft^3/s)/mi^2$]	.0109	Cubic metre per second per square kilometre [$(m^3/s)/km^2$]
Cubic foot per second-day (ft^3/s-day)	.02832	Cubic metre per second-day (m^3/s-day)
Degree Fahrenheit (°F)	$-32\times 5/9$	Degree Celsius (°C)

SEDIMENT CHARACTERISTICS OF FIVE STREAMS NEAR HARRISBURG, PENNSYLVANIA, BEFORE HIGHWAY CONSTRUCTION

By LLOYD A. REED

ABSTRACT

Rainfall, streamflow, sediment, and turbidity data are being collected as part of a study to evaluate the effects of highway construction on sediment discharge. The study is also designed to determine the effectiveness of different erosion-control measures in reducing sediment discharges. The study area, near Enola, Pa., consists of five adjacent drainage basins, four of which will be crossed by Interstate 81. Ninety percent of the land in each of the basins is in forest or grass. Active farmland accounts for less than 10 percent, and the remainder is in roadways and buildings. The major factor affecting sediment concentrations and discharges was the construction of a one-lane roadway and a 5-acre (2 hm^2) farm pond in basin 2. Approximately 100 tons (90 t) of sediment was discharged by the stream as a result of the roadway and pond construction.

INTRODUCTION

The Pennsylvania Departments of Transportation and Environmental Resources (State Conservation Commission) and the U.S. Geological Survey are cooperating in a field study to determine the effects of highway construction on discharges and sediment concentrations of streams. The study is also designed to determine the effectiveness of different types of erosion-control measures in reducing sediment during and after construction.

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Pennsylvania Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

The study area is in Cumberland County, west of Enola, Pa., and is composed of five adjacent drainage basins (fig. 1). Four of

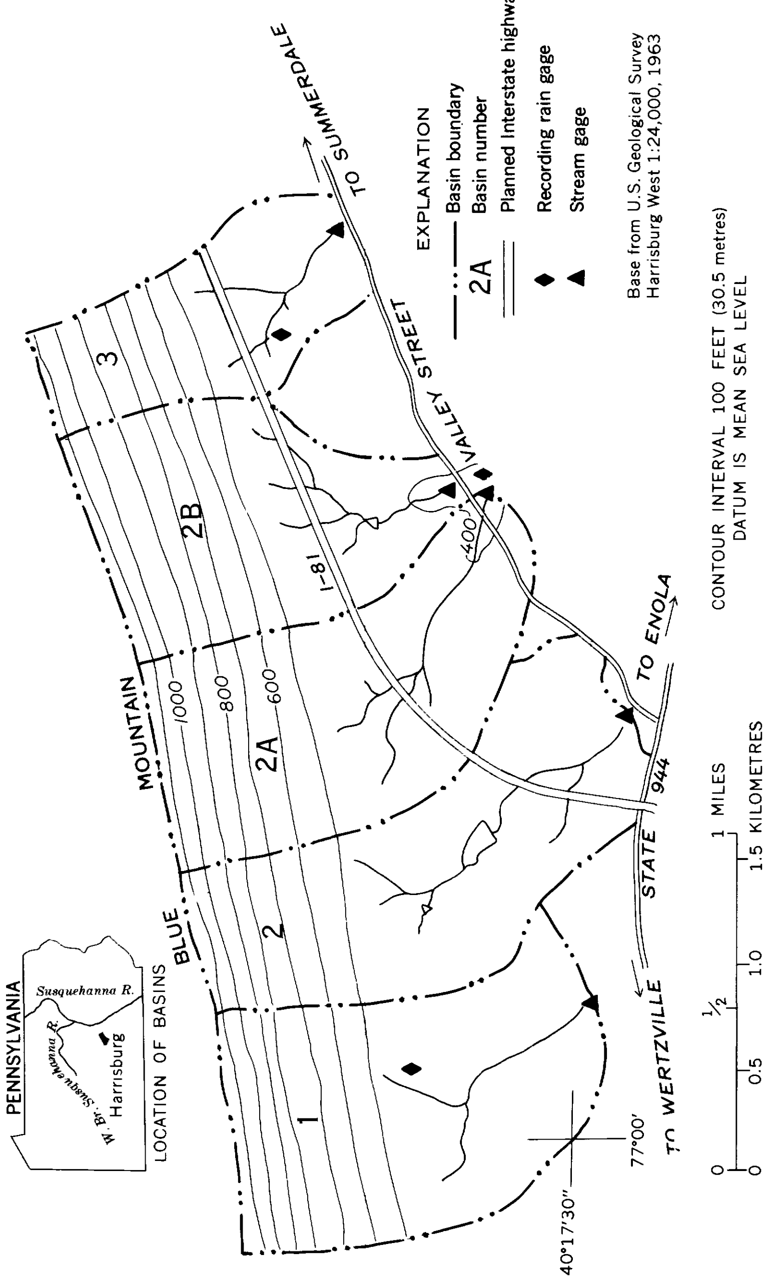

FIGURE 1.—Location of basins and data-collection sites.

the basins are being crossed by Interstate 81 (L.R. 1005, sections 2 and 3), and the fifth basin is serving as a control. In each of the four basins where the highway is being constructed, a different method of sediment control is being used. Construction began in the fall of 1972. The basins range in size from 0.38 to 0.77 mi^2 (0.98 to 2.0 km^2) and are drained by streams with headwaters near the base of Blue Mountain. Each stream is monitored near the point where it crosses State Route 944 or Valley Street.

This report presents a summary of the preconstruction data collected from October 1, 1969, to September 30, 1971, and describes the activities or characteristics in the basins that affect sediment concentrations, sediment discharges, and turbidities. The data-collection activities consist of monitoring rainfall, stream stage, and turbidity and collecting suspended-sediment samples periodically. During 1970, a 5-acre (2 hm^2) farm pond was constructed in one of the basins. Another basin has a moderate amount of developed urban area. In a third basin, a 4-foot (1.2 m) high dam forms a 0.1 acre (0.04 hm^2) pond. As many as 95 ducks and geese occupy the pond during the summer.

THE BASINS

The basins extend in a southeasterly direction from the crest of Blue Mountain (fig. 1) to the monitoring stations, an average distance of just over 1 mile (1.6 km). The average width of each basin is 0.6 mile (1 km). The basins, from west to east, are drained by Conodoguinet Creek tributaries 1, 2, 2A, 2B, and 3. Drainage areas at the monitoring stations are 0.77, 0.76, 0.70, 0.65, and 0.38 mi^2 (2.0, 2.0, 1.8, 1.7, and 0.98 km^2), respectively.

CLIMATE

Precipitation data for the study area are based on National Oceanographic and Atmospheric Administration (NOAA) records from Harrisburg and Carlisle, each with 83 years of record, and Blosserville, with 59 years of record. The weighted average annual precipitation is 40.6 inches (1,030 mm), which is near the 41.6 and 38 inches (1,060 and 960 mm) recorded in the project area for the 1970 and 1971 water years. The climate is typical of temperature zones at 40° latitude. Temperatures range from an average of 32°F (0°C) in January to 76°F (24°C) in July. Average yearly temperature is about 53°F (11.6°C). Normal maximum and minimum temperatures range from 0°F (−18°C) in January or February to 95°F (35°C) in July or August.

Precipitation is uniformly distributed throughout the year; however, it is highest from March to August when the average is 3.5 inches (89 mm) per month, and is lowest in January, February, and September, when the average is 2.6 inches (66 mm) per month.

GEOLOGY

The geologic setting of the basins is similar. Blue Mountain is underlain by shale and sandstone of the Clinton Formation and quartzitic sandstone of the Tuscarora Formation, both of Silurian age. The valley, from the base of the mountain, is underlain by shale of the Martinsburg Formation of Ordovician age.

TOPOGRAPHY

Relief ranges from relatively steep to nearly flat. Slopes on Blue Mountain average about 30 percent, some as high as 50 percent. Slopes in the valley from the base of Blue Mountain to the monitoring stations average about 4 percent. Stream slopes average about 1 percent in most of the valley area.

SOILS

Soils on Blue Mountain are classified from very stony to stony and gravelly loams. The valley soils derived from the Martinsburg Formation are mostly shaly silt loams from 1 to 5 feet (0.3 to 1.5 m) thick, though most are 2 to 3 feet (0.6 to 0.9 m) thick. The topsoil is generally 44 percent sand, 41 percent silt, and 15 percent clay. Permeability is moderate to low and the available moisture capacity is about 3 inches (76 mm).

LAND USE

Land uses in the basins are summarized in table 1. Forests, the chief land use, occupy the mountainous area and the steeper parts of the valley. Most of the flatter areas in the valley are in open fields. A few of the fields are actively farmed, but most are in permanent grassland. Residential development is light; the number of houses in the basins ranges from 6 in basin 2A to 28 in basin 3. The size and percentage of each basin in forest, grass, active farmland, roadways, and buildings are given in table 1.

PRECIPITATION

Three weighing 12-inch (300 mm) capacity rain gages having recording chart speeds of half an inch (12.7 mm) per hour are in use at locations shown in figure 1. The rain gage in basin 1 is at an elevation of 460 feet (140 m); the one near basin 2A is at 380 feet (120 m); and the one in basin 3 (fig. 2) is at 470

FIGURE 2.—Recording rain gage in basin 3, with cover removed, showing recording chart.

TABLE 1.—*Land use in basins drained by Conodoguinet Creek tributaries 1, 2, 2A, 2B, and 3, March 30, 1972*

Basin number	1	2	2A	2B	3
Area (sq mi)	0.77	0.76	0.70	0.65	0.38
Elevation at gage (feet)	425	405	380	385	415
LAND USE [Percentage of basin]					
Forest	65	54	78	85	85
Grass	29	36	12	4.5	12.3
Active farmland	5.3	9.2	9.5	9.5	0
Roadways	.4	.5	.3	.5	1.5
Buildings	.3	.3	.2	.5	1.2

feet (140 m). In general, the rainfall quantities and intensities recorded at each of the three gages are similar. The quantity of precipitation may differ considerably from basin 1 to basin 3 during intense summer storms. One such occasion was on July 2, 1970, when 1.45 inches (36.8 mm) was recorded by the gage in basin 1, 2.24 inches (56.8 mm) near basin 2A, and 2.16 inches (54.9 mm) in basin 3.

The rainfall recorded during the 1970 and 1971 water years (October 1, 1969, to September 30, 1971) is shown in figure 3.

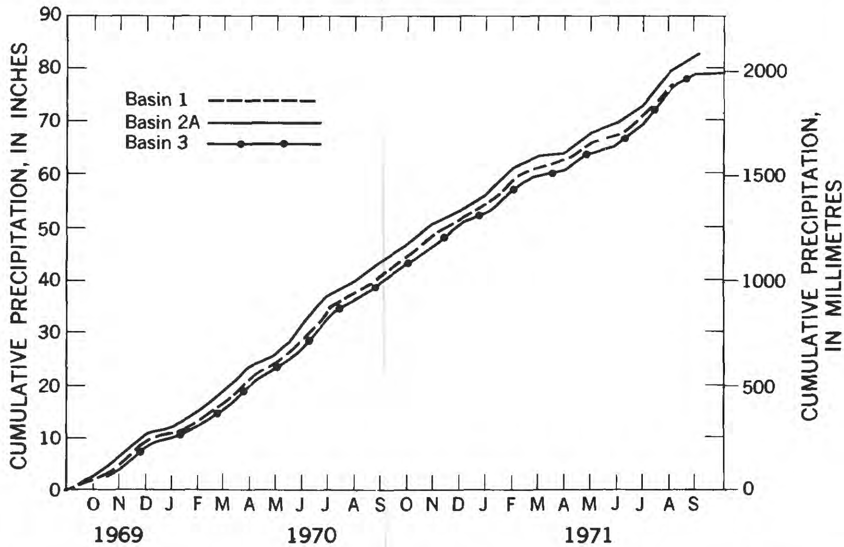

Figure 3.—Cumulative precipitation recorded in basins 1, 2A, and 3, October 1, 1969, to September 30, 1971.

During the 2-year period, 81 inches (2,050 mm) of precipitation was recorded in basin 2A and a total of 79 inches (2,000 mm) in basins 1 and 3. January 1970 and April 1971 were the driest months, having 0.60 and 0.85 inch (15 and 22 mm), respectively; and December 1969 and August 1971 were the wettest, having 4.90 and 6.60 inches (120 and 170 mm), respectively.

STREAMFLOW

Streamflow from each of the five basins is measured indirectly by continuous recorders that record stages (water levels) behind weir-flow controls. Figure 4 shows the stream draining basin 2 as it flows over the control. The figure also shows the recorders installed in the shelter adjacent to the stream. The relation between stage and flow for each stream is developed from current-meter measurements made on a regular schedule and during periods of unusual high or low flow. The streamflow is then computed by relating the recorded stages to the stage-discharge relation.

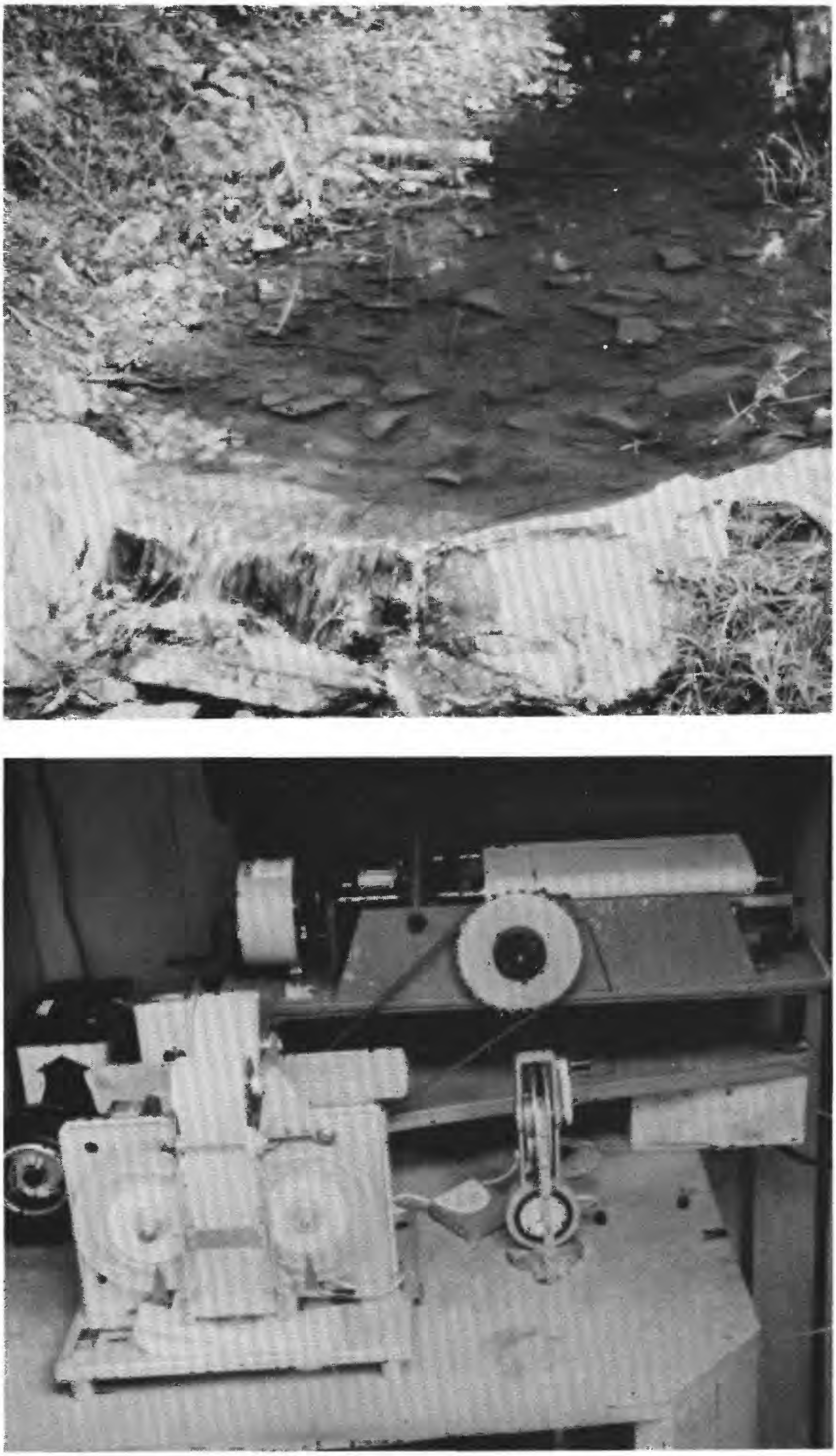

FIGURE 4.—Gage pool and stage recorders in basin 2.

Figure 5 is a graph of the cumulated monthly flow from each of the five basins for the 1970 and 1971 water years. The flow is plotted on a per square mile (sq km) basis because drainage areas differ. Figure 5 shows also the slope of the accumulation graph for flows from 0.15 to 6.0 $(ft^3/s)/mi^2$ [0.0016 to 0.065 $(m^3/s)/km^2$].

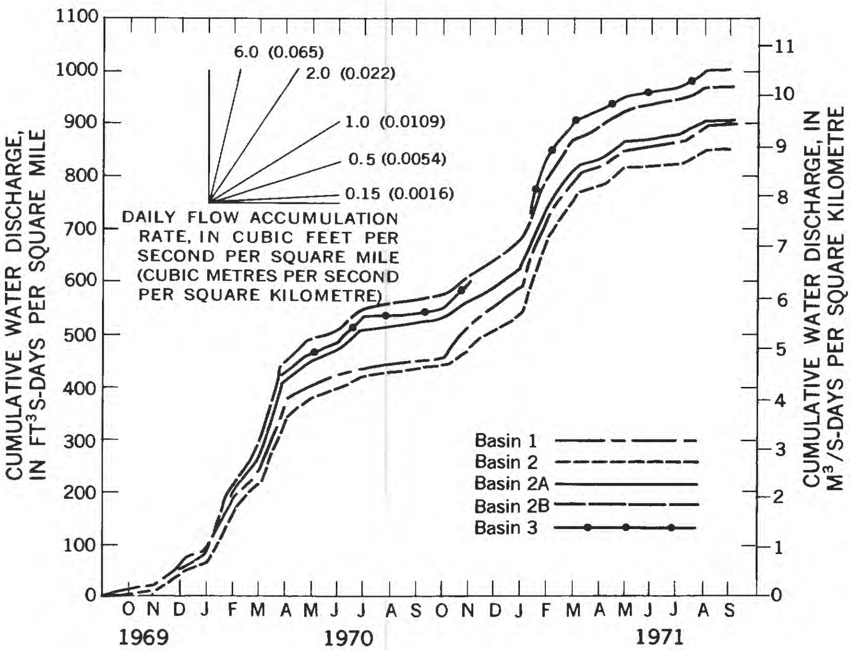

FIGURE 5.—Cumulative water discharge, Conodoguinet Creek tributaries 1, 2, 2A, 2B, and 3, October 1, 1969, to September 30, 1971.

Figure 5 shows that the water discharged from each of the five basins follows the same general pattern of accumulation with respect to time. The slightly higher discharges per unit area from basins 2B and 3 could reflect errors in computing the size of the drainage area or in measuring the flows. Also, the higher discharge could indicate underground water movement that does not follow the surface-basin divides. The flow from any one of the five streams is within 8 percent of the average flow of the other four streams, and the measured streamflow from each of the five basins has been similar with respect to time and quantities of water discharged.

The number of days that streamflow was less than 0.15 (ft³/s)/mi² [0.0016 (m³/s)/km²] for each of the five streams is shown in figure 6. During periods when the flow was less than 0.15 (ft³/s)/

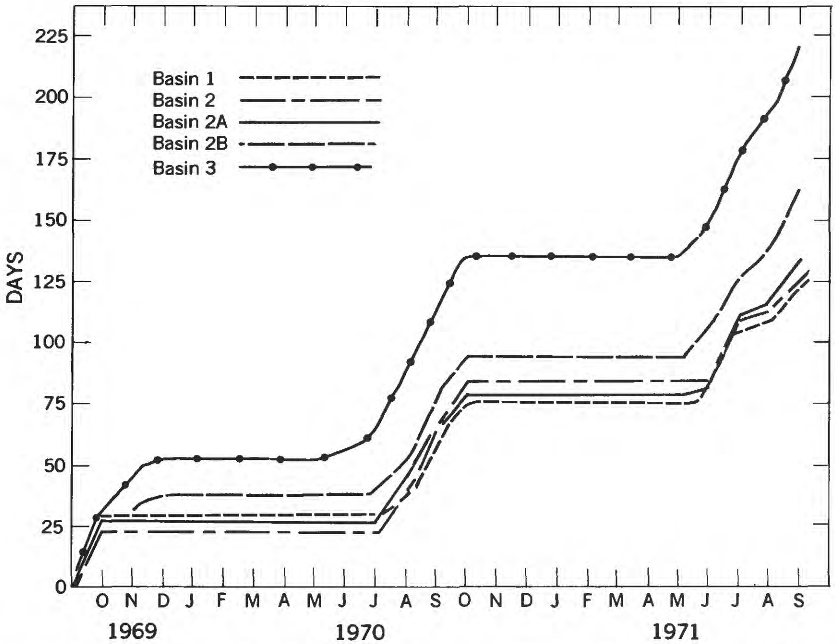

FIGURE 6.—Cumulative number of days flow was less than 0.15 (ft³/s)/mi² [0.0016 (m³/s)/km²]. Conodoguinet Creek tributaries 1, 2, 2A, 2B, and 3, October 1, 1969, to September 30, 1971.

mi² [0.0016 (m³/s)/km²], most of the streamflow was sustained by infiltrating ground water. Figure 6 shows that the streams draining basins 1, 2, and 2A had almost identical low-flow patterns. The streams draining basins 2B and 3 had flows less than 0.15 (ft³/s)/mi² [0.0016 (m³/s)/km²] during 20 and 80 percent more days, respectively, than the streams draining basins 1, 2, or 2A. These lower flows in 2B and 3 could have been the result of the smaller drainages, the larger percentage of forest area, or simply that 2B and 3 have less ground-water storage capacity available to sustain streamflow during dry weather. The filling of a newly constructed 5-acre (2 hm²) pond in the early fall of 1970 caused about 10 days of flows less than 0.15 (ft³/s)/mi² [0.0016 (m³/s)/km²] at the gage in basin 2.

An evaluation of peak flows was not made owing to a lack of data. Only four storms occurred which produced peak discharges near 100 (ft³/s)/mi² [1.08 (m³/s)/km²].

SEDIMENT CONCENTRATIONS AND DISCHARGE

Sediment concentrations were determined by collecting samples periodically during base-flow periods, when concentrations are normally low, and at more frequent intervals during storms, when concentrations are high and changing rapidly. Most of the samples were collected by hand during the base-flow periods. During storms, most samples were collected by the Spotts Pendulum Sampler [1] (fig. 7), which is an automatic sampler installed in the

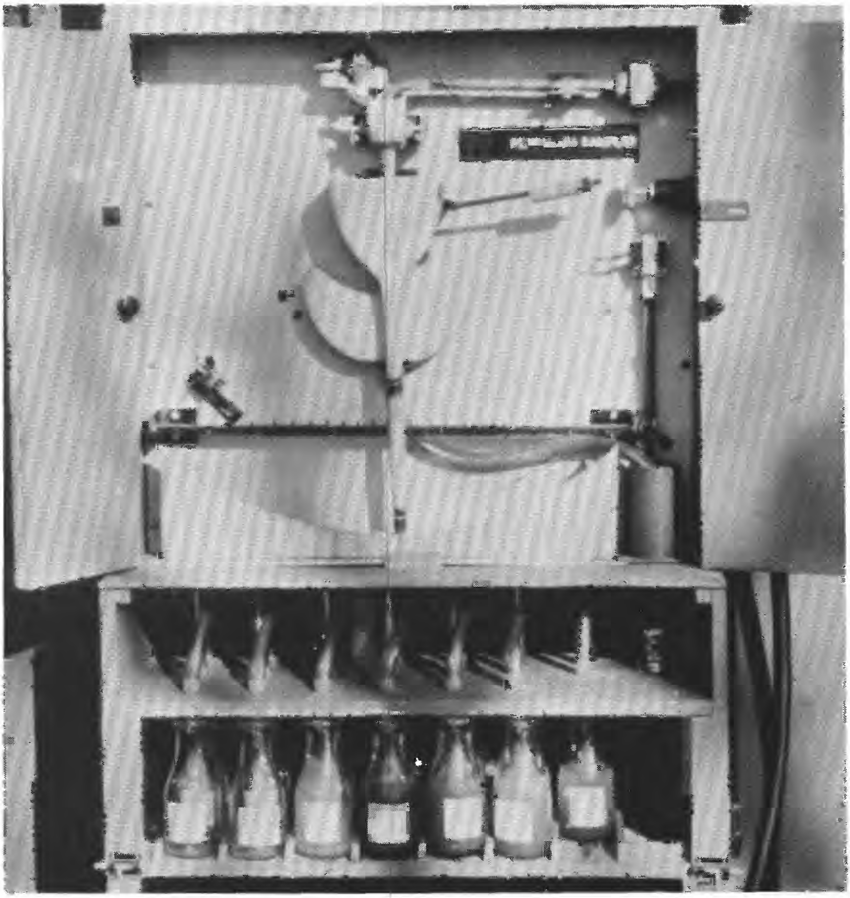

FIGURE 7.—Spotts Pendulum Sampler.

monitoring station. Hand samples were also collected during storms to supplement and check the automatic samples. Samples were analyzed in the U.S. Geological Survey sediment laboratory in Harrisburg.

[1] The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Analysis of the sediment data is divided into three sections. The first section discusses the sediment concentrations observed in the five streams during base-flow periods. During these periods, the streamflow normally contains the lowest sediment concentrations, and little if any sediment is being transported. The 24 days from each month with the lowest mean-daily sediment concentrations were tabulated as the days of base-flow sediment concentration. The second section discusses mean-daily sediment concentrations during the remaining 6 days of each month, which are mostly days when storm runoff occurred and the streams were carrying significant concentrations of suspended sediment. The third section discusses the quantity of sediment discharged from each of the basins. A land-use condition or activity in a basin may affect one of the three parameters discussed and not the other two. Several such instances will be shown in the following sections.

BASE-FLOW SEDIMENT CONCENTRATIONS

The 24 lowest mean-daily suspended-sediment concentrations for each of the five streams were tabulated and accumulated for each month from October 1969 through September 1971. Figure 8 shows the cumulative plot of the base-flow sediment concentrations plotted versus time for the five streams. The figure also shows the slope of the accumulation graph for concentrations of 2, 5, 10, 20, and 30 mg/l, respectively. Figure 8 shows that significant base-flow sediment concentrations have occurred in the streams draining basins 2B, 2, and 1. The following basin-by-basin analysis describes the source of the sediment starting with the area of highest concentrations.

BASIN 2B

The primary factor affecting base-flow sediment concentrations in the stream draining basin 2B is a pond formed by a 4-foot (1.2 m) dam approximately one-quarter of a mile (0.4 km) upstream from the gage. From the spring through the fall of 1970, as many as 95 ducks and geese occupied the pond (fig. 9). During the summer of 1971 the population of ducks decreased to 15.

Base-flow sediment concentrations in the stream draining basin 2B averaged 30 mg/l during June, July, August, and September 1970. These high concentrations were caused by the ducks and geese disturbing the sides and bottom of the pond in search of food. Samples collected above the pond during the same period

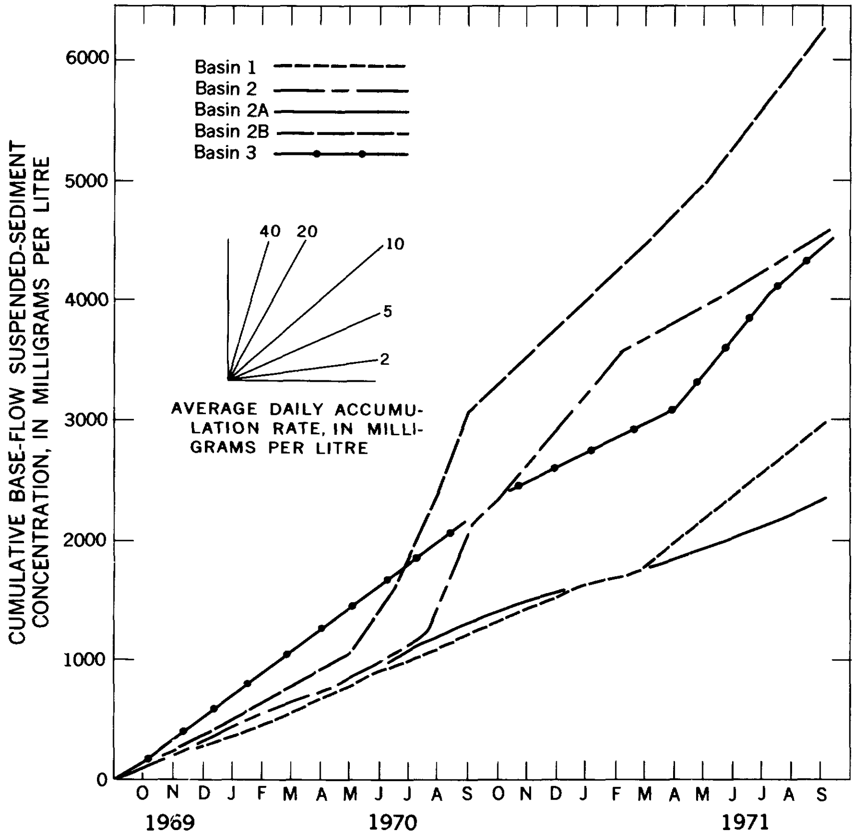

FIGURE 8.—Cumulative base-flow suspended-sediment concentrations, Conodoguinet Creek tributaries, 1, 2, 2A, 2B, and 3, October 1, 1969, to September 30, 1971.

showed base-flow sediment concentrations of 2 to 8 mg/l. The stream draining basin 2B had the highest base-flow sediment concentrations of the streams for the 2-year period, averaging about 15 mg/l. (See fig. 8).

BASIN 2

A one-lane roadway and dam forming a 5-acre (2 hm^2) farm pond were constructed in basin 2 during June, July, August, and September 1970. Construction of the roadway disturbed 15 acres (6 hm^2), and construction of the dam disturbed 10 acres (4 hm^2). Figure 10 is an aerial photograph of the area taken on August 18, 1970, showing the roadway nearly complete and construction of the dam in progress. The dam, which carries the roadway, was constructed on the main stream. The upstream drainage area is 300 acres (121 hm^2).

The construction of the roadway during June and July to within 300 feet (90 m) of the stream slightly affected base-flow sediment concentrations, which averaged 7 mg/l during the period as compared with 5 mg/l before construction. Base-flow sediment concentrations averaged 30 mg/l during construction of the dam in August and September, even though construction equipment was not operated in the stream and precautions were taken to prevent sediment from entering the stream. Most of the increase was due to small storms that did not appreciably affect base flow but washed sediment into the stream from the nearby construction surface.

FIGURE 9.—On-stream pond in basin 2B.

Suspended-sediment concentrations averaged 10 mg/l during October 1970, when base flow at the gage was nearly zero because all flow from above the dam was being stored (fig. 11). The pond filled with water from a combination of base flow and storm runoff from the basin headwaters and from the pond construction area upstream from the dam. The full pond contained water with moderate suspended-sediment concentrations that contributed to the

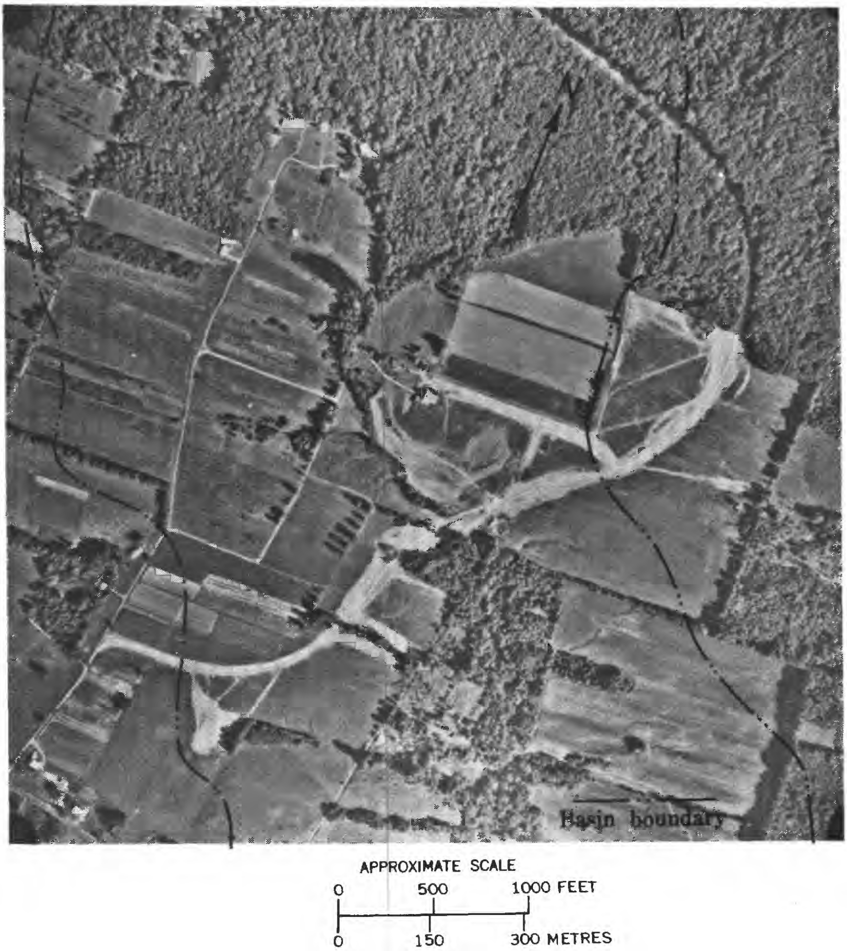

FIGURE 10.—Aerial photograph of basin 2 taken August 18, 1970, showing roadway and pond construction.

concentration in the base flow, which averaged 15 mg/l from October 1970 to February 1971. The pond appeared to have been flushed of excess suspended-sediment after February, and base-flow concentrations in the stream decreased to an average of 7 mg/l. Further decreases in base-flow concentrations should occur as the pond and surrounding area continue to stabilize.

BASIN 3

Base-flow sediment concentrations in the stream draining basin 3 averaged about 8 mg/l during the 2-year period, about twice as high as those measured in basins 1 and 2A. The reason is probably

FIGURE 11.—Channel of tributary 2 below dam during period when pond was filling and streamflow was near zero.

the greater number of residences and roads in basin 3. Most of the residential area and potential sources of sediment are in the headwaters of the basin (fig. 12). Little sediment-free water is available upstream from the potential sources of sediment to flush the stream rapidly after storms.

BASIN 1

The base-flow suspended-sediment concentrations from basin 1 averaged 4 mg/l and were as low as those in any of the other basins from October 1969 through April 1971. After April 1971, a field 600 feet (180 m) upstream from the gage was used as a pasture for eight head of young cattle (fig. 13). This caused the average base-flow sediment concentrations to increase to 10 mg/l from May through September 1971. The cattle spent a significant amount of time standing in the stream, which extends 1,200 feet (360 m) through the pasture.

BASIN 2A

During the 2 years of data collection the stream draining basin 2A had very low suspended-sediment concentrations at times of base flow. (See fig. 8.) No activity in the basin appreciably affected

FIGURE 12.—Part of the developed area of basin 3.

FIGURE 13.—Overgrazed area in basin 1 just upstream from the gage, 1971.

the base-flow suspended-sediment concentrations. Some of the road-construction activity from basin 2 did overlap (fig. 10) into basin 2A, but storm runoff and sediment from the construction area entered the stream downstream from the headwaters and were quickly flushed through the stream system.

SUSPENDED-SEDIMENT CONCENTRATIONS DURING STORM RUNOFF

The six highest mean-daily suspended-sediment concentrations, usually from storm runoff, were tabulated and accumulated on a monthly basis from October 1969 through September 1971 for each of the five streams (fig. 14).

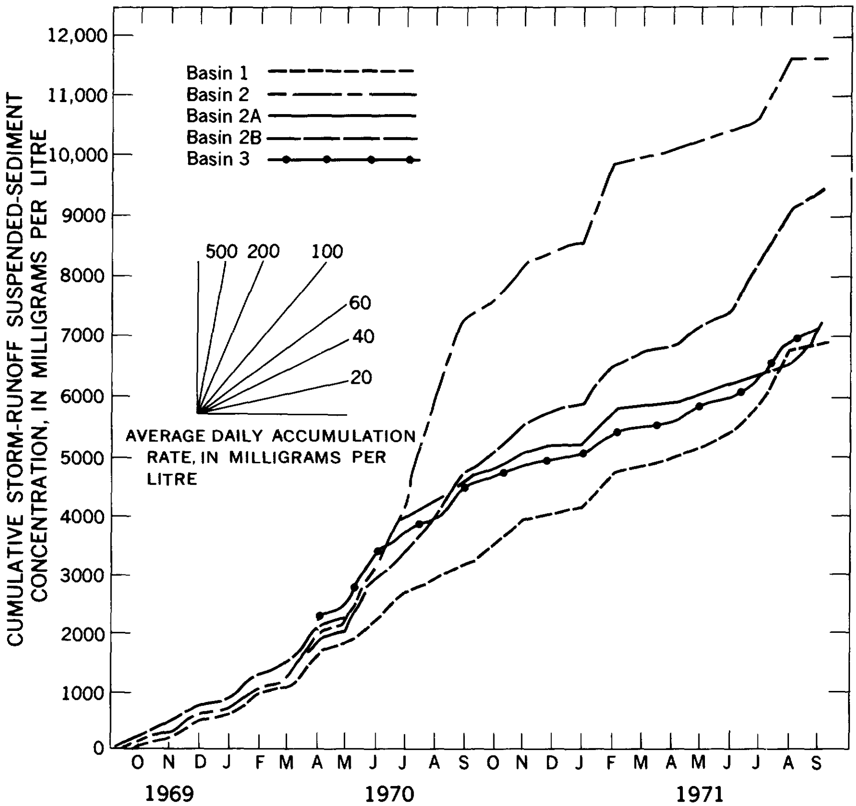

FIGURE 14.—Cumulative storm runoff suspended-sediment concentrations, Conodoguinet Creek tributaries 1, 2, 2A, 2B, and 3, October 1, 1969, to September 30, 1971.

Figure 14 shows that the mean-daily suspended-sediment concentrations during storm runoff were very similar from October 1969 through May 1970 for the five streams. During this period, the mean daily sediment concentrations averaged 45 mg/l for 6 days each month from each of the five basins. Changes in the suspended sediment during storm runoff after May 1970 are discussed in the following section, starting with the basin having the greatest observed changes.

BASIN 2

The greatest change occurred in basin 2. The mean daily sediment concentrations averaged 165 mg/l during storm runoff in June and July 1970. The average during the prior 8 months had been 45 mg/l. The increase was caused by the construction of the roadway shown in figure 10. Mean daily sediment concentrations during storm runoff averaged 250 mg/l in August and September 1970, the period of dam construction in basin 2. These were the highest concentrations in the basins during any period.

When the pond was filling in October, suspended-sediment concentrations during storm runoff averaged 65 mg/l at the gage. The suspended sediment that entered the stream from the disturbed area just below the pond during minor storms tended to settle on the stream bottom, because the flow from upstream was all being stored. Figure 11 is a photograph of the stream taken during this low-flow period showing the fine sediment deposited on the surface of the streambed. The deposited fine sediment was flushed after the pond filled and streamflow returnd to near normal at the gage. Mean daily storm runoff concentrations averaged 65 mg/l after October.

In summary, the mean-daily suspended-sediment concentrations during storm runoff averaged 45 mg/l before the construction in the basin, 165 mg/l during the 2 months of the roadway construction, 250 mg/l during construction of the pond, and 65 mg/l after construction ended.

BASIN 2B

Mean-daily suspended-sediment concentrations during storm runoff in the stream draining basin 2B also increased after May 1970 from an average of 45 mg/l to an average of 75 mg/l (fig. 14). The increase can be correlated with the introduction of the flock of ducks and geese (fig. 9) in the pond upstream from the gage.

BASIN 2A

During June and July 1970, the stream draining basin 2A had suspended-sediment concentrations that averaged 165 mg/l during storm runoff. The pre-June average was 40 mg/l. After the June-July period, storm-runoff concentrations returned to the original average of 40 mg/l. Figure 10 shows that the roadway discussed previously with respect to basin 2 extended into the drainage of basin 2A. The area in basin 2A disturbed by the road construction was approximately 15 acres (6 hm^2), equal to the area disturbed in basin 2. In both basins the storm runoff suspended-sediment concentrations during June and July 1970 were also equal, 165 mg/l.

BASIN 1

Sediment concentrations during storm runoff in the stream draining basin 1 averaged 48 mg/l for the 2 years of data shown on figure 14. Concentrations during storms were highest in basin 1 during July and August 1971 (fig. 14), when they averaged 120 mg/l, which is significantly greater than the 2-year average. Figure 13 shows a field upstream from the gage in basin 1 that was used as a pasture for cattle during this period. Apparently the cattle disturbed significant areas along the streambank, which was the reason for the increases in storm-runoff concentrations.

BASIN 3

Sediment concentrations during storm runoff in the stream draining basin 3 averaged 48 mg/l for the 2-year period. Figure 14 shows that no dramatic changes in stormflow sediment concentrations occurred in basin 3. No changes in land use were observed during the 2-year period.

SEDIMENT DISCHARGE

The quantity of suspended sediment discharged by a stream is computed from data of streamflow and sediment concentration. Figure 15 shows the quantity of sediment discharged by each of the five streams by months, plotted on a tons/mi^2 (t/km^2) basis to accommodate the different size drainage areas.

Sediment yields from basins 1 and 2A were similar except for June and July 1970. For this period, basin 2A yielded 30 tons/mi^2 (10.5 t/km^2), while basin 1 yielded 12 tons/mi^2 (4.2 t/km^2). The difference is the result of the construction in basin 2A, shown on figure 10 and discussed in the preceding section. The average annual yield from basins 1 and 2A was about 75 tons/mi^2 (26 t/km^2) if the effects of the construction (fig. 10) are removed.

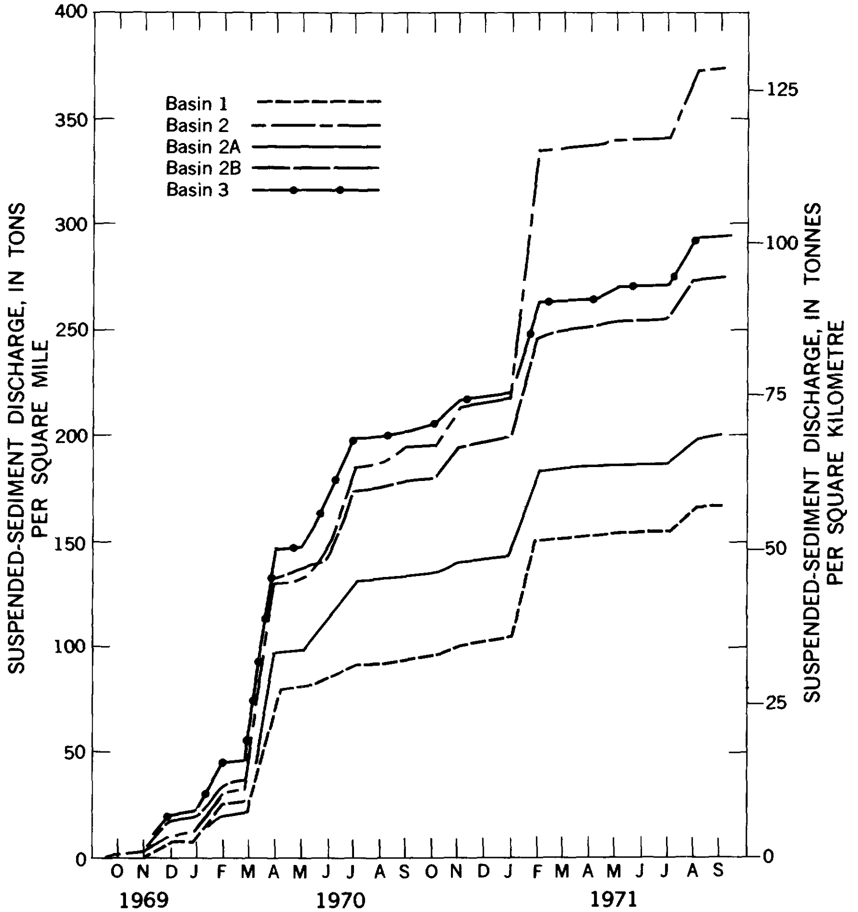

FIGURE 15.—Cumulative sediment discharge, Conodoguinet Creek tributaries 1, 2, 2A, 2B, and 3, October 1, 1969, to September 30, 1971.

Basins 2, 2B, and 3 had significantly higher sediment yields than basins 1 and 2A, as shown by figure 15. The higher yields in basin 2 are attributable to the construction of the pond and roadway in 1970 (fig. 10). The data indicate that approximately 100 tons (90 t) of sediment has been discharged as a result of the construction, most of which was discharged in February 1971 when a large storm flushed the stream. Under normal conditions the basin would probably have yielded 100 to 125 tons/mi² (35 to 44 t/km²) per year. After the basin stabilizes, sediment yields will probably be less than 125 tons/mi² (44 t/km²) because sediment will be trapped in the pond (fig. 10). Although no reduction in sediment yield has occurred to date, the pond has a capacity of about 25 acre-feet (31,000 m³), a capacity inflow ratio of 0.08, and a trap efficiency of 85 percent (Brune, 1953). The yields from basin 2B and 3 (fig. 15) averaged 130 tons/mi^2 (45 t/km^2). The high yields are probably due to the slightly larger developed area. Only minor increases in the total sediment load were caused by the ducks and geese in the pond in basin 2B, because of the small area involved.

TURBIDITY

Turbidity is a measure of the amount of suspended material in water. It reflects the size, shape, refractive index, and number of particles in suspension. Turbidity in this report is measured in Jackson Turbidity Units (JTU). The U.S. Public Health Service (1962) has placed a maximum standard of 5 JTU on water used for consumption. Turbidity was measured on tributaries 2, 2A, and 2B continuously by means of surface-scatter turbidimeters installed in the gaging stations (fig. 16). In addition, the turbidity

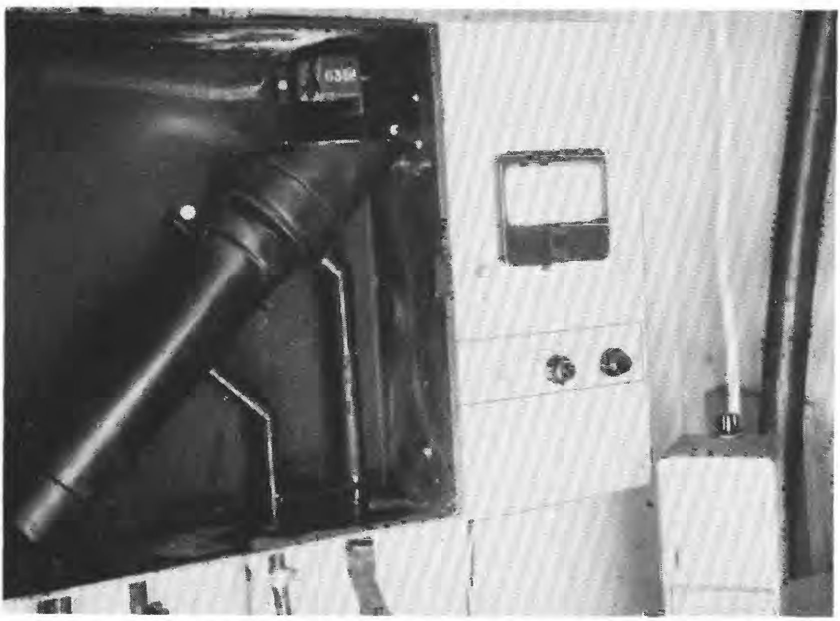

FIGURE 16.—Surface-scatter turbidimeter installed in basin 2.

of all suspended-sediment samples collected after January 1, 1971, from each of the five streams was measured in the laboratory.

Analysis of the turbidity data is divided into three sections. The first section concerns base-flow turbidity (when the streams are normally clear), the second section concerns turbidity during storm runoff (when streams are normally turbid), and the third section concerns the turbidity load carried by the streams. Figures 17–20 show a range in turbidity from 5 to 100 JTU. In figure 17

FIGURE 17.—Stream with a turbidity of 5 JTU and a flow of 0.2 ft^3/s (0.006 m^3/s).

FIGURE 18.—Streams with a turbidity of 10 JTU and a flow of 0.15 ft^3/s (0.004 m^3/s).

FIGURE 19.—Stream with a turbidity of 30 JTU and a flow of 0.3 ft³/s (0.008 m³/s).

FIGURE 20.—Stream with a turbidity of 100 JTU and a flow of 0.2 ft³/s (0.006 m³/s).

the flow is 0.2 ft^3/s (0.006 m^3/s), the turbidity is 5 JTU, and the stream appears clear. In figure 18 flow is 0.15 ft^3/s (0.004 m^3/s), turbidity is 10 JTU, and the stream has a slight milky appearance.

In figure 19 flows is 0.3 ft^3/s (0.008 m^3/s), turbidity is 30 JTU, and the bottom of the 6-inch-deep (150 mm) stream is hidden by the turbid water. Flow in figure 20 is 0.2 ft^3/s (0.006 m^3/s), turbidity is 100 JTU, and visibility is limited to 1 to 2 inches (25–50 mm). Differences above 100 JTU can generally be detected only by sampling.

Turbidity measurements are shown on figure 21 for base-flow

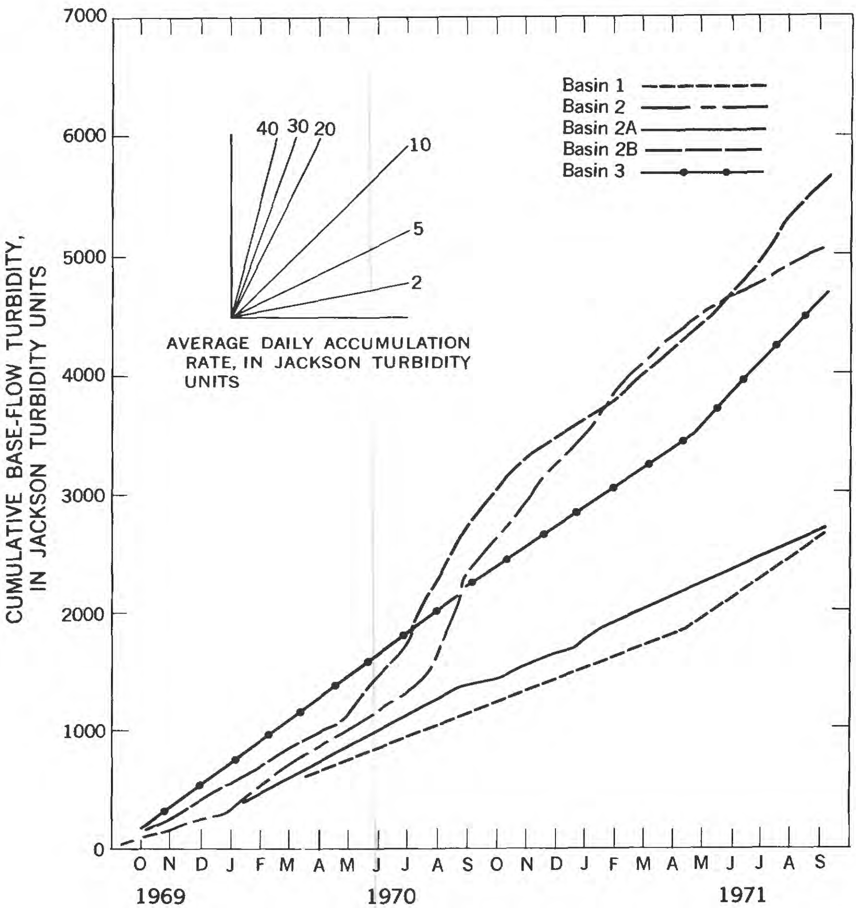

Figure 21.—Cumulative base-flow turbidity, Conodoguinet Creek tributaries 1, 2, 2A, 2B, and 3, October 1, 1969, to September 30, 1971.

periods, when the streams are normally clear. The lowest 24 mean-daily turbidity measurements each month were tabulated and accumulated for each of the five basins for the periods when data were available. Figure 21 shows the resulting curves. The highest turbidity during base flow was observed during September and October 1970 in basins 2 and 2B; turbidity averaged 25 JTU. The lowest observed turbidity during base flow was observed in basins 1 and 2A; turbidity averaged 6 JTU. For the basins where data were not available prior to January 1971, turbidity was computed from the relation between suspended-sediment concentrations and turbidity shown on figure 22. Figure 22 is a plot of the turbidity

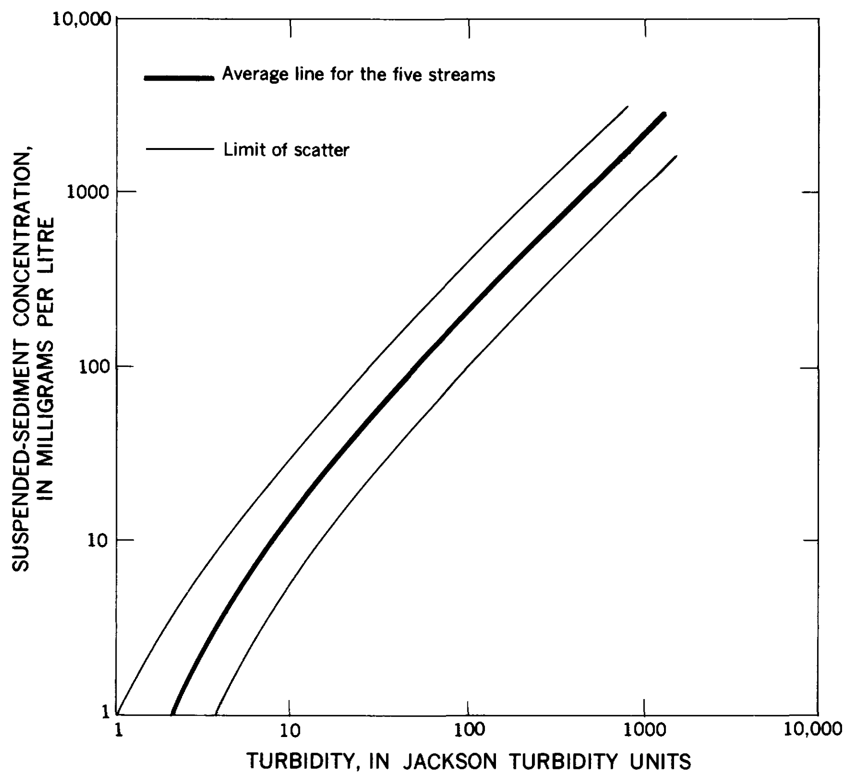

FIGURE 22.—Relation between sediment concentration and turbidity, Conodoguinet Creek tributaries 1, 2, 2A, 2B, and 3, May 1, 1971, to September 23, 1971.

determined in the laboratory versus the suspended-sediment concentration of about 1,000 samples from all the basins from January 1 to September 30, 1971. Figure 21 (base-flow turbidity) is very similar to figure 8 (base-flow suspended-sediment concentrations). Figure 21 shows that during the base-flow period (80 percent of the time) the stream draining basin 2B has been as turbid or more turbid than the stream draining basin 2, even during the construction of the roadway and dam in basin 2 in the summer of 1970. The cause of the high turbidity in basin 2B during base flow was the ducks and geese occupying the on-stream pond. The high turbidity in basin 3 is the result of the slightly larger developed areas in the basin headwaters.

Turbidity measurements during storm runoff are shown on figure 23. The highest six mean-daily measurements each month

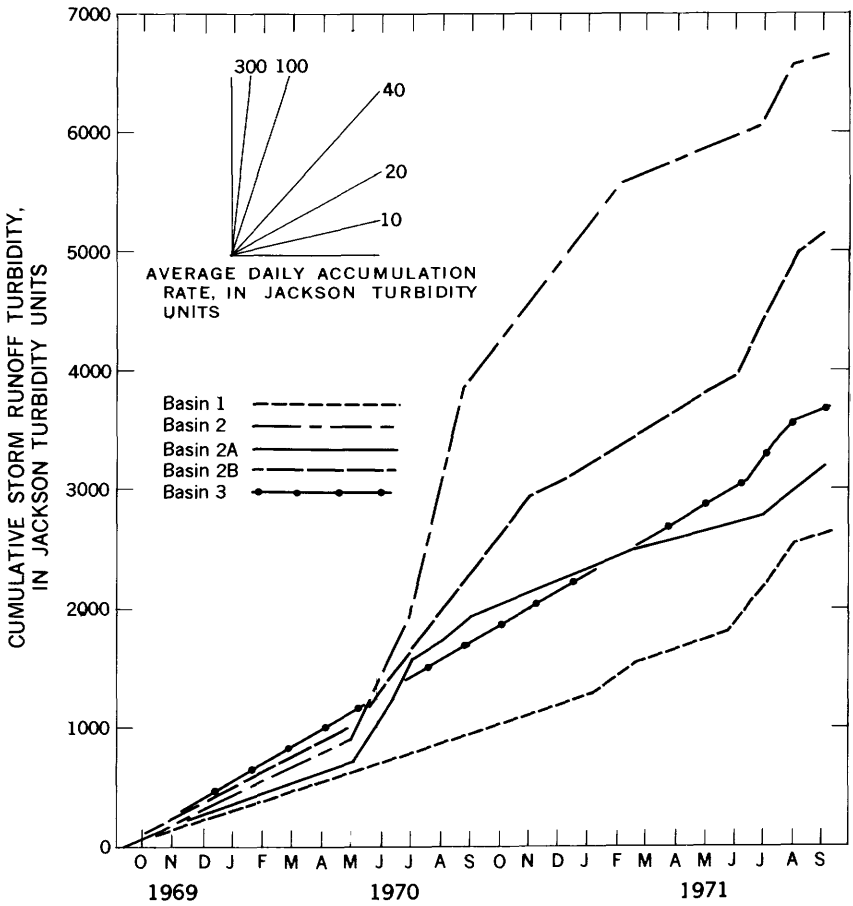

FIGURE 23.—Cumulative storm-runoff turbidity, Conodoguinet Creek tributaries 1, 2, 2A, 2B, and 3, October 1, 1969, to September 30, 1971.

were tabulated and accumulated for each of the five streams and plotted as a cumulative graph versus time. Average turbidity during storms for a 2-month period ranged from 150 JTU in basin 2 to 20 JTU in basin 1. Turbidity in the stream draining basin 2 averaged 150 JTU during storm runoff in August and September 1970, when the dam was being constructed.

The following analysis relates the turbidity of the streamflow to the quantity of flow and shows the turbidity load carried by the stream. In the suspended-sediment analysis, the sediment load was determined by relating streamflow to sediment concentration. Turbidity load is computed by relating streamflow to turbidity. For April 2, 1970, the mean daily flow from basin 2 was 32 ft^3/s (0.91 m^3/s), and the water-weighted turbidity was 130 JTU. The water discharge from basin 2 for the entire year was 336 ft^3/s-days (9.52 m^3/s-days). Therefore, the turbidity load for the day (April 2) is

$$\frac{32\ ft^3/s \times 130\ JTU}{336\ ft^3/s} = 12.4\ JTU \qquad \frac{0.91\ m^3/s \times 130\ JTU}{9.52\ m^3/s} = 12.4\ JTU$$

and is the turbidity that would result if the flow from April 2 were stored and enough clear water added and mixed in to bring the total volume equal to the volume of flow discharged in the year. The turbidity loads were computed for each day and were then tabulated, accumulated, and plotted bi-monthly (fig. 24). Steps in the plot that exceed 5 JTU represent periods when, if the flow from the stream were entering and mixing with clear water stored in a reservoir with a capacity of a years runoff from the basin, the resulting reservoir turbidity would exceed 5 JTU (the U.S. Public Health Service standard for drinking water). Figure 24 shows the turbidity load for the five basins for the 2 years of data. The turbidity loads were estimated from the sediment turbidity relation (fig. 22) for periods when turbidity data were not being collected.

Major storms in April 1970 and February 1971 produced turbidity loads of 15 JTU or more from all the streams. Each of the curves in figure 24 reflect these storms; however, the curve for basin 2 shows a turbidity load three times the average of the other four basins (45 versus 15) for the February 1971 period. Since the time of roadway and pond construction (June to September 1970), basin 2 has been discharging nearly three times the turbidity load during major storms.

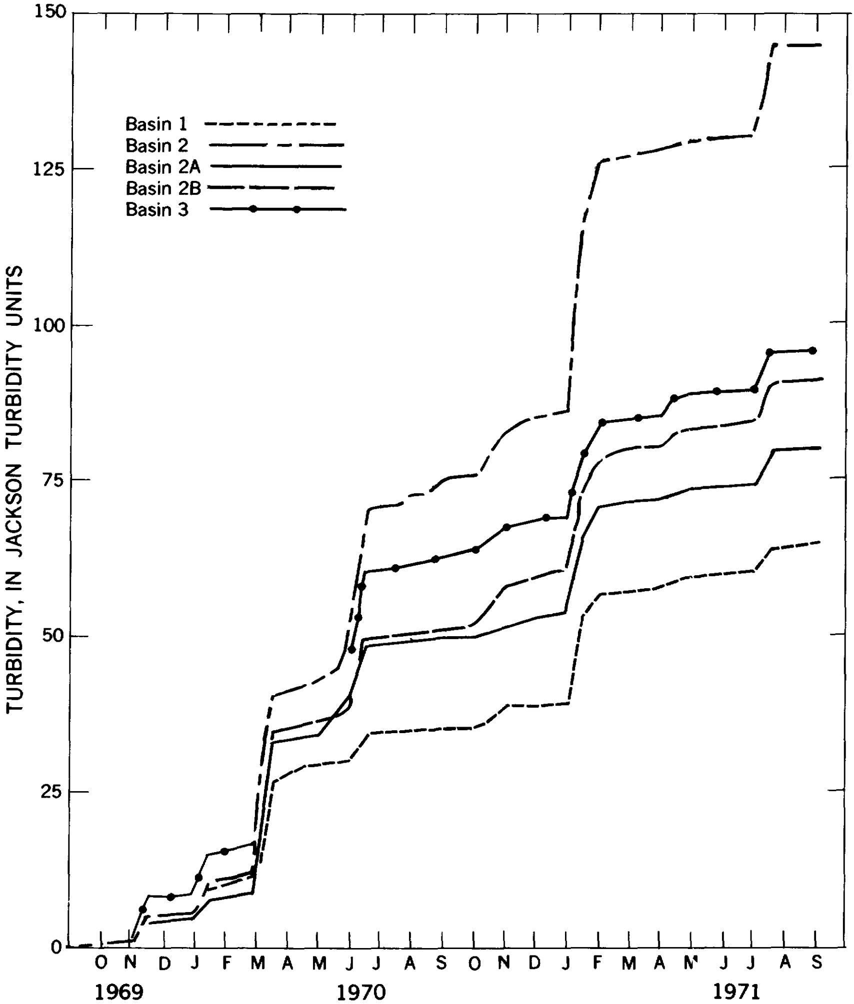

FIGURE 24.—Cumulative turbidity load, Conodoguinet Creek tributaries 1, 2, 2A, 2B, and 3, October 1, 1969, to September 30, 1971.

SUMMARY AND CONCLUSIONS

Precipitation data presented on a cumulative graph versus time show that precipitation is evenly distributed by months and that the three data-collection sites receive nearly equal amounts. Streamflow data, shown by plotting cumulative streamflow from each of the five basins versus time, indicate that streamflow in each basin is similar with respect to time and quantities of water discharged.

In basin 1 the pasturing of a meadow upstream from the gage significantly affected suspended-sediment concentrations during base-flow periods and slightly affected them during storm-runoff periods. Total suspended-sediment discharge was not affected.

In basin 2 the construction of a roadway to within 300 feet (90 m) of the stream caused a significant increase in sediment concentrations during storms and a significant increase in sediment load. Construction of the dam in basin 2 significantly affected sediment concentrations during base-flow periods and storm-runoff periods and affected the total suspended sediment discharged by the stream.

In basin 2A significant increases in sediment concentrations during storms and an increase in sediment discharge were caused by construction on 15-acres (6 hm^2) approximately 300 feet (90 m) from the stream. No increase in base-flow concentrations was detected.

In basin 2B the use of an on-stream pond by ducks and geese greatly affected base-flow sediment concentrations and slightly affected storm-runoff sediment concentrations. There was no appreciable affect on total sediment discharge.

Changes in basin 3 were too slight to affect any of the discussed parameters during the 2-year period. Sediment concentrations in the stream during base-flow and storm-runoff periods are slightly affected by roadways and dwellings in the basin. The turbidity data show essentially the same results as the sediment data.

REFERENCES

Brown, Eugene, Skougstad, M. W., and Fishman, M. J., 1970, Methods for collection and analysis of water samples for dissolved minerals and gases: U.S. Geol. Survey Techniques of Water-Resources Inv., Chap. A1, Book 5, 169 p.

Brune, G. M., 1953, Trap efficiency of reservoirs: Am. Geophys. Union Trans., v. 34, no. 3, p. 407–418.

Jones, B. L., 1966, Effects of agricultural conservation practices on the hydrology of Corey Creek basin, Pennsylvania, 1954–60: U.S. Geol. Survey Water-Supply Paper 1532–C, 55 p.

Pennsylvania Geological Survey, 1960, Geologic map of Pennsylvania: Pennsylvania Geol. Survey, scale 1:250,000.

U.S. Department of Agriculture, 1968, Soil maps for developing areas in Cumberland County, Pennsylvania: U.S. Soil Conservation Service.

U.S. Public Health Service, 1962, Drinking water standards: U.S Public Health Service Pub. no. 956, 61 p.

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