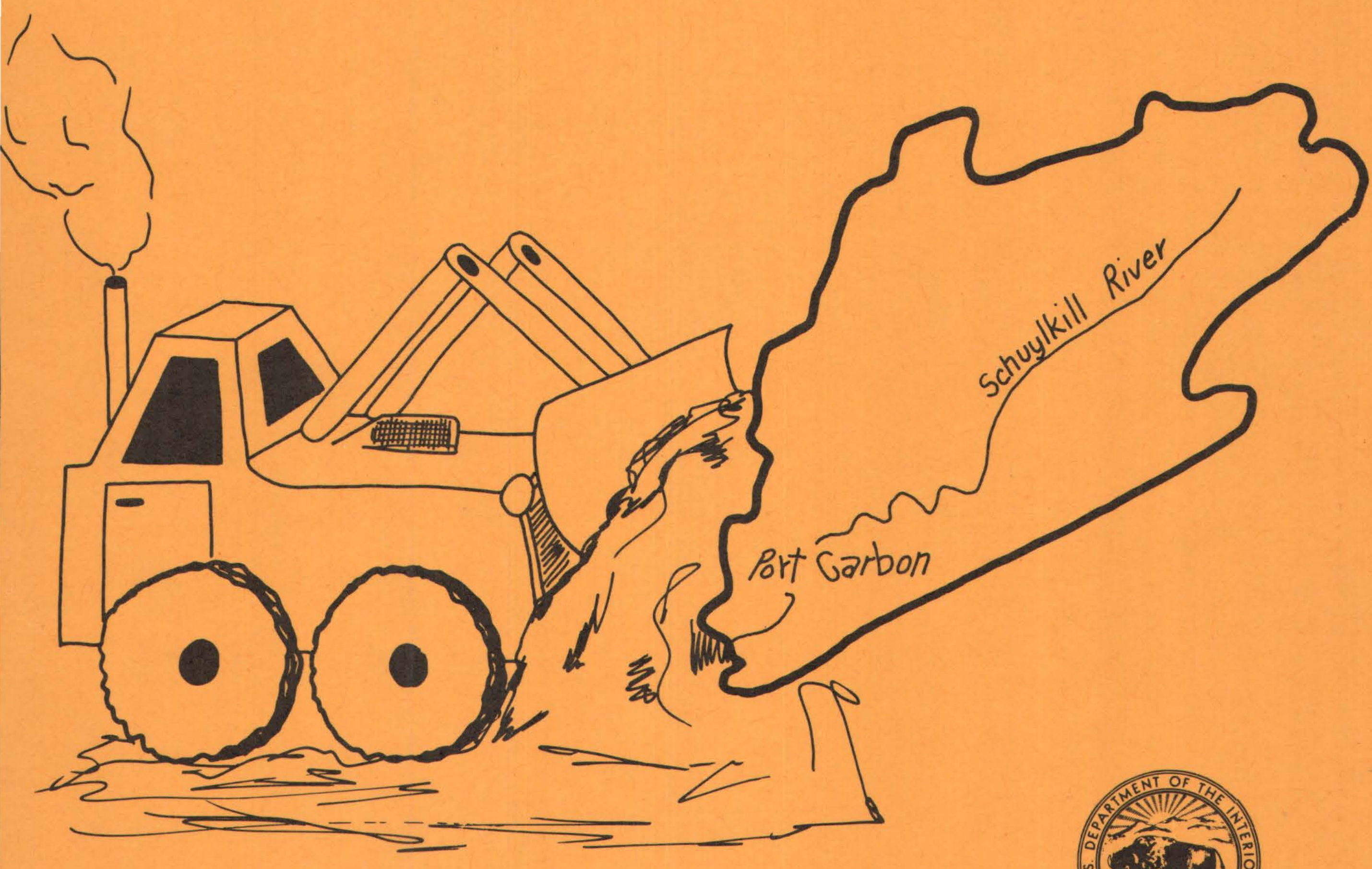
L. A. Reed

Sediment Discharge From Highway Construction Near Port Carbon, Pennsylvania

U.S. GEOLOGICAL SURVEY
WATER RESOURCES INVESTIGATION 78-35



PREPARED IN COOPERATION WITH THE
PENNSYLVANIA DEPARTMENT OF TRANSPORTATION

BIBLIOGRAPHIC DATA SHEET	1. Report No. WRI 78-35	2.	3. Recipient's Accession No.
4. Title and Subtitle Sediment Discharge from Highway Construction near Port Carbon, Pennsylvania			5. Report Date
			6.
7. Author(s) Robert E. Helm			8. Performing Organization Rept. No. USGS/WRI 78-35
9. Performing Organization Name and Address U.S. Geological Survey, Water Resources Division P.O. Box 1107 Harrisburg, Pennsylvania 17108			10. Project/Task/Work Unit No.
			11. Contract/Grant No.
12. Sponsoring Organization Name and Address U.S. Geological Survey Water Resources Division P.O. Box 1107 Harrisburg, Pennsylvania 17108			13. Type of Report & Period Covered Final
			14.

15. Supplementary Notes Prepared in cooperation with the Pennsylvania Department of Transportation

16. Abstracts The effects of highway construction on suspended-sediment loads were studied in the upper reaches of the Schuylkill River basin, Schuylkill County, Pennsylvania, from April 1975 to March 1977. From March 1975 to October 1976, 4.3 miles of State Route 209 was relocated through the upper reaches of the basin, a mountainous watershed with a drainage area of 27.1 square miles.

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17. Key Words and Document Analysis. 17a. Descriptors

Sedimentation, sediment control, *sediment discharge, sediment yield, *road construction, *storm runoff, turbidity, water-quality.

17b. Identifiers/Open-Ended Terms

Delaware River basin, Schuylkill County, Pennsylvania

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 30
NO RESTRICTIONS ON DISTRIBUTION	20. Security Class (This Page UNCLASSIFIED	22. Price

SEDIMENT DISCHARGE FROM HIGHWAY CONSTRUCTION NEAR PORT CARBON, PENNSYLVANIA

By Robert E. Helm

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 78-35

Prepared in cooperation with

Pennsylvania Department of Transportation

To Lloyd,
thanks for all your help
and support on this project!
Bob

April 1978

UNITED STATES DEPARTMENT OF THE INTERIOR

Cecil D. Andrus, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

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Harrisburg, Pennsylvania 17108

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ILLUSTRATIONS

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ILLUSTRATIONS

FACTORS FOR CONVERTING U.S. CUSTOMARY UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply U.S. Customary units	By	To obtain (SI) units
Inches (in)	25.40	Millimeters (mm)
Feet (ft)	.3048	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Acres	.4047	Hectometers (hm^2)
Tons, short	907.2	Kilograms (kg)
Cubic feet per second (ft^3/s)	.02832	Cubic meters per second (m^3/s)
Cubic feet per second-day (ft^3/s-d)	.02832	Cubic meters per second-day (m^3/s-d)
Square yard (yd^2)	.8361	Square meter (m2)
Cubic yard (yd^3)	.7645	Cubic meter (m^3)
Square mile (mi^2)	2.590	Square kilometer (km^2)
Tons per square mile (tons/mi^2)	350.3	Kilograms per square kilometer (kg/km^2)
Tons per day (tons/day)	907.2	Kilograms per day (kg/d)
Degree Fahrenheit (°F)	-32 x 5/9	Degree Celsius (°C)

SEDIMENT DISCHARGE FROM HIGHWAY CONSTRUCTION

NEAR PORT CARBON, PENNSYLVANIA

By Robert E. Helm

ABSTRACT

The effects of highway construction on suspended-sediment loads were studied in the upper reaches of the Schuylkill River basin, Schuylkill County, Pennsylvania, from April 1975 to March 1977. From March 1975 to October 1976, 4.3 miles of State Route 209 was relocated through the upper reaches of the basin, a mountainous watershed with a drainage area of 27.1 square miles.

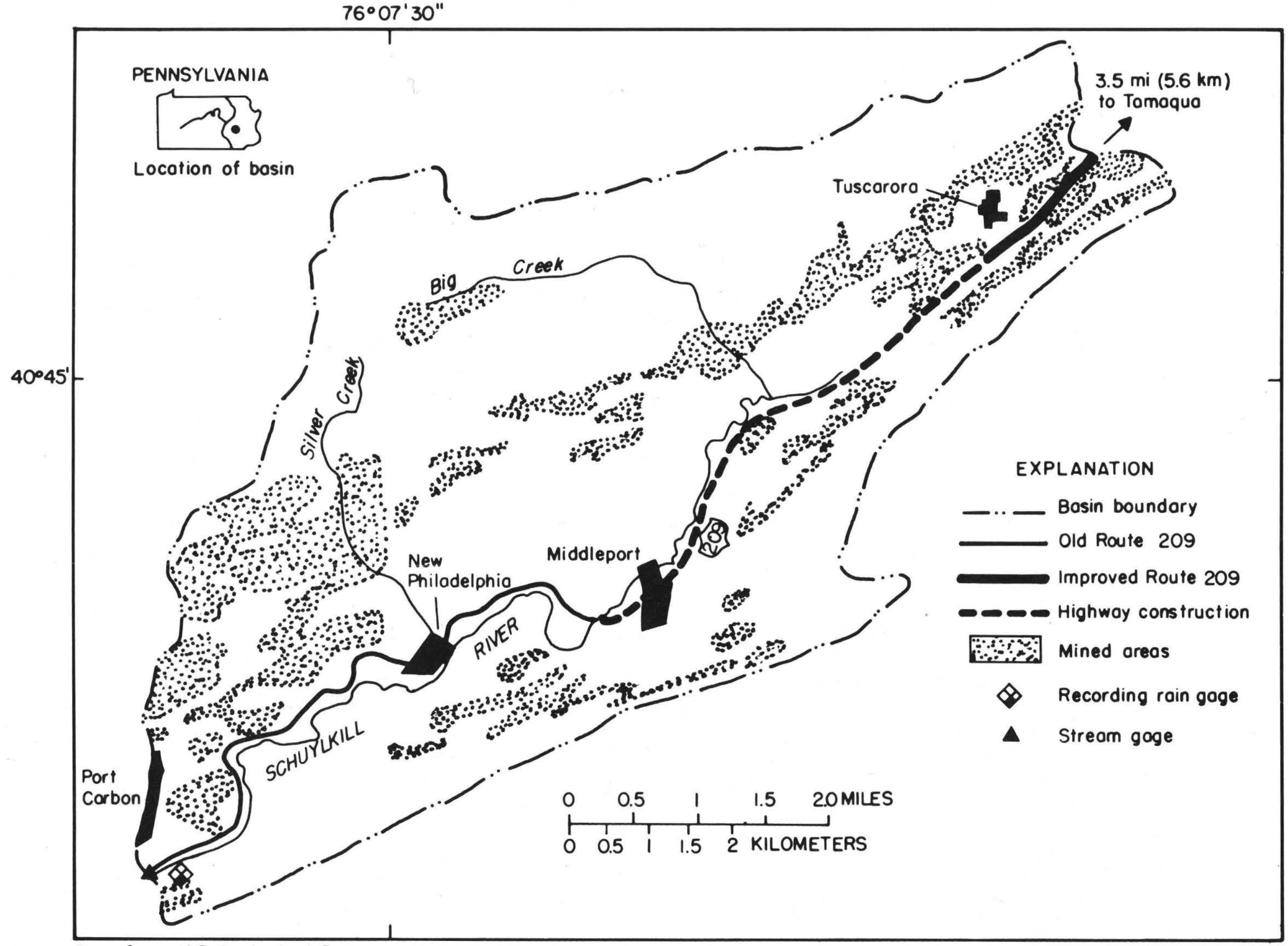
About 16,000 tons of suspended-sediment was discharged from the basin during the construction. The highway construction produced about 8,000 tons or 50 percent of the total sediment discharge. Steep slopes, the availability of fine coal wastes, coal-washing operations, and other land uses in the basin were responsible for most of the remaining sediment discharge. Seventy percent of the total suspended-sediment discharge occurred during eight storms.

INTRODUCTION

This report describes an investigation by the U.S. Geological Survey, in cooperation with the Pennsylvania Department of Transportation (PennDOT), of the effects of highway construction on sediment transport in the upper Schuylkill River basin, a 27.1 mi^2 (square mile) drainage area in Schuylkill County near Port Carbon, Pa. From March 1975 to October 1976, PennDOT relocated 4.3 mi (miles) of State Route 209 through the Upper Schuylkill River basin (fig. 1) Most of the construction was adjacent to the river.

Large quantities of natural sediment and fine coal are transported from the Port Carbon region by the Schuylkill River. Average annual sediment yields of 350-500 tons/mi^2 (tons per square mile) were reported by Biesecker and others (1968). Most of the sediment is deposited in an artificial lake 20 mi downstream from Port Carbon. The sediment and coal transported by the river and deposited in the lake is periodically dredged, stored in holding areas, and processed to recover the coal.

This report documents sediment loads during and for 6 months after the construction and appraises the methods of erosion control used by PennDOT. This was done by using data collected on the flow, sediment load, turbidity, and precipitation at the Port Carbon station on the Schuylkill River.



Base from U.S. Geological Survey
Orwigsburg 1:24,000, 1968

Figure 1.--The Schuylkill River basin above Port Carbon

A gaging station with a stage recorder, turbidimeter, automatic pumping sediment sampler and precipitation recorder (fig. 2) was installed 6 miles downstream from the construction. The data collection program spanned 23 months, from April 1975, a month after the start of construction, until March 22, 1977, 6 months after its completion.

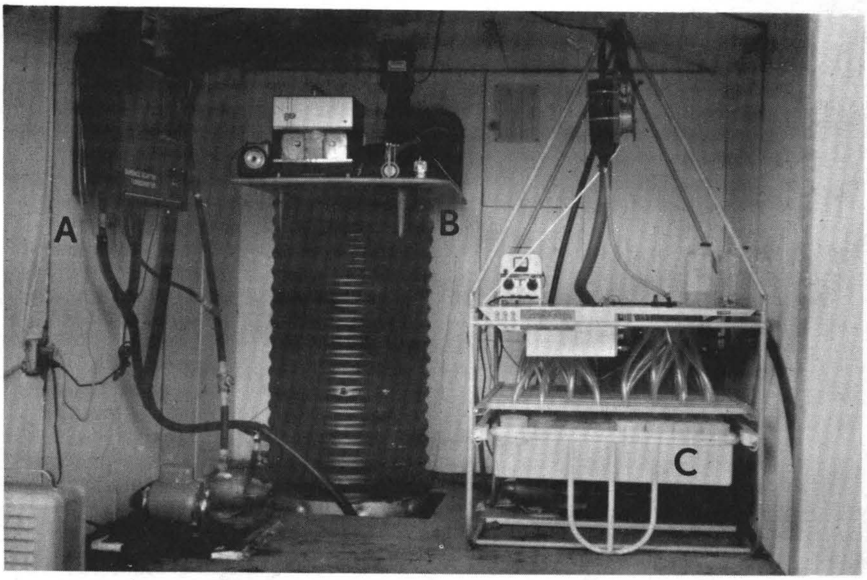


Figure 2.--Data collection equipment in gaging shelter

A- Recording turbidimeter
B- Stream-stage recorder
C- PS-69 Automatic sediment sampler

The water-stage recorder provided a continuous record of the stream's stage (height above an arbitrary datum). The stage was converted to water discharge by using the stage-discharge relation, defined by water discharge measurements at various stages. Suspended-sediment samples were collected automatically by a pumping sampler (USGS-PS-69) and manually with a US-DH-48 sampler. Samples were collected during base-flow periods and storms. The automatic sampler was set to collect three samples per day at predetermined times and every 30 minutes when the stream reached a predetermined stage or turbidity. The concentrations of suspended sediment were determined in the U.S. Geological Survey laboratory in Harrisburg, using the filtered dry-weight method outlined by Guy (1969).

Daily mean water discharge, sediment concentrations, and sediment discharges were calculated for the upper Schuylkill River basin according to the techniques described by Porterfield (1972). Turbidity was monitored continuously at the station with a surface-scatter turbidimeter. Precipitation was recorded continuously at the station, and the records were compared with those from a continously recording station operated by the U.S. Weather Service at Tamaqua, 2 mi northeast of the study area.

BASIN DESCRIPTION

The 27.1 mi^2 basin in the Appalachian Mountains in eastern Schuylkill County is drained by the Schuylkill River. The basin is underlain by part of the southern anthracite coal fields.

The Schuylkill River rises between Tuscarora and Tamaqua, flows southwest to Pottsville, then turns southeast for 87 miles, where it empties into the Delaware River at South Philadelphia, Pa. The river valley above Port Carbon is narrow and is flanked by high, steep slopes. The gaging station below the construction and 0.2 mi upstream from Port Carbon, is 640 ft (feet) above mean sea level. Highest altitudes are about 1,700 feet. The slopes in the basin average about 10 percent. The basin terrain is rugged and contains active and abandoned strip mines, as well as numerous culm banks. Stream gradients are about 0.3 percent.

Climate

The climate is characterized as continental inland. The prevailing winds are from the west and northwest. Summers are warm, and moderately long, cold winters are typical. The average January temperature at Tamaqua (37 years of record) is 35°F and the average July temperature is 72°F.

Precipitation was recorded continuously at the gaging station (fig. 3) and substantiated by comparison to that recorded by the National Weather Service at Tamaqua. The average annual precipitation at Tamaqua (34 years of record) is 48 in. and is distributed fairly uniformly throughout the year. During the 23 month study period, from April 22, 1975, to March 22, 1977 precipitation totaled 115.90 in. The highest monthly precipitation was 11.2 in. in October 1976, and the lowest was 0.60 in. in November 1976. Precipitation was 16 in. above normal during this period.

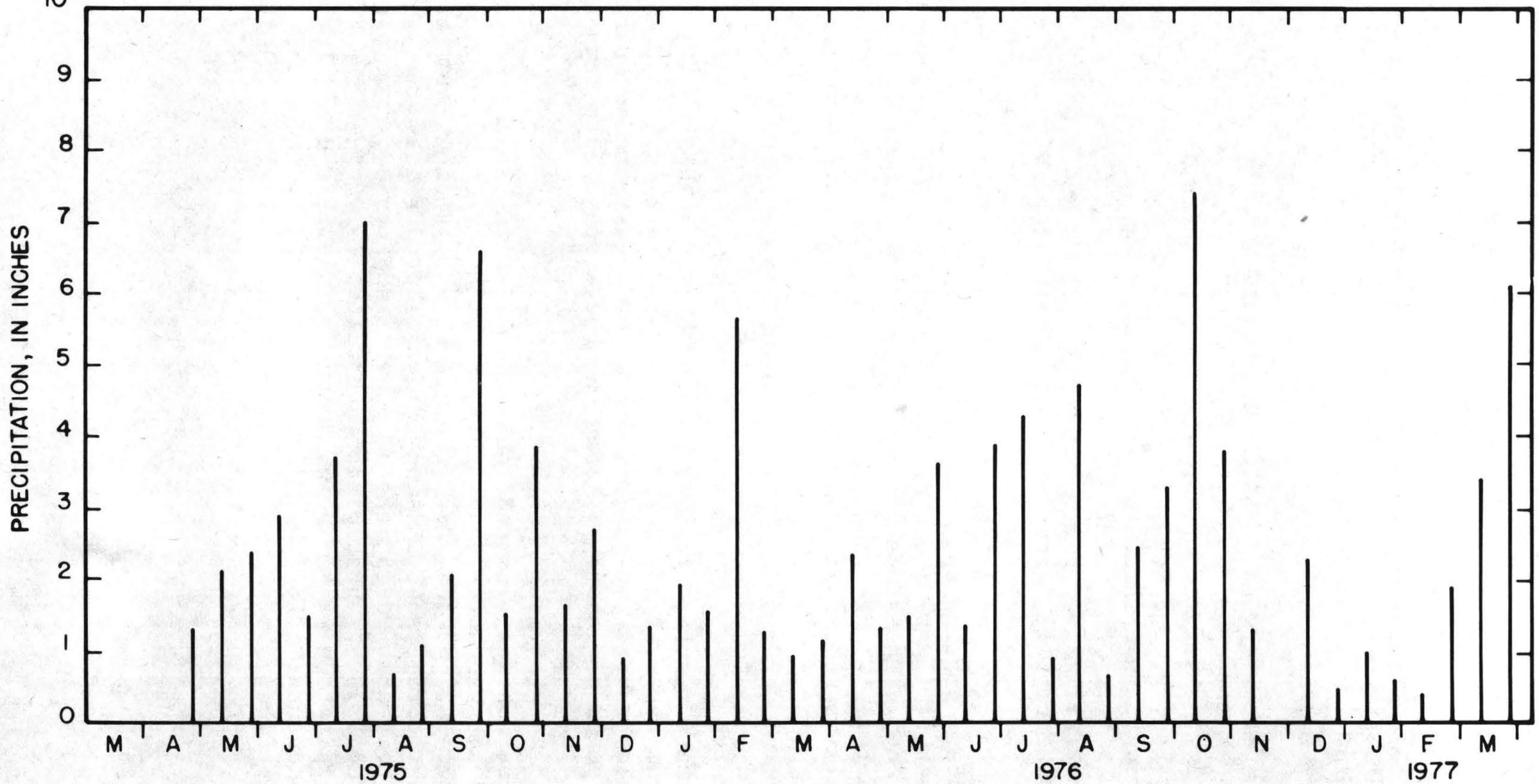


Figure 3.--Biweekly precipitation recorded at the gaging station April 22, 1975, to March 22, 1977

Geology

The valley floor of the basin is underlain by the Llewellyn Formation of Pennsylvanian age. This formation is composed of gray and brown quartzose sandstone, subgraywacke, and siltstone and includes some conglomerate, shale, and anthracite. The underlying Pottsville Formation, also of Pennsylvanian age, crops out along some of the higher elevations. This formation is lithologically described as cobble and pebble conglomerate, conglomeratic sandstone, and sandstone and includes some siltstone, shale, and coal. (Biesecker and others, 1968).

Soils

The soils consist of material weathered from noncarbonate sedimentary rocks. Most of the soils are sandy loams, with some loams and sandy clay loams.

Most of the basin is forested, except for the mining areas. Erodibility of the soil is considered to be low; however, the erodibility of the fine coal and mine wastes exposed in the basin is high. (U.S. Department of Agriculture, 1972).

Land Use

U.S. Geological Survey topographic maps (1:24,000) indicate that almost 35 percent of the basin has been disturbed by coal mining and related activities; towns occupy about 2 percent, and the remaining 63 percent is forested. Figure 1 shows the areas that have been affected by mining operations.

HIGHWAY CONSTRUCTION

From March 1975 to October 1976 PennDOT relocated a 4.3 mi section of Route 209 between Tuscarora and Middleport. The relocated roadway is graded for four lanes, but only two lanes were paved. Along most of its length the relocated roadway is adjacent to the south bank of the Schuylkill River. During construction the stream channel was changed and widened at several locations. When channel changes were being made, particular attention was paid to sediment concentrations at the gaging station. PennDOT reported excavation on the 11th and 26th of each month. The excavation was reported in four catagories: Class I, major earthmoving; Class II, drainage ditches; Class III, foundation excavation for structures; and Class IV, excavation of trenches for placement of drainage pipe. Figures 4, 5, 6, and 7 illustrate the bi-weekly and cumulative values of earth moved for the different classes of construction.

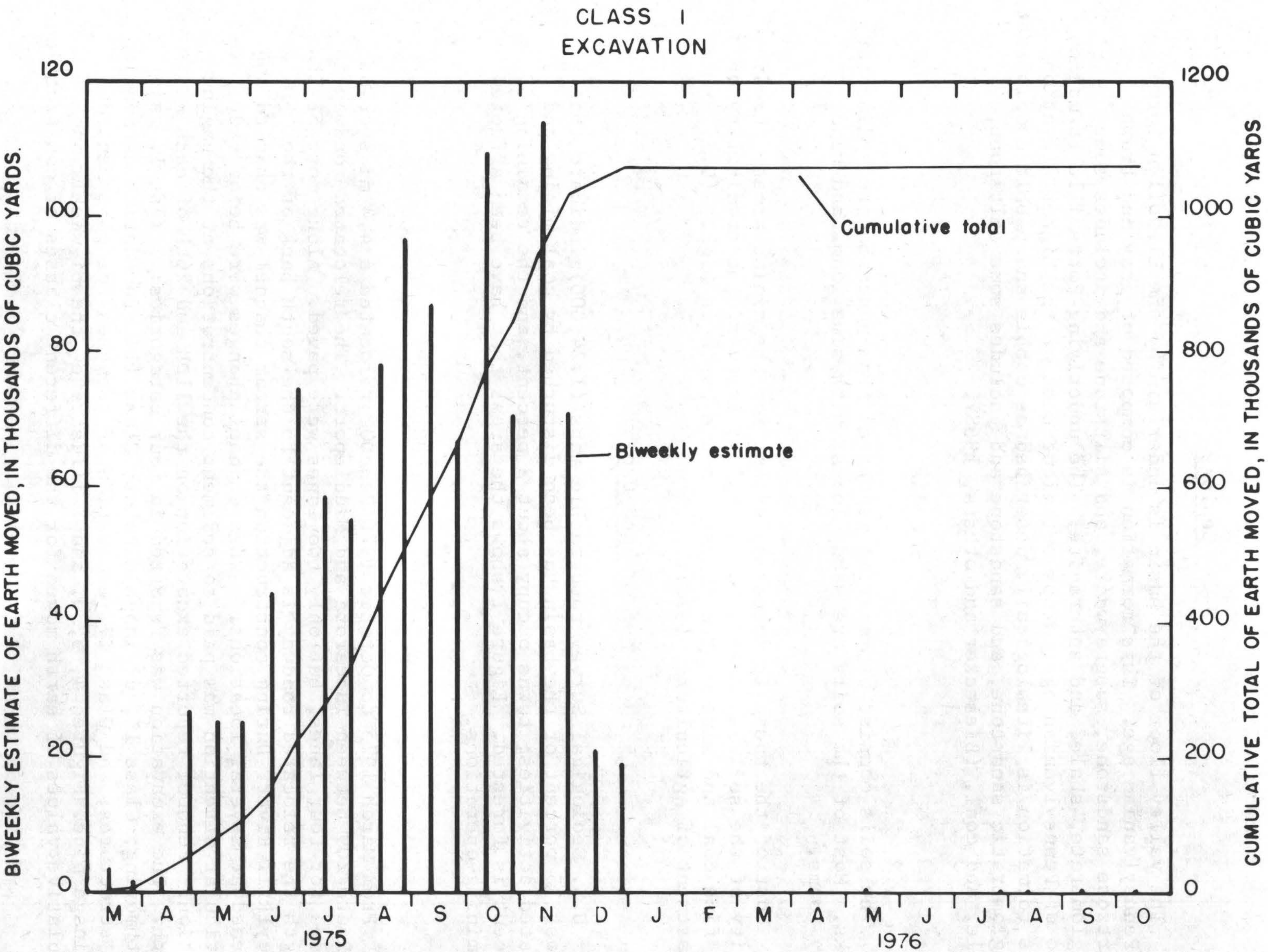


Figure 4.--Biweekly and cumulative amounts of earth moved. Class I excavation between Tuscarora and Middleport, March 1, 1975, to October 26, 1976

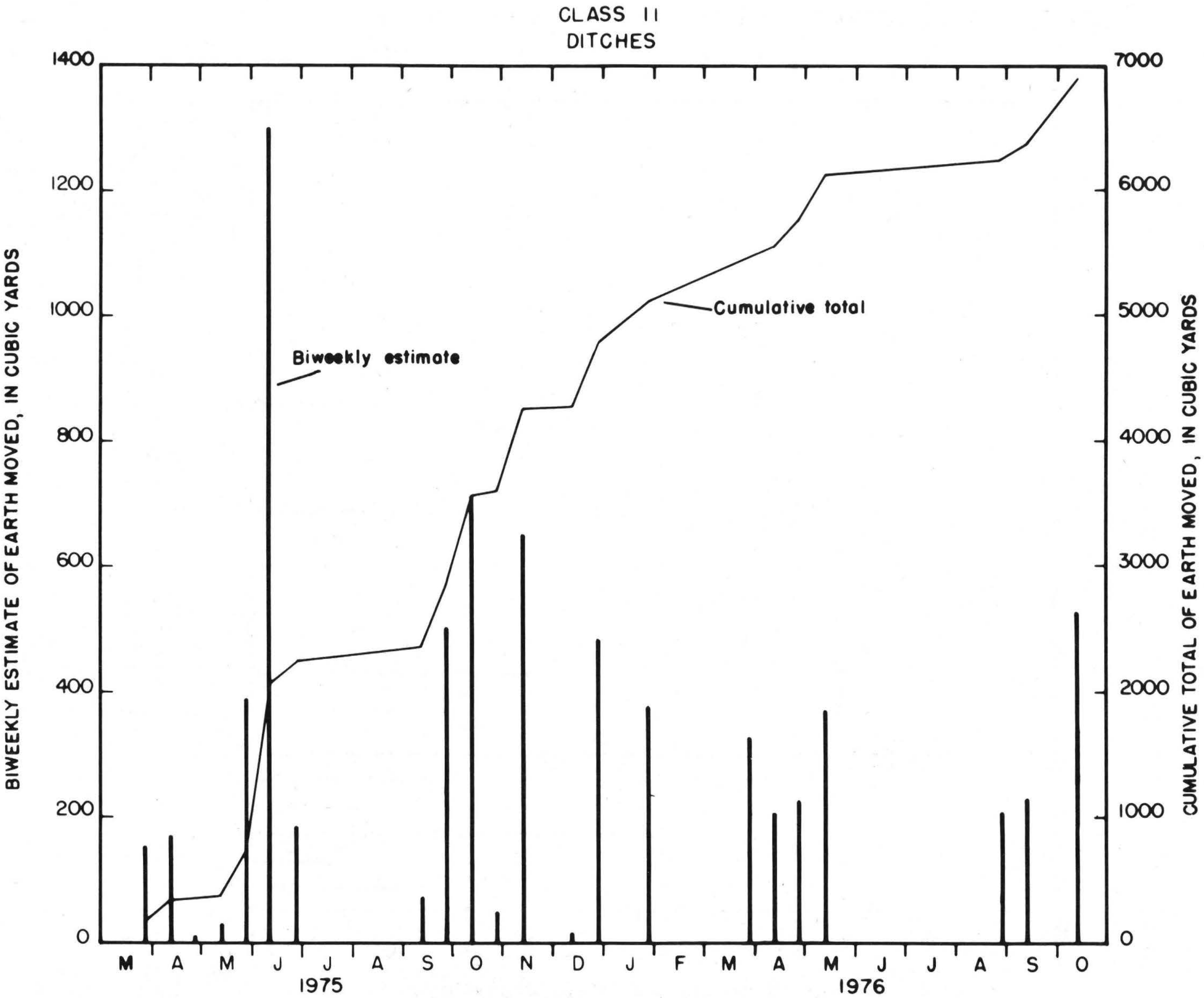


Figure 5.--Biweekly and cumulative amounts of earth moved. Class II execavation between Tuscarora and Middleport, March 1, 1975, to October 26, 1976

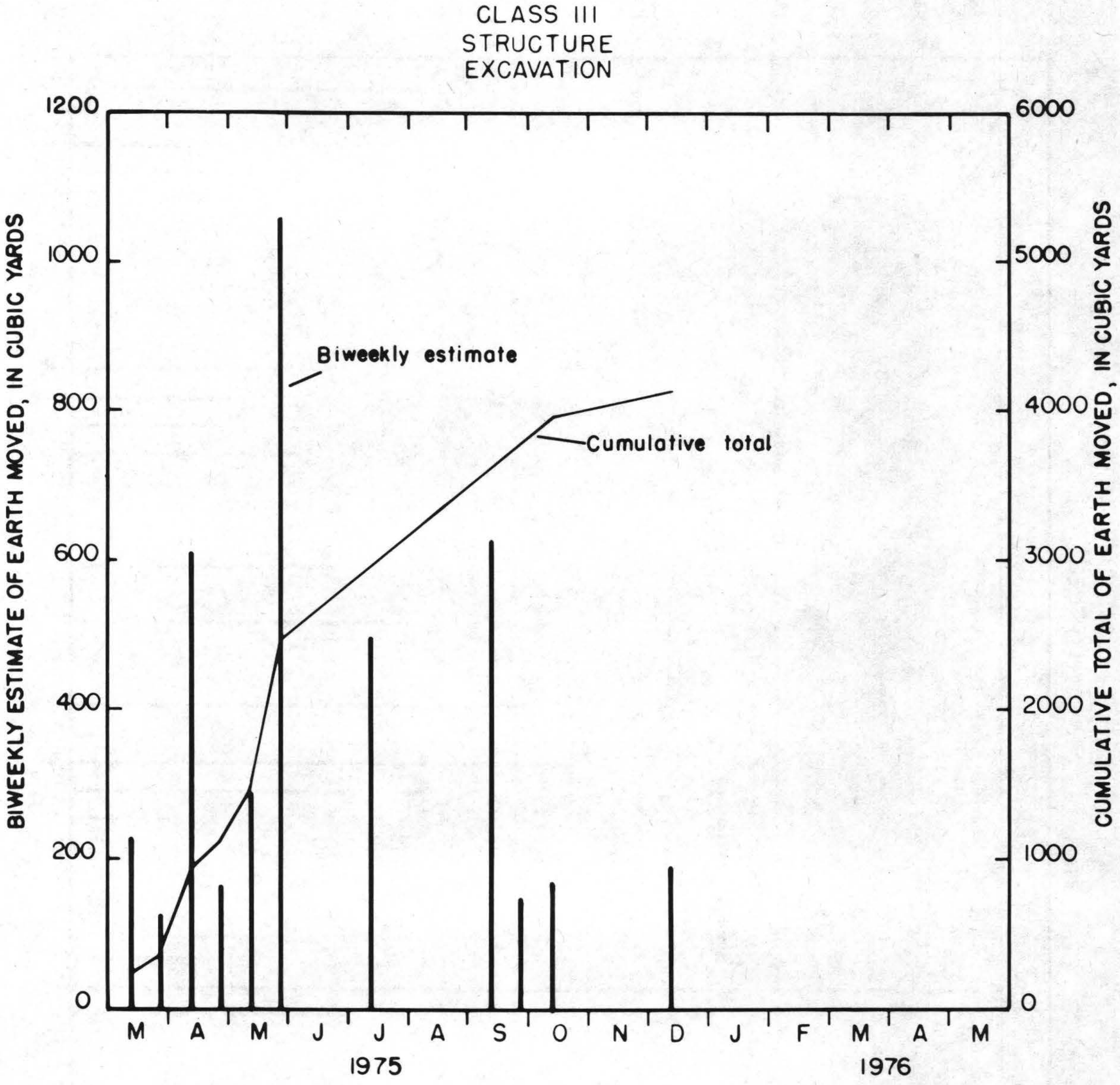


Figure 6.--Biweekly and cumulative amounts of earth moved. Class III excavation between Tuscarora and Middleport, March 1, 1975, to May 26, 1976

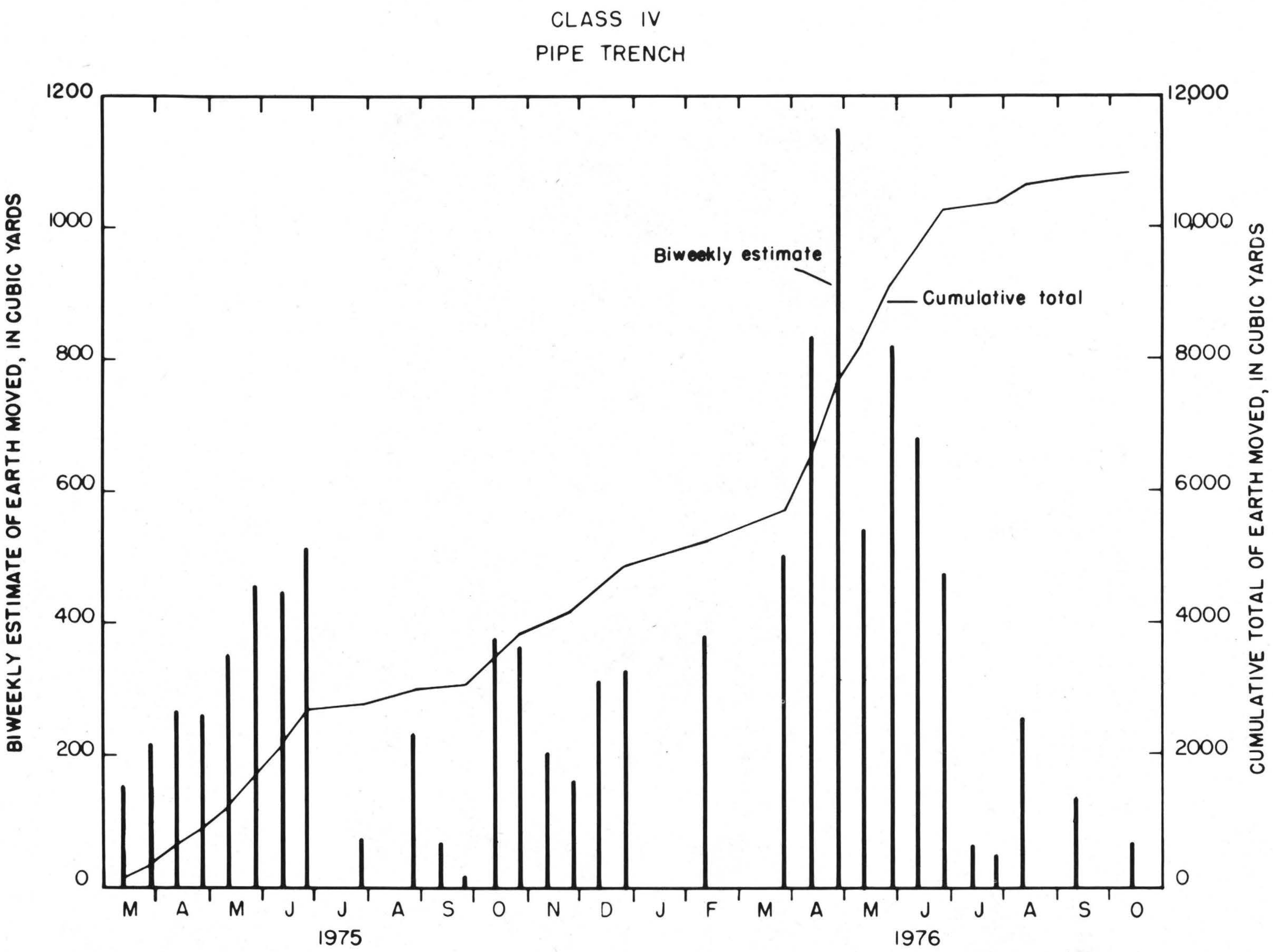


Figure 7.--Biweekly and cumulative amounts of earth moved. Class IV excavation between Tuscarora and Middleport, March 1, 1975, to October 26, 1976

Mulching

During clearing and grubbing, harvested trees were chipped and stockpiled for later use as mulching on the cut and fill slopes (fig. 8). Mulching hay was used in addition to the chips. Seeding, soil supplement, and hay-mulching operations began in May 1975. Wood-chip mulching began in July 1975. Figure 9 illustrates the amount of seeding and hay mulching done during bi-weekly periods, and figure 10 illustrates the amount of wood-chip mulching done during biweekly periods.

Figure 8.--An area where wood-chip mulch was placed

Mulching with wood chips was judged to be successful in controlling sediment erosion; however, placing the chips on cut slopes with mulch blowers was not practical. An attempt was made to grade them with a bulldozer, but depth control was difficult and time consuming. (C. J. Churilla, PennDOT Research Coordinator, oral commun. 1976)

Paving

The construction included grading for four lanes, but only two lanes, or a width of 24 ft, were paved. Paving with bituminous concrete base course was begun on July 15, 1976, and completed by September (fig. 11). Because paving covers much of the exposed soils, it immediately reduces the amount of sediment runoff from the construction area.

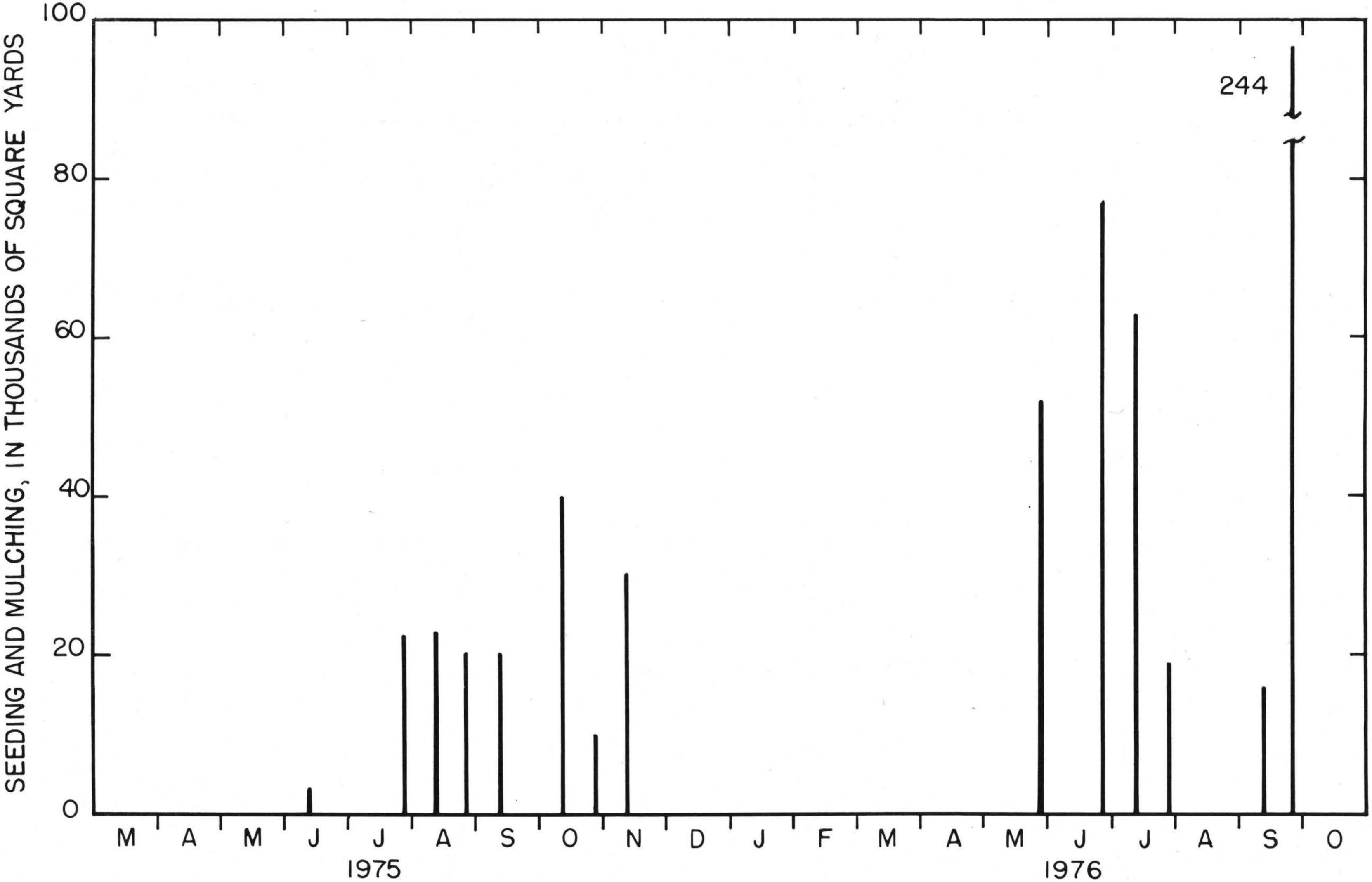


Figure 9.--Biweekly seeding and hay-mulching applications

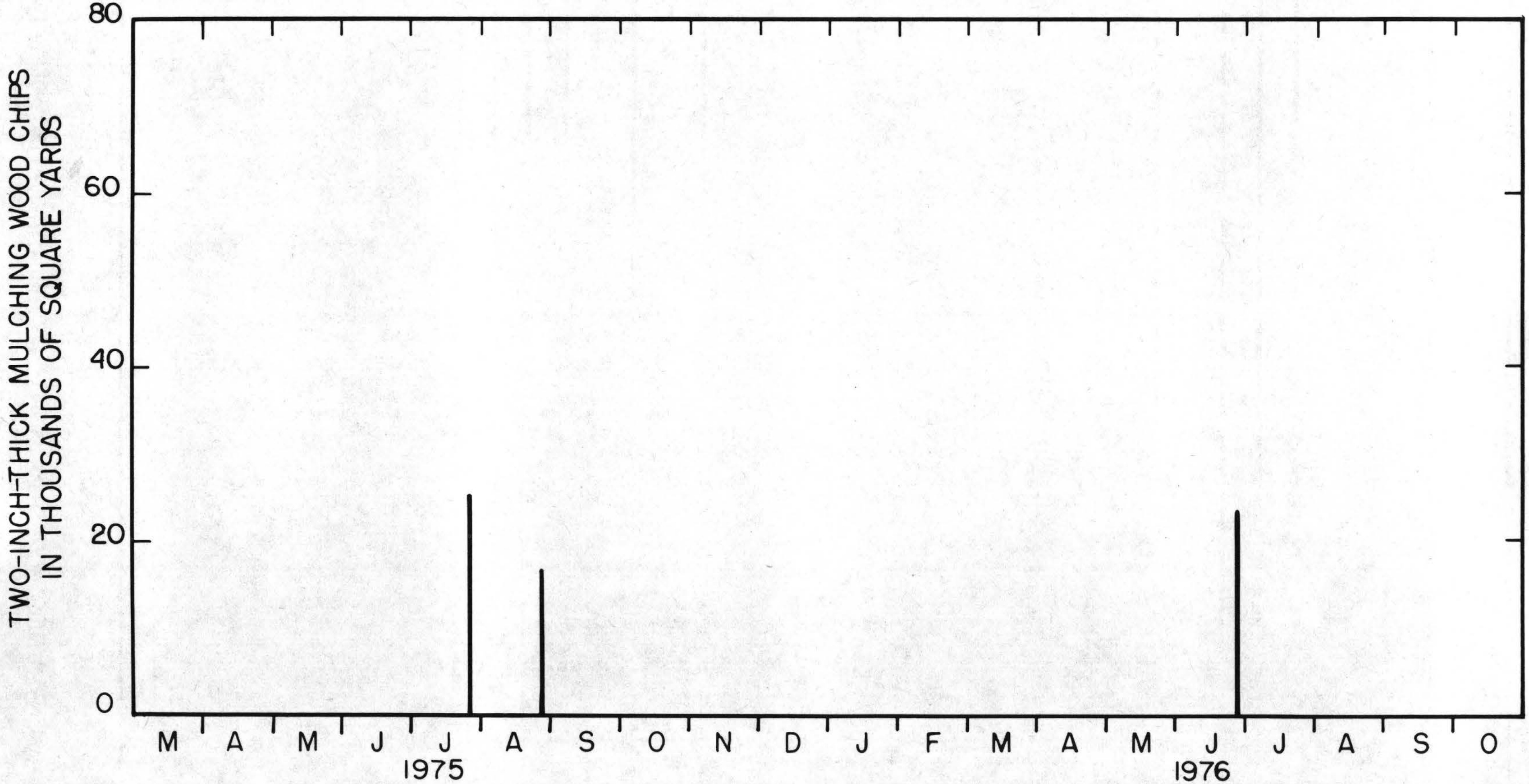


Figure 10.--Biweekly wood-chip-mulching applications

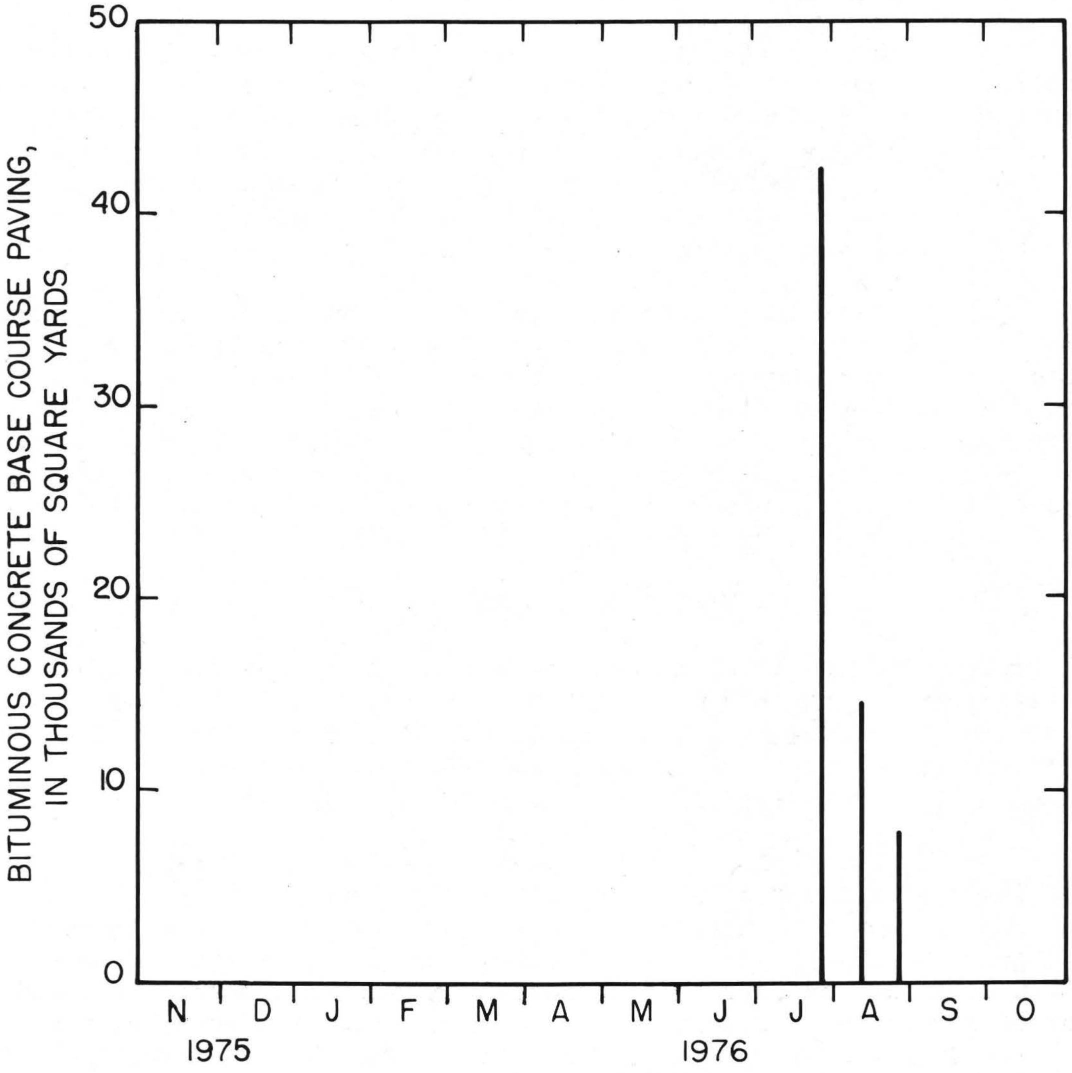


Figure 11.--Biweekly paving placement

STREAMFLOW

Average annual runoff from the basin (1940-64) was 27 in. (Biesecker and others, 1968). For the 23 month period of data collection, which included three low-flow periods and two high-flow periods, streamflow was 42,000 ft^3/s-day (cubic feet per second-day). This is equivalent to 58 in. of runoff. The lowest recorded streamflow was 19 ft^3/s (cubic feet per second), on September 9, 1976, and February 9-12, 1977. Figure 12 shows bi-weekly streamflow for the period of study.

Eight major storms occurred during the study. The first, in July 1975, produced 0.55 in. of runoff over a 2-day period. The second in September 1975 produced 2.0 in. of runoff over a 5-day period. The third during January 26-30, 1976, produced 2.4 in. of runoff. A storm during October 9-12, 1976 produced 1.8 in. of runoff; another during Oct. 20-23 produced 1.3 in. of runoff. A storm on March 4, 1977, produced 1.37 in. of runoff, one on March 13-14 produced 2.70 in. of runoff, and another on March 22 produced 1.50 in. of runoff.

SUSPENDED-SEDIMENT DISCHARGE

Figure 13 illustrates suspended-sediment loads measured bi-weekly. The major part of the sediment load transported during the study period was discharged during relatively short periods. During the study eight storms produced 70 percent of the total suspended-sediment discharge and 18 percent of the total flow over 4 percent of the time.

Figure 14 shows the relation between increase in streamflow and suspended-sediment discharge observed during and after construction at times when streamflow increased by more than 100 ft^3/s. The lines on the figure represent the means of sediment discharge during and after construction and indicate that about 50 percent of the suspended-sediment discharge was a result of the construction. For example, the figure indicates that during construction an increase in streamflow of 400 ft^3/s, produced a mean sediment discharge of about 1,350 tons, but after construction an increase in streamflow of 400 ft^3/s produced a mean sediment discharge of about 700 tons.

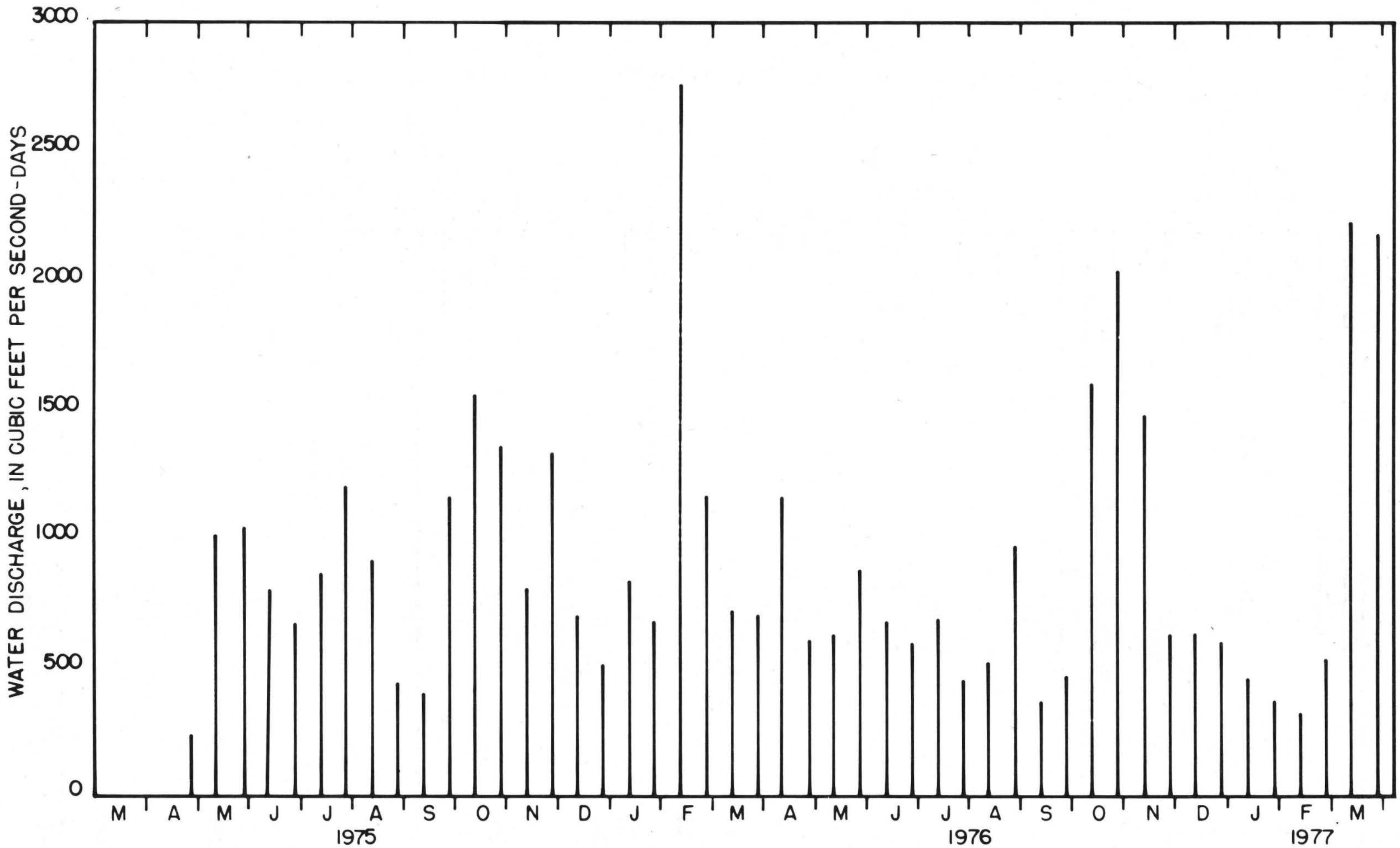


Figure 12.--Biweekly streamflow, Schuylkill River at Port Carbon April 22, 1975, to March 22, 1977

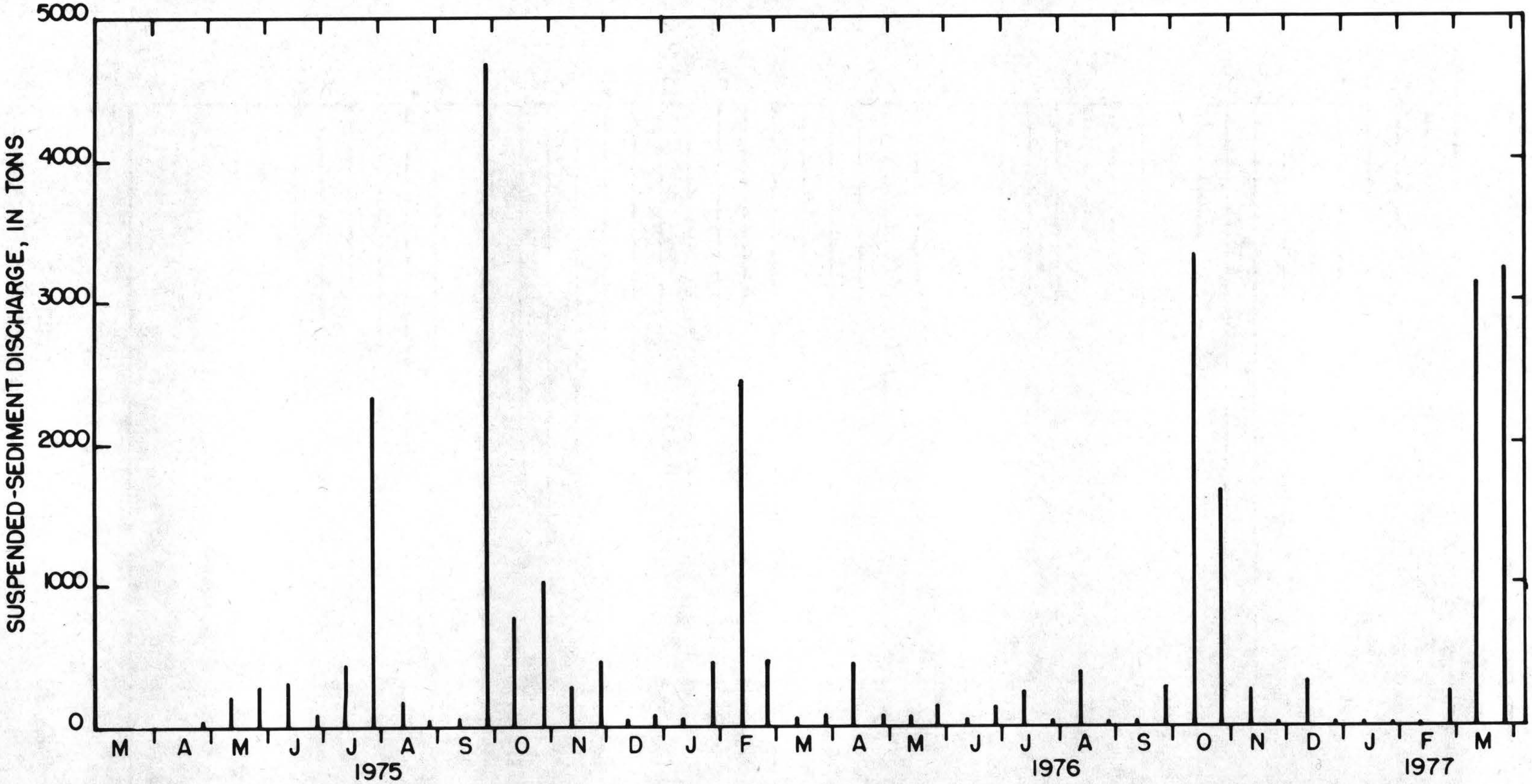


Figure 13.--Biweekly suspended-sediment discharge, Schuylkill River at Port Carbon, April 22, 1975, to March 22, 1977

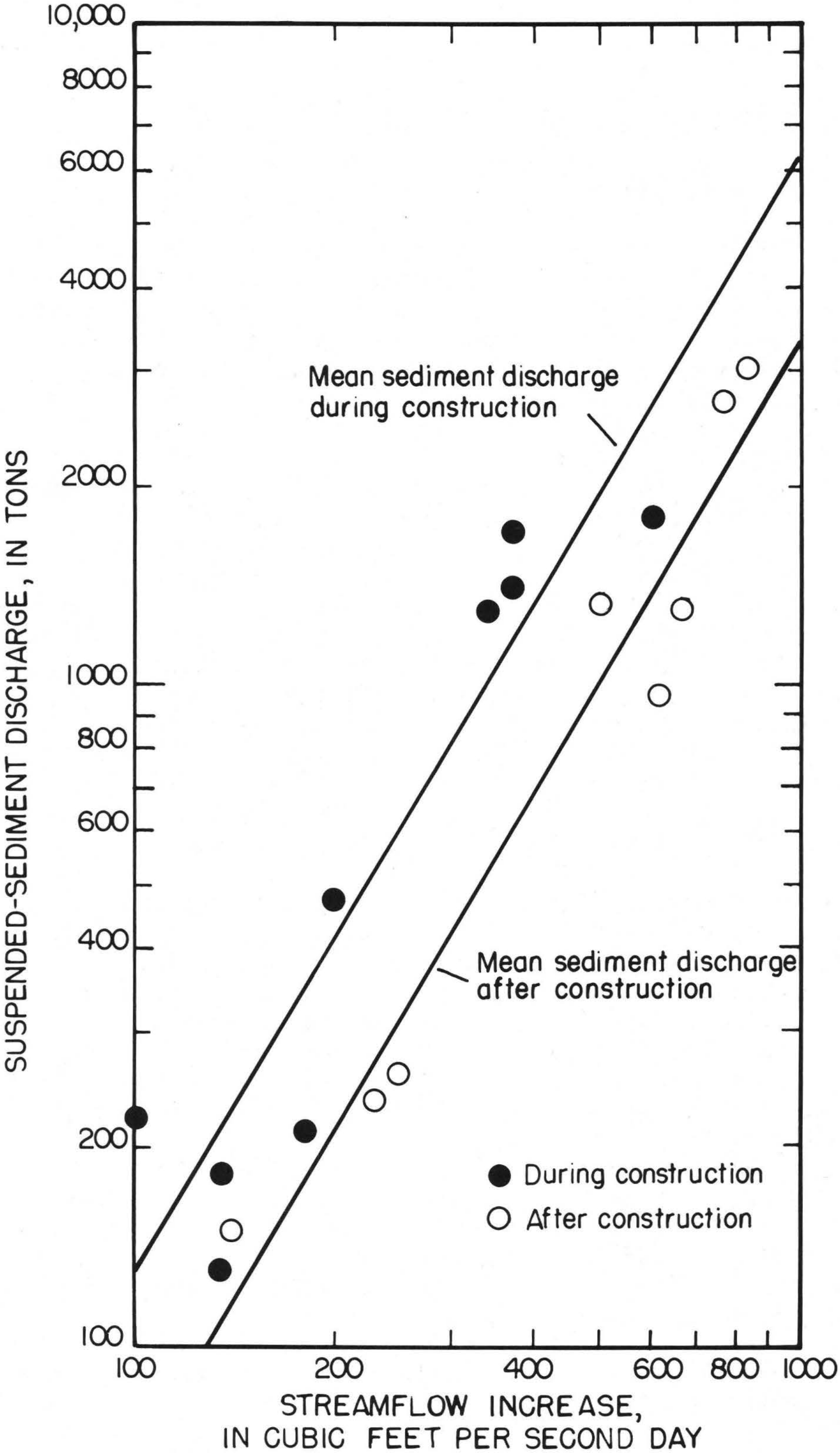


Figure 14.--Relation between increase in streamflow and suspended-sediment discharge from storms during and after highway construction

Figures 15, 16, and 17 show stream stage and suspended-sediment concentrations during three storms, two during construction, and one a month after completion of paving, seeding, and mulching. The storms on July 25, 1975 (fig. 15) and September 25, 1975 (fig. 16) produced sediment loads of 1,800 and 1,400 tons, respectively. The storm on October 21, 1976 (fig. 17) had a peak flow about 30 percent higher than the July and September storms and produced a sediment load of 1,200 tons. Had the storms been identical, the sediment load transported by the October storm would have been about 750 tons. Using data collected during highway construction in soils with a similar erodibility the storm on July 25, 1975, should have produced a sediment discharge of 3 to 5.5 tons per acre of construction (L.A. Reed, oral commun. 1977). The 130 acres exposed by construction should, therefore, have yielded a sediment load of between 400 and 750 tons.

Land use and individual basin characteristics are the dominant influence on sediment yield from small basins (Brown, 1950). In this basin the combination of steep slopes and the availability of fine coal determined the nature of the sediment load. During some periods of high flow as much as 30 percent of the suspended sediment was coal. The study period coincided with the recent and on-going "energy-crisis," which has stimulated increased coal mining and related activities in the area.

TURBIDITY AND SUSPENDED-SEDIMENT CONCENTRATION

Turbidity was monitored continuously at the gaging site, using a surface-scatter turbidimeter, as an aid in estimating the daily sediment concentration when suspended-sediment samples were not available. Figure 18 shows a section of the turbidity record and the estimated suspended-sediment concentration at a time when the stream stage remained constant and the increase in concentrations was caused by construction work in the stream channel. The suspended-sediment concentration shown in figure 18 was constructed from the turbidity record by methods outlined by Truhlar (1976).

The suspended-sediment samples filtered for concentration analysis were classified into one of four color categories: orange, brown, gray, or black. The color-coded sediment concentrations were plotted against turbidity (fig. 19). At low concentrations, or low flows, the suspended sediment was mostly orange, and at moderate concentrations, or flows, it was mostly brown. The suspended sediment was mostly gray when the stream was rising and mostly black near and during peak flow. The gray and black colors were caused by coal.

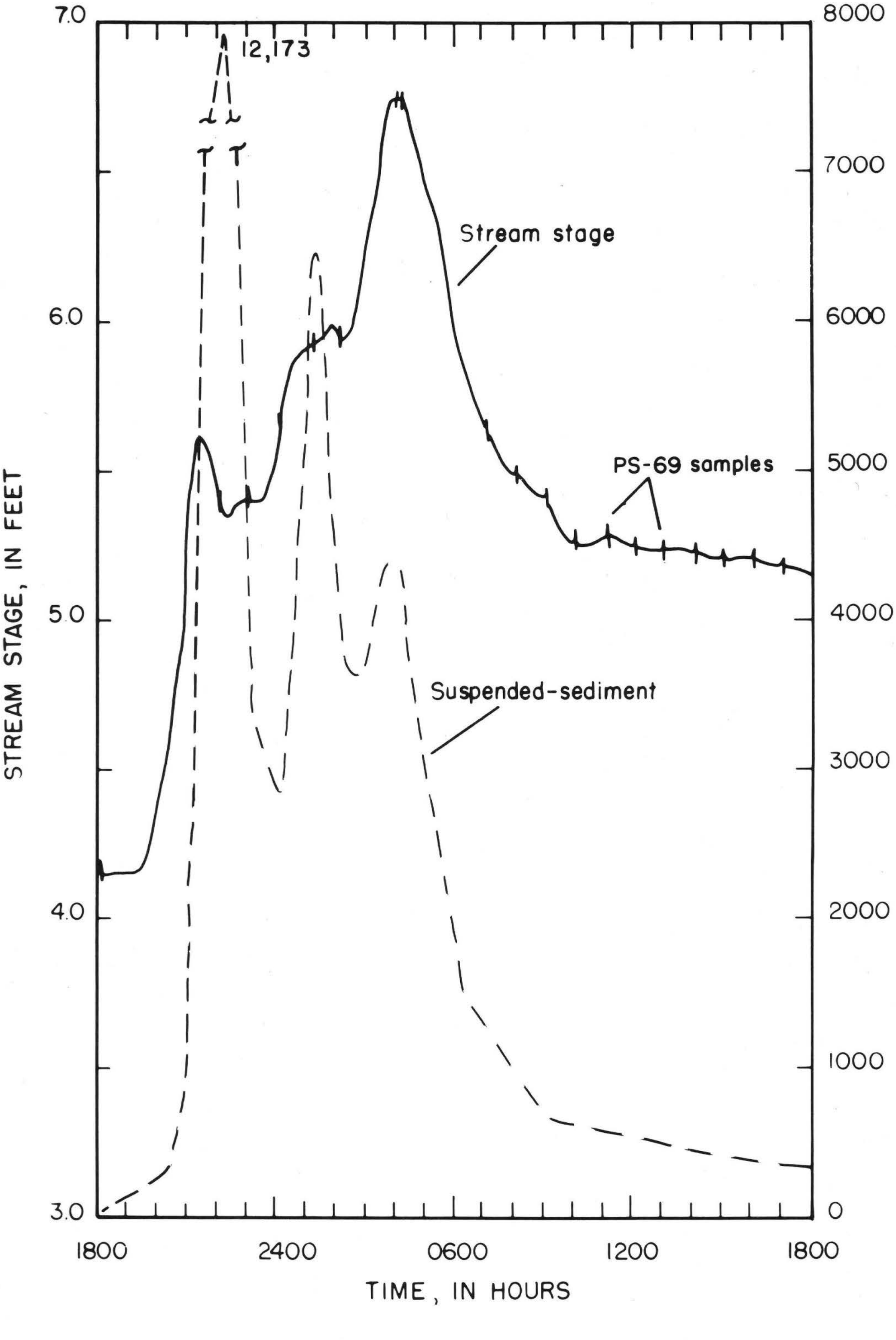


Figure 15.--Stream stage and suspended-sediment concentration Schuylkill River at Port Carbon, July 25, 1975

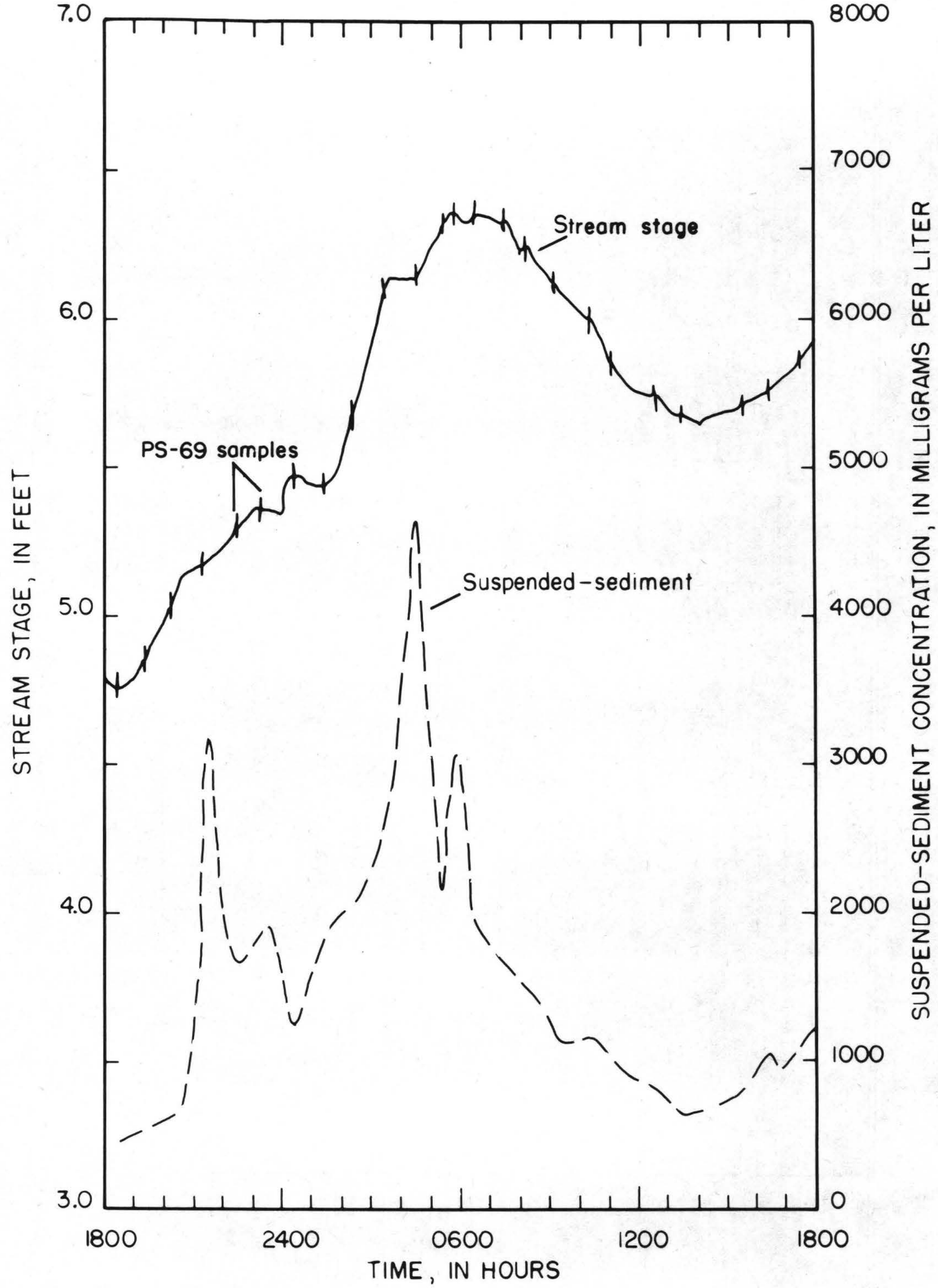


Figure 16.--Stream stage and suspended-sediment concentration, Schuylkill River at Port Carbon, September 25, 1975

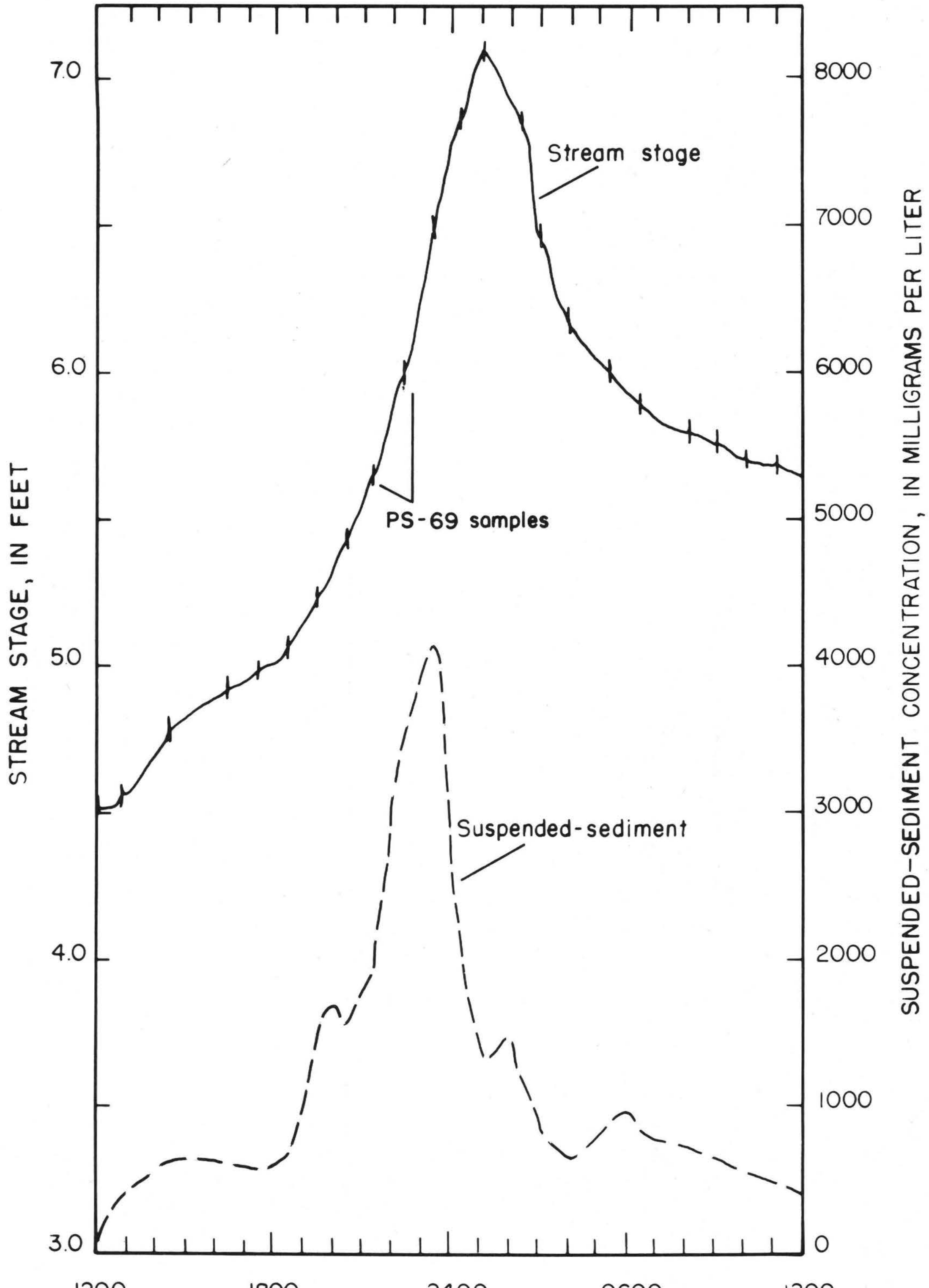


Figure 17.--Stream stage and suspended-sediment concentration, Schuylkill River at Port Carbon, October 21-22, 1976

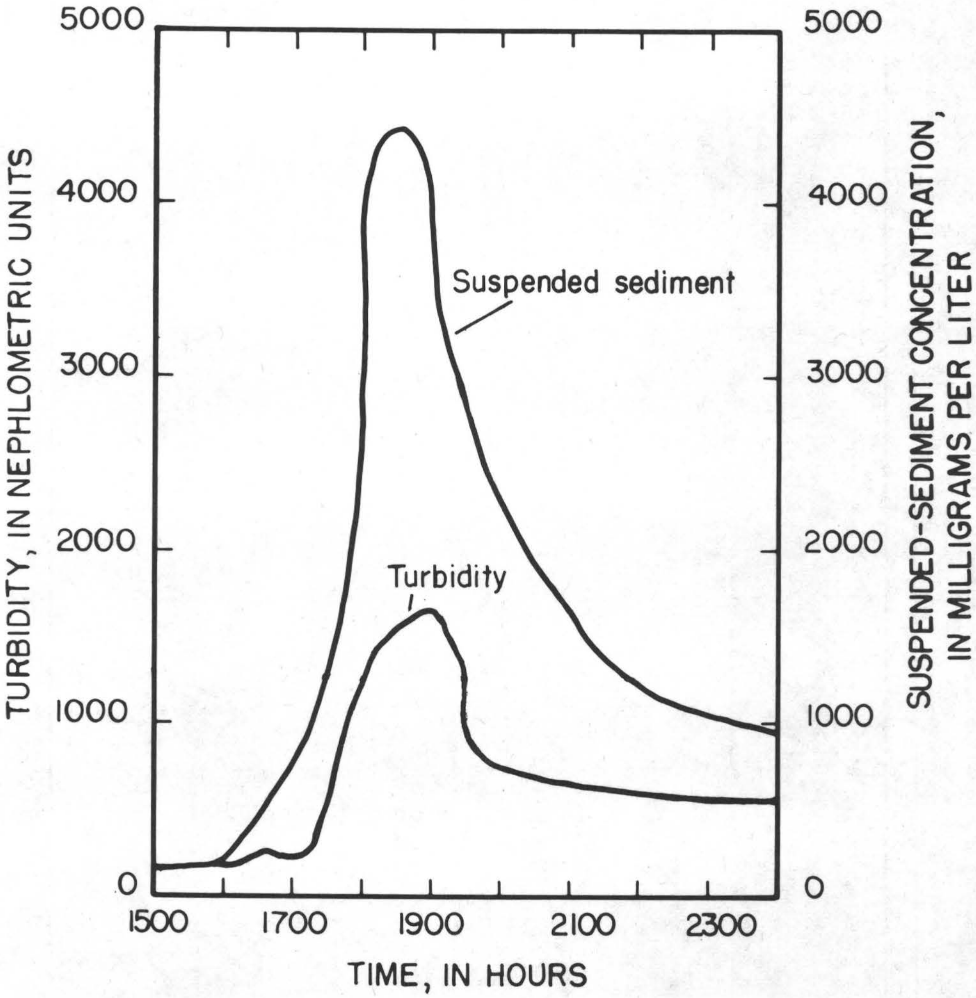


Figure 18.--Suspended-sediment concentration during a period of channel construction, when stream stage remained constant, as reconstructed from a turbidity record, Schuylkill River at Port Carbon, October 6, 1975.

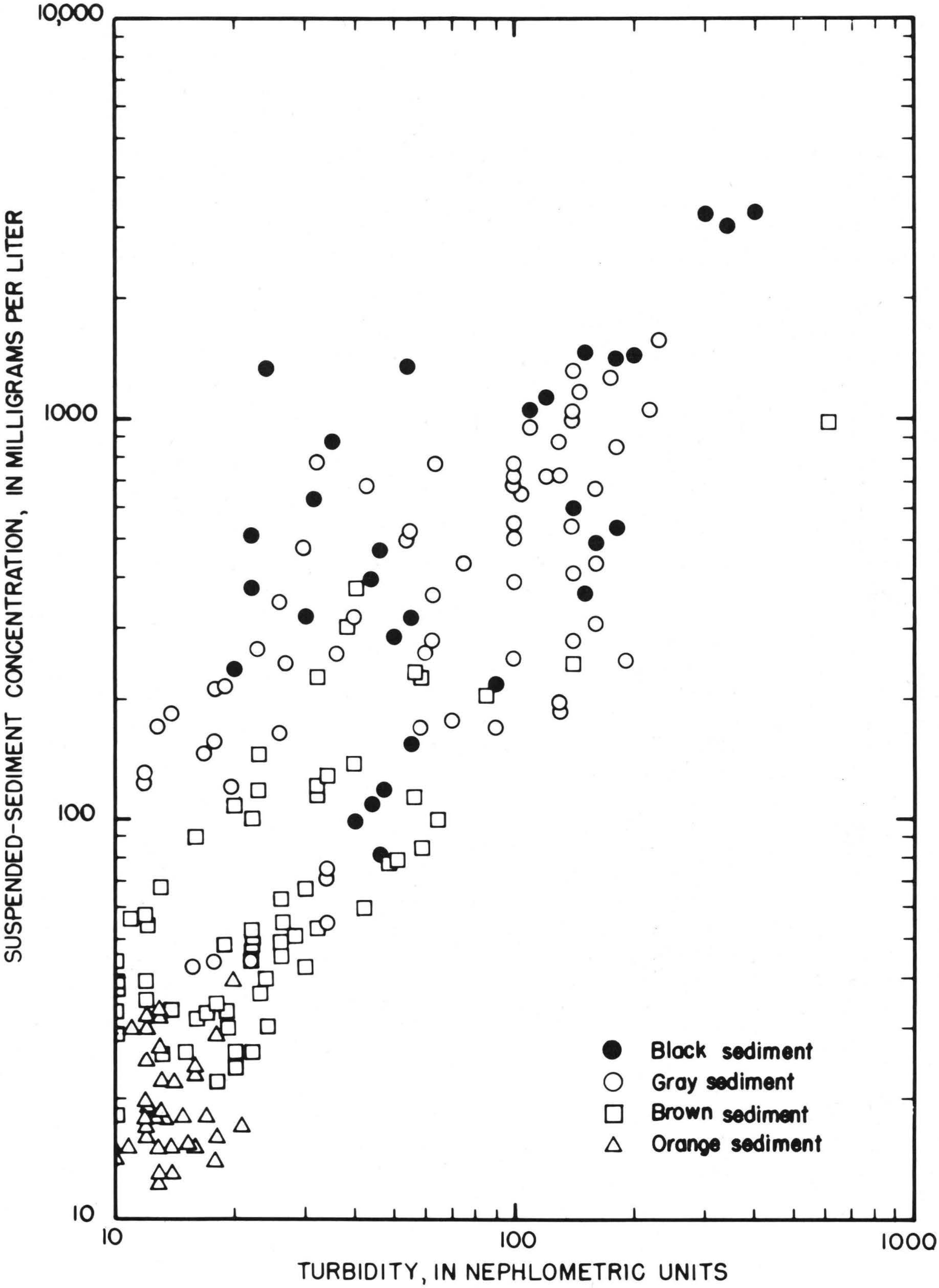


Figure 19.--Relation between suspended-sediment concentration, turbidity, and color of sediment, Schuylkill River at Port Carbon, April 22, 1975, to October 26, 1976

SUMMARY AND CONCLUSIONS

An investigation of a 27.1 mi^2 drainage area in the upper Schuylkill River basin, in Schuylkill County near Port Carbon, Pa., was made from April 1975 to March 1977 to document the sediment loads and to appraise the methods of erosion control used by PennDOT in relocating 4.3 mi of State Route 209 through the basin. Most of the construction was adjacent to the river.

A gaging station with stage recorder, turbidimeter, automatic sediment sampler, and precipitation recorder was installed 6 miles downstream from the construction. The automatic sediment sampler was triggered by the turbidimeter and by stream stage to collect samples during periods of increased turbidity and increased streamflow, as well as periodically. Data collection began shortly after the start of construction (March 1975) and continued for 6 months after its completion, a period of 23 months.

The primary method of sediment erosion control employed by PennDOT was prompt seeding and mulching of exposed soils. Seeding and mulching operations began in May 1975 and were concluded in September 1976. Mulching with wood chips was judged to be successful in controlling erosion; though the placement of chips on the cut slopes was difficult. Because paving covers much of the exposed soils and immediately reduces the amount of sediment runoff from the construction area, it was also considered an effective method of reducing erosion. Paving was begun on July 15, 1976, and completed by mid-September.

The major part of the sediment load transported during the study period was discharged during relatively short periods of time. Seventy percent of the total suspended-sediment discharge and eighteen percent of the total flow occurred during eight storms that occupied only four percent of the study period. Average annual sediment yields from the basin are 350-500 tons/mi^2. During construction, about 50 percent of the sediment load was produced by the construction; the remaining load was produced from the steep slopes and fine coal in the basin.

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