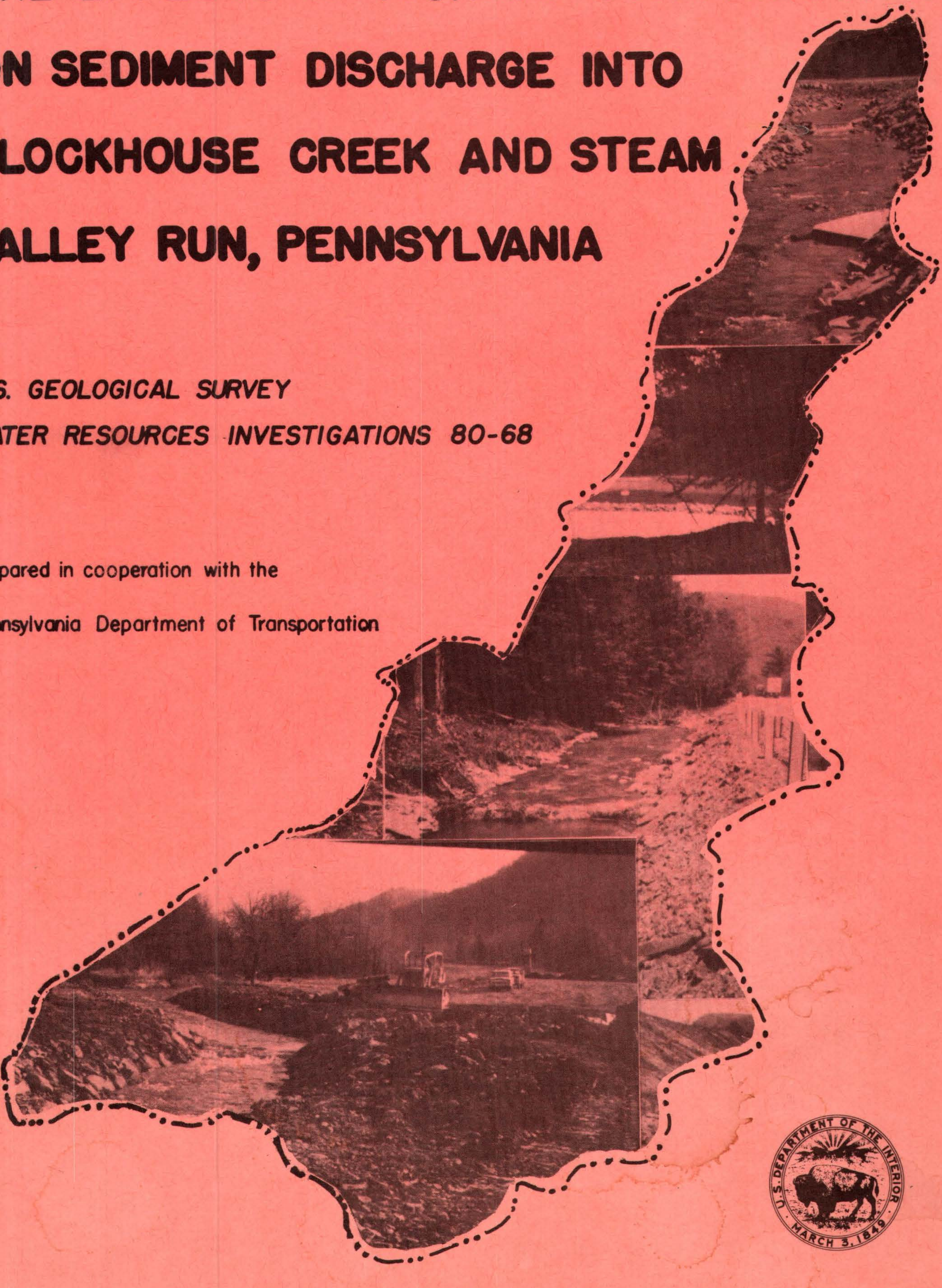
THE EFFECTS OF HIGHWAY CONSTRUCTION ON SEDIMENT DISCHARGE INTO BLOCKHOUSE CREEK AND STEAM VALLEY RUN, PENNSYLVANIA



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From October 1972 through September 1977, the effects of highway construction in the 38 square mile Blockhouse Creek basin were studied. Water discharge suspended-sediment discharge, and stream-temperature data were collected at four stations in the basin. The 5-year period included 1 year before construction, 2 years during construction, and 2 years after construction. The effects of stream relocation and sediment-control methods used in the highway construction were also investigated.

During the period of data collection, about 35,500 tons of suspended sediment were transported by Blockhouse Creek and Steam Valley Run. The data collected indicate that 9,100 tons were introduced to the stream from construction areas. The normal sediment yield for the two basins was determined to be 80 tons per square mile per year. Most of the sediment was transported by the streams during high flows and probably passed through Blockhouse Creek, as little deposition was observed below the construction area. Stream temperature appeared to be relatively unaffected by the stream relocations and diversions.

Stream relocation and diversion methods were successful in limiting the amount of sediment discharged by the new channels. Physical sediment-control methods limited sediment discharge during baseflow periods and small storms. Coarse sediments especially were controlled by these methods. The most effective method of sediment control was limiting the amount of time that the construction-area soils were exposed.

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AND STEAM VALLEY RUN, PENNSYLVANIA

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Williamsport, Pennsylvania 17701

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Multiply inch-pound units	By	To obtain SI units
inch (in.)	25.40	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	.4047	hectometers (hm^2)
ton, short	907.2	kilomgrams (kg)
cubic foot per second (ft^3/s)	.02832	cubic meter per second (m^3/s)
cubic foot per second-day (ft^3/s-d)	.02832	cubic meter per second-day (m^3/s-d)
cubic foot per second per square mile $(ft^3/s)/mi^2$	1.609	cubic meter per second per square kilometer $(m^3/s)/km^2$
square foot (ft^2)	.0929	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
ton per square mile (ton/mi^2)	350.3	kilograms per square kilometer (kg/km^2)
ton per day (ton/day)	907.2	kilograms per day (kg/d)
degree Fahrenheit (°F)	-32 x 5/9	degree Celsius (°C)

THE EFFECTS OF HIGHWAY CONSTRUCTION ON SEDIMENT DISCHARGE INTO BLOCKHOUSE CREEK AND STEAM VALLEY RUN, PENNSYLVANIA

By Robert A. Hainly

ABSTRACT

From October 1972 through September 1977, the effects of highway construction in the 37.7 square mile Blockhouse Creek basin were studied. Water discharge, suspended-sediment discharge, and stream-temperature data were collected at four stations. The 5-year period included 1 year before construction, 2 years during construction, and 2 years after construction. The effects of stream relocation and sediment-control methods used in the highway construction were also investigated.

During the period of data collection, about 35,500 tons of suspended sediment was transported by Blockhouse Creek and Steam Valley Run. The data collected indicate that 9,100 tons was introduced to the stream from construction areas. Preconstruction sediment yield of the two basins was determined to be 80 tons per square mile per year. Most of the sediment was transported by the streams during high flows and probably passed through Blockhouse Creek, as little deposition was observed below the construction area. Stream temperature seemed to be relatively unaffected by the stream relocations and diversions.

Stream relocation and diversion methods were successful in limiting the amount of sediment discharged by the new channels. Physical sediment-control methods limited sediment discharge during baseflow periods and small storms. Coarse sediments, especially, were controlled by these methods. The most effective method of sediment control was limiting the amount of time that the construction-area soils were exposed.

INTRODUCTION

The U.S. Geological Survey, in cooperation with the Pennsylvania Department of Transportation (PennDOT) and the Federal Highways Administration, has investigated stream-sediment discharges in several basins affected by highway construction (Reed, L. A., 1971, 1978; Helm, R. E., 1978; Eckhardt, D. A. V., 1976). This report describes sediment discharge before, during, and after the relocation and reconstruction of 9 mi of Pennsylvania Route 15 in the Blockhouse Creek basin in northern Lycoming and southern Tioga counties. The construction area extended from 18.5 mi north of Williamsport to 12.5 mi south of Blossburg. The Route 15-construction project is part of the Appalachian throughway system and will open an area where commerce, recreation, and communication have been inhibited by lack of adequate access.

A concentrated effort was made during construction to avoid disturbance of the ecological balance in and downstream from the construction area. Extensive sediment controls were installed to control excess sedimentation. The road construction started in May 1973 and was completed by October 1975. This report presents the data collected from October 1972 through September 1977 and shows the effects of construction on suspended-sediment discharge and the effectiveness of controls established by PennDOT.

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 Highways Administration. This report does not constitute a standard, specification, or regulation.

BASIN DESCRIPTION

Hardwood forest covers most of the southern half of the basin, and dairy farming predominates in the northern half.

Figure 1 shows the division in land use and the locations of the four stream sampling stations. Blockhouse Creek drains 37.7 mi^2; 13 mi^2 is devoted to agriculture, and the remaining 24 mi^2 is primarily forest land or abandoned farm land, which is reverting to forest. Elevations range from 1,042 ft above mean sea level near English Center to just over 2,300 ft at the top of Laurel Mountain. Stream slopes range from 40 ft/mi in the main stem of Blockhouse Creek to 150 ft/mi in Steam Valley Run.

Land use is generally determined by the terrain. The steep slopes in the south make dairy farms such as those in the north impractical.

The dairy farms of the northern region are small, family-owned operations of about 150 acres. The forested regions consist mostly of trees typical of a northern hardwood forest. Common species are sugar maple, beech, yellow birch, black cherry, and hemlock. Some sections also contain stands where varieties of oak predominate (Denny and Lyford, 1963).

Geology

The Blockhouse Creek basin is near the border of the Pleistocene Wisconsin Drift in north-central Pennsylvania. The Drift boundary crosses the study area south of Buttonwood. The glacier covered the entire basin except for about half of the Steam Valley Run basin and half of the drainage area between Buttonwood and English Center.

Figure 2 shows the general locations of the major geologic units (Pennsylvania Topographic and Geologic Survey, 1960).

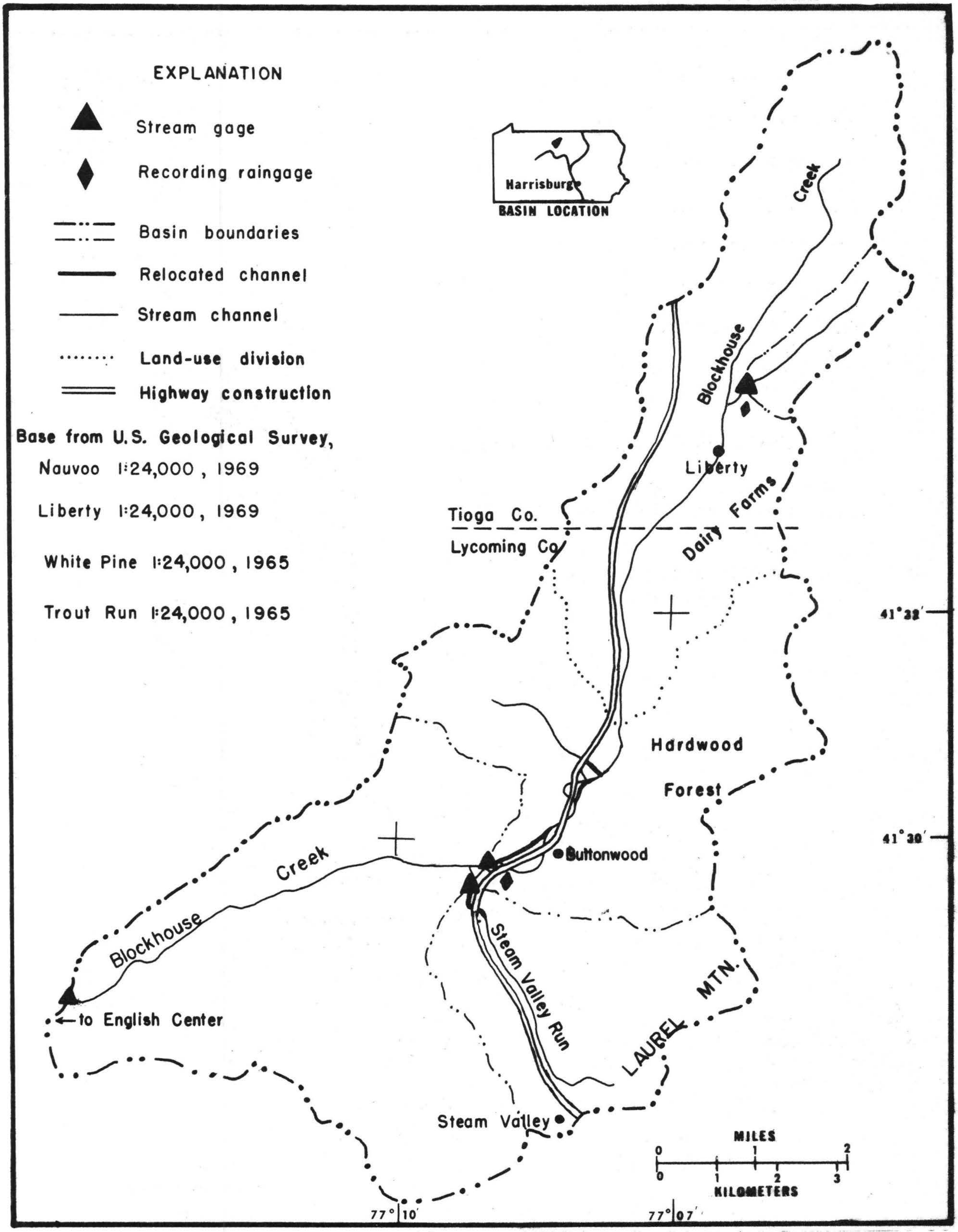

Figure 1.--Blockhouse Creek basin, showing stream monitoring sites, the highway, and a land-use-division line.

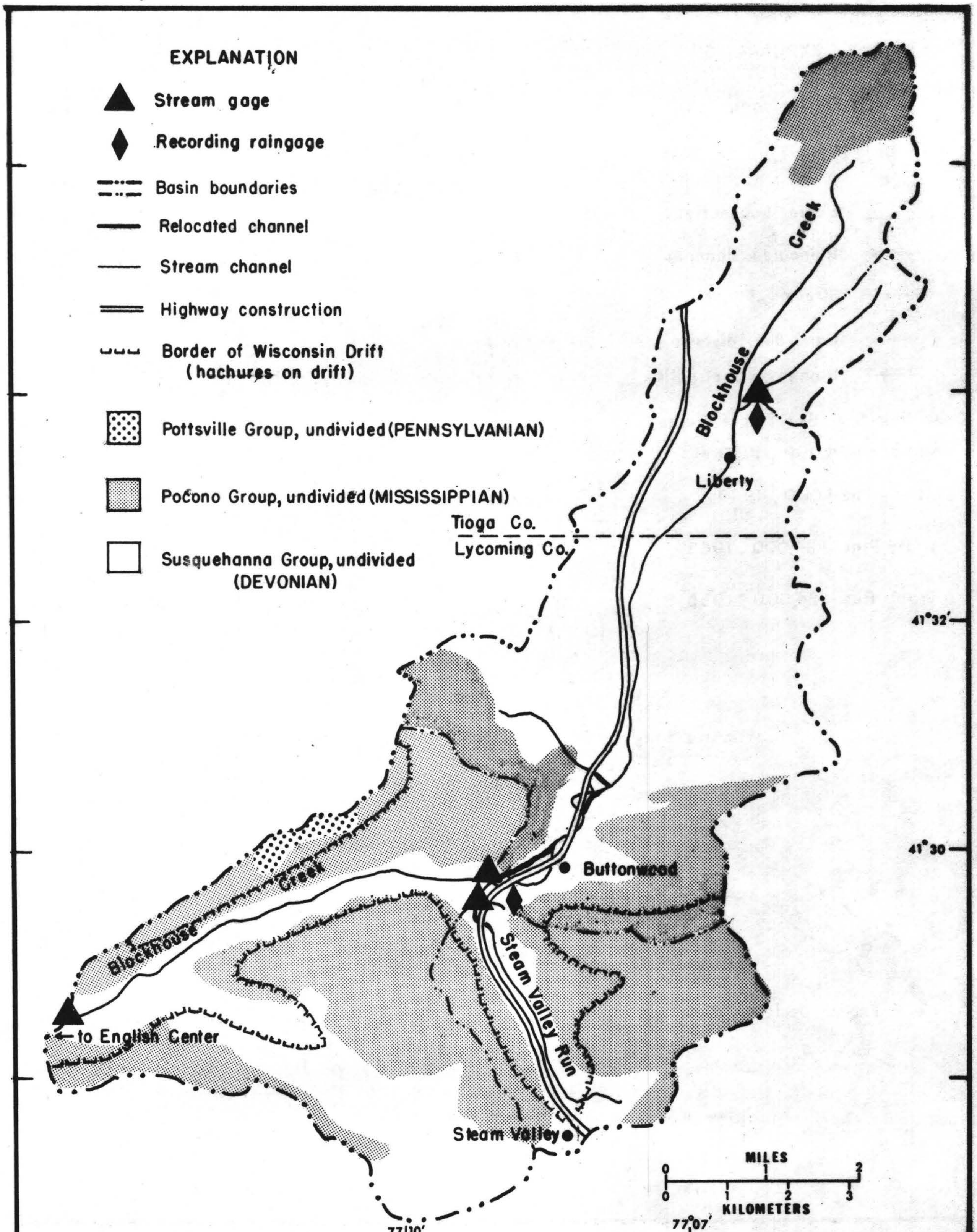

Figure 2.--General geology of the Blockhouse Creek basin.

Most of the upstream section of the basin and the valleys in the downstream section are underlain by formations of the Susquehanna Group of Devonian age. The areas at higher altitude in the south are underlain by the predominantly gray, hard, and massive cross-bedded conglomerate and sandstone. Some shale is also present. These formations are characteristic of the Pocono Group of Mississippian age. A small area known locally as "Sugar Hill," 2.8 mi west of Buttonwood, is underlain by light-gray to white coarse-grained sandstone and conglomerate and some mineable coal, of the Pottsville Group of Pennsylvanian age.

Soils

Most soils were formed from till. Reddish substrata predominates and grayish substrata occurs locally. The till was deposited during Wisconsin Glaciation of the Pleistocene Epoch. Bedrock outcrops protrude through the soil, and small pockets of waterlaid drift and alluvium are present in the till. The exposed thickness of till is as much as 40 ft, and the maximum thickness is more than 100 ft. The exposed thickness of colluvium reaches a maximum of 15 ft (Denny and Lyford, 1963).

The soils, except those in the Steam Valley Run basin, belong to the Morris-Wellsboro-Oquaga Association. About 30 percent of the association is Morris soils, 20 percent Wellsboro soils, and 10 percent Oquaga soils. The percentage does not total 100 percent because of the presence of minor amounts of other soils. Each of these soils has a K value (Wischmeier and Smith, 1965) of 0.28. Soils with a K value of 0.17 are generally considered erodible, those with a K value of 0.28 moderately erodible, and those with a K value of 0.43 or higher highly erodible. Soil erodibility values are partly based on the particle-size composition and structure of the soil. Soils on a construction area can be much more erosive if the structure is changed by heavy equipment traffic (U.S. Department of Agriculture, 1972).

Soils in the Steam Valley Run basin belong to the Oquaga-Wellsboro-Morris Association. About 40 percent of the association is Oquaga, and about 10 percent each is Wellsboro and Morris. Figure 3 shows the general location of the soil types.

CLIMATE

Climate of the basin is characterized as continental inland. Typically, cold and dry winds are from the west and northwest, and warm and humid winds are from the south and southwest. National Oceanic and Atmospheric Administration (NOAA) records from English Center, 9 mi southwest of the centroid of the area under investigation (fig. 1), show average January and July temperatures to be 26.3°F (-3.2°C) and 72.6°F (22.6°C) (table 1). The average frost-free season from mid-May to mid-September is about 130 days. Mean monthly and annual temperatures for 18 years of record are shown in table 1. (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 1972-1977.)

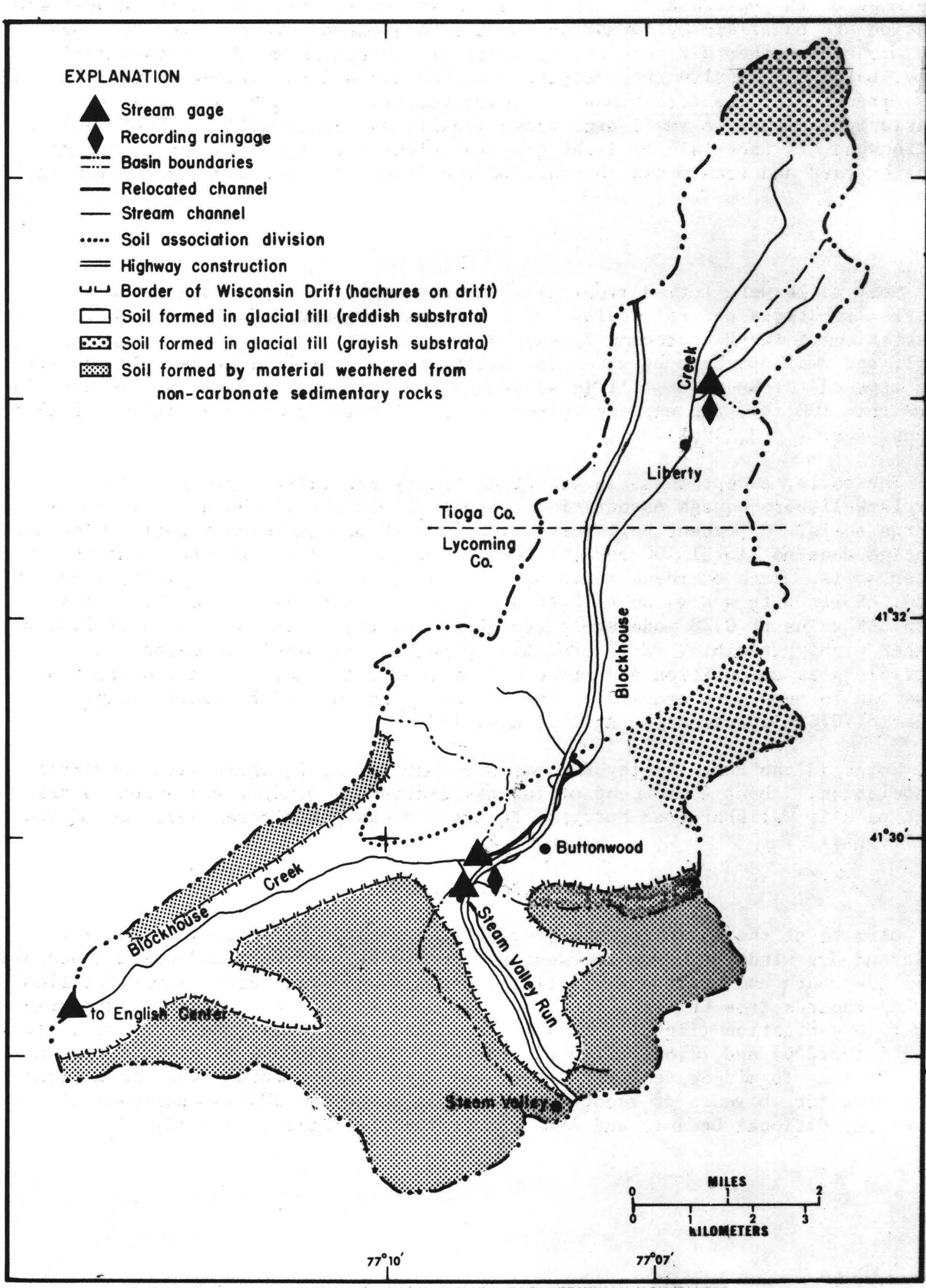

Figure 3.--General location of soil types and the border of the Wisconsin drift.

Table 1.--Mean monthly temperature at English Center, Pa., for 18-year period of record, in degrees Fahrenheit (°F)

January	February	March	April	May	June	July
26.3	28.8	37.5	49.5	59.6	68.4	72.6
August	September	October	November	December	Mean Annual Temp.	
70.7	63.8	46.7	46.1	30.1	50.0°F	

NOAA climatological records show average winter temperatures in the high 20's and average summer temperatures in the low 70's. Temperature extremes during the 5-year investigation were 98°F (36.7°C) and -20°F (-28.9°C).

Precipitation was recorded continuously at the Blockhouse Creek gage at Liberty and at the Blockhouse Creek gage at Buttonwood. Average monthly precipitation ranges from 4.10 in. in May to 2.16 in. in February. Most summer storms have intense rainfalls of short duration. Whereas, most winter storms are moderate to light in intensity.

Precipitation at the Liberty and Buttonwood stations was averaged and compared with precipitation at the NOAA station at English Center (fig. 4). Monthly precipitation for the period of investigation is shown in figure 5. The average monthly precipitation measured at the NOAA station for the period of record is listed in table 2.

Table 2.--Average monthly precipitation in inches at English Center for 38-year period of record

January	February	March	April	May	June	July
2.17	2.16	3.31	3.26	4.10	3.36	3.72
August	September	October	November	December	Average Annual Precipitation	
3.26	2.85	3.05	3.51	2.58	37.33 in.	

Precipitation during December, January, and February may be entirely in the form of snow, but occasionally precipitation will start as snow and change to sleet and freezing rain or simply rain before ending.

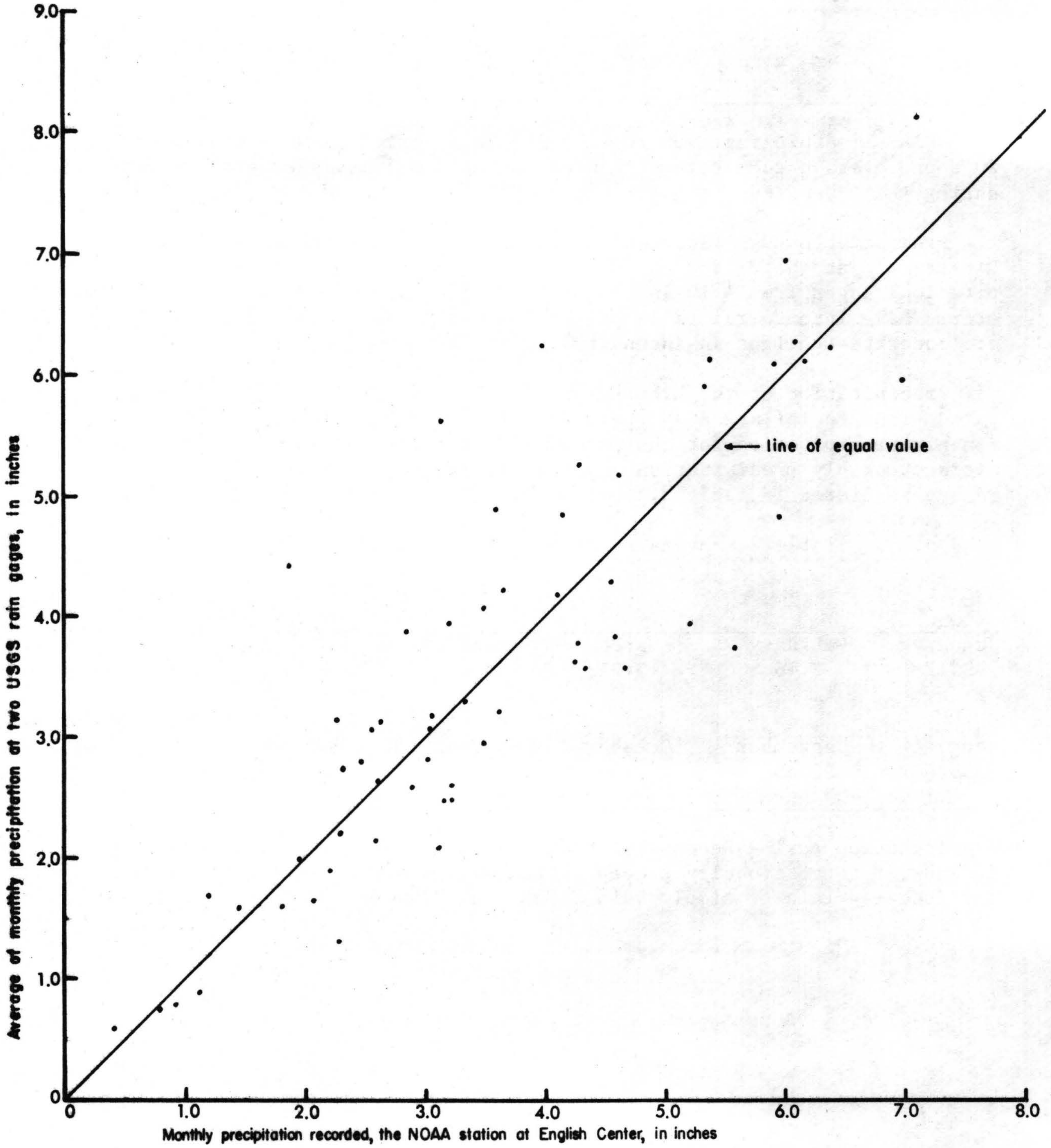

Figure 4.--Comparison on the precipitation averages of the two USGS rain gages in the Blockhouse Creek basin and the NOAA rain gage at English Center, October 1972 to September 1977.

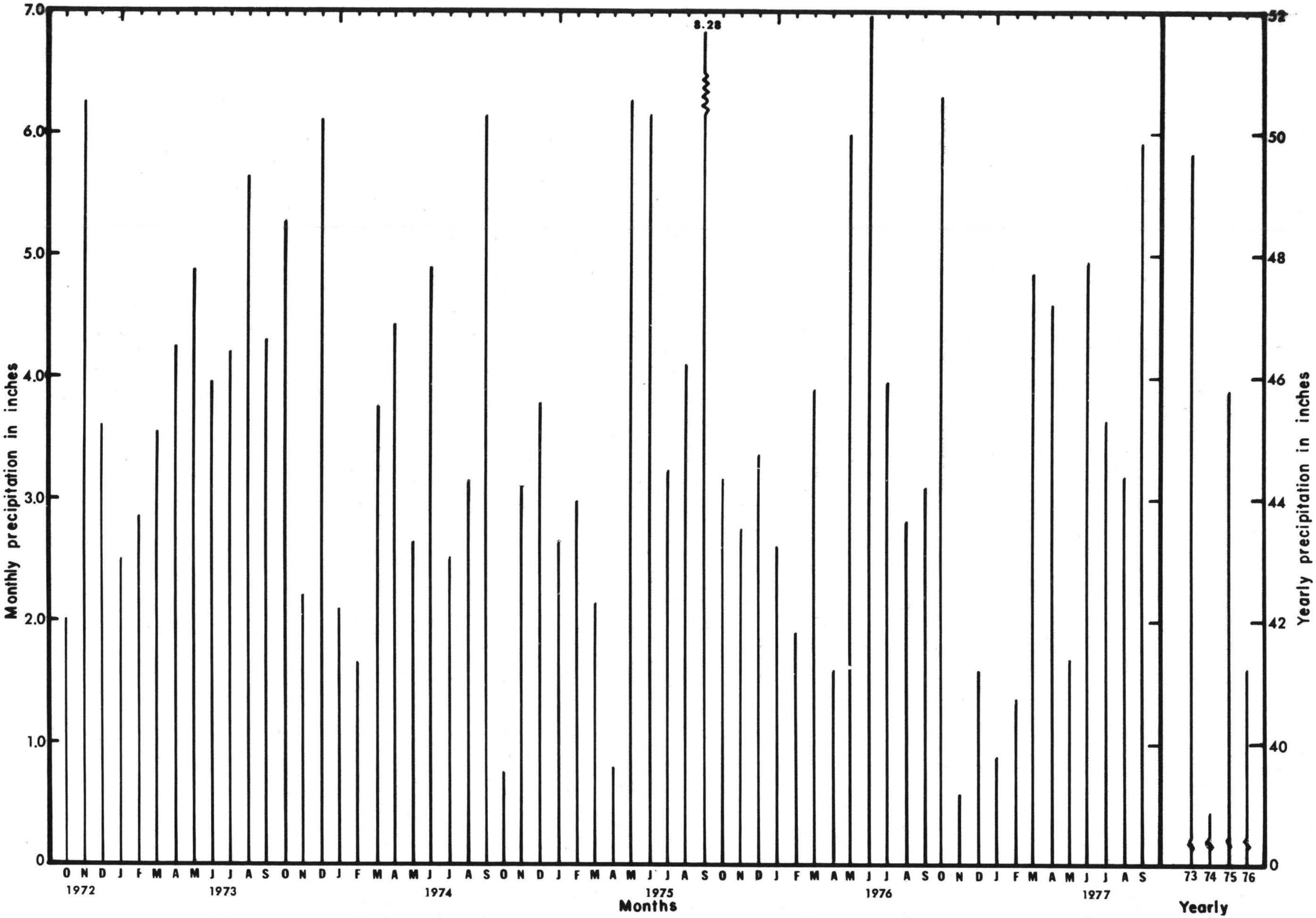

Figure 5.--Monthly and annual precipitation in the Blockhouse Creek basin for the period October 1972 to September 1977.

The difference between the precipitation data collected at gages within the basin and the long-term average precipitation at the NOAA station at English Center is shown on figure 6. The annual rainfall was above average as much as 12.35 in. in 1973 and as little as 1.54 in. in 1974. The average annual difference was 6.5 in., or about 17 percent, higher than average. The maximum monthly difference for the period was 5.43 in. in September 1975. Monthly differences of more than 3.0 in. occurred six times, five during the fall and early winter (September through December). The largest monthly difference below average was 2.93 in., in November 1976, when only 0.58 in. of rainfall was recorded. Monthly differences below average of greater than 1.50 in. occurred six times during the study. More than two-thirds of the deviations above and below average fell within 1.50 in. per month.

During the 8 months of data collection before highway construction began, precipitation totaled 31.29 in. The long-term average was 24.60 in. During the 28 months when construction was active, precipitation totaled 102.51 in., whereas the average was 88.77 in. During the 2 years of post-construction data collection, precipitation totaled 79.36 in. The average for this period was 75.78 in.

Storms of greater than 2.0 in. of accumulation in 24 hours occurred seven times during the study. The largest 24 hour accumulation was 3.37 in. This occurred on August 18, 1973, shortly after active construction began.

HYDROLOGIC SAMPLING EQUIPMENT

Four data-collection stations were established in the Blockhouse Creek basin; each was equipped with a digital and a graphic water-stage recorder, a digital temperature recorder, a continuously recording surface-scatter turbidimeter, and an automatic sediment sampler.

The upstream station, Blockhouse Creek tributary at Liberty, was equipped with a pendulum-type automatic sediment sampler and a recording rain gage, in addition to the stream-stage recording equipment. This station served as a control, as the 1.08 mi^2 basin was not affected by construction.

The station, Blockhouse Creek at Buttonwood, was about 5 mi downstream from the initial area of construction and just below the area of construction directly affecting Blockhouse Creek. The drainage area was 22.3 mi^2, and the station was equipped with a continuously recording rain gage and a PS-69 automatic sediment sampler, in addition to the stream-stage recording equipment.

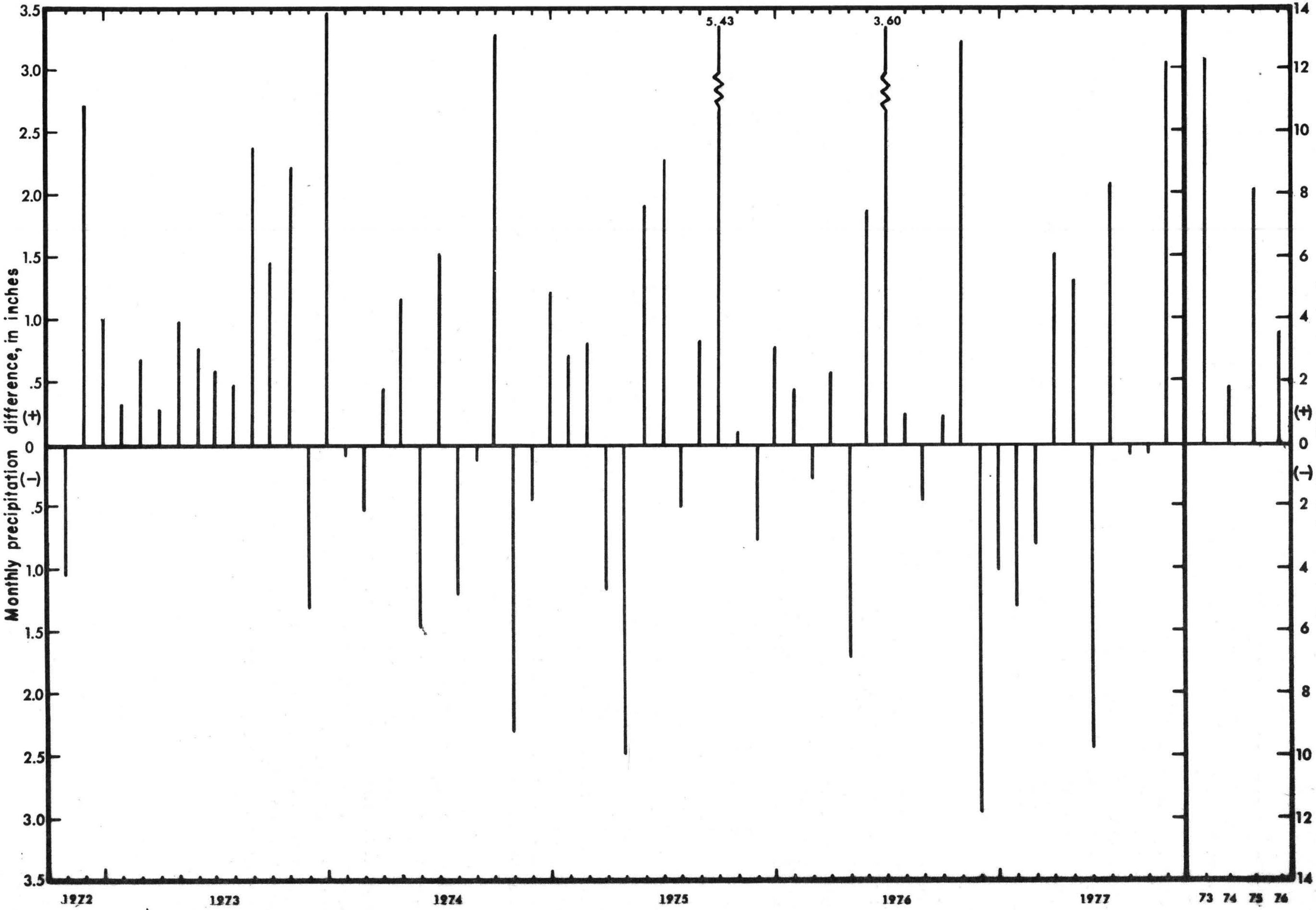

Figure 6.--Departure of monthly and annual rainfall from the 38-year-average at English Center.

II

A third station, Steam Valley Run at Buttonwood, was on Steam Valley Run near its confluence with Blockhouse Creek; the drainage area was 5.3 mi^2. This stream, a major tributary to Blockhouse Creek, was directly affected by about 2 mi of highway construction upstream from the monitoring station. Equipment at the station included a PS-69 automatic sediment sampler, as well as the monitoring equipment common to all stations.

The station farthest downstream, Blockhouse Creek at English Center, is a long-term surface-water data-collection site and is about 5 mi downstream from the area affected by construction (fig. 1). The drainage area was 37.7 mi^2, and the station measured the sediment discharges of both Blockhouse Creek and Steam Valley Run. Sediment data were collected with a pendulum-type sampler. Figure 7 is a map showing the type of data collected at each station. Figure 8 shows the equipment installed at the Steam Valley Run station.

DATA COLLECTION

Streamflow and sediment-concentration data were collected for 5 years. Discharge measurements were made periodically at various stages to establish a stage-discharge relationship. Turbidity, stream temperature, and rainfall were also recorded continuously. Data collection started in October 1972 and continued until construction was completed and the area had stabilized. Water-stage recorders provided a continuous record of stream levels or gage height. A stage-discharge relation was defined for each site by a series of discharge measurements at various gage heights and during various periods. The stage-discharge relationship for each site was related to stream stage with time and daily stream discharges computed.

Suspended-sediment samples were collected automatically and by hand. The automatic sediment samplers were activated by a rise in stream stage or by an increase in turbidity. Depth-integrated samples were collected by hand with a DH-48 sediment sampler (figs. 8 and 9). These samples and simultaneous automatic samples were used to determine the reliability of the sediment samples taken by the pumping sampler. Concentrations of the suspended sediment samples were determined by the filtered dry-weight method outlined by Guy (1969).

Mean water discharge, mean sediment concentration, and sediment discharge for each day during the study period were calculated for each station according to the techniques outlined by Porterfield (1972). The turbidity of all sediment samples was measured nephlometrically in the laboratory. The turbidity of the stream was also monitored continuously at all four stations by a surface-scatter turbidimeter. The turbidity data were used as a guide when sediment-concentration curves were developed, especially during periods when sediment data were insufficient, as outlined by Truhlar (1976). Stream-temperature data were collected to investigate the possibility of a change in average and maximum stream temperatures due to stream relocations and altered sun exposure.

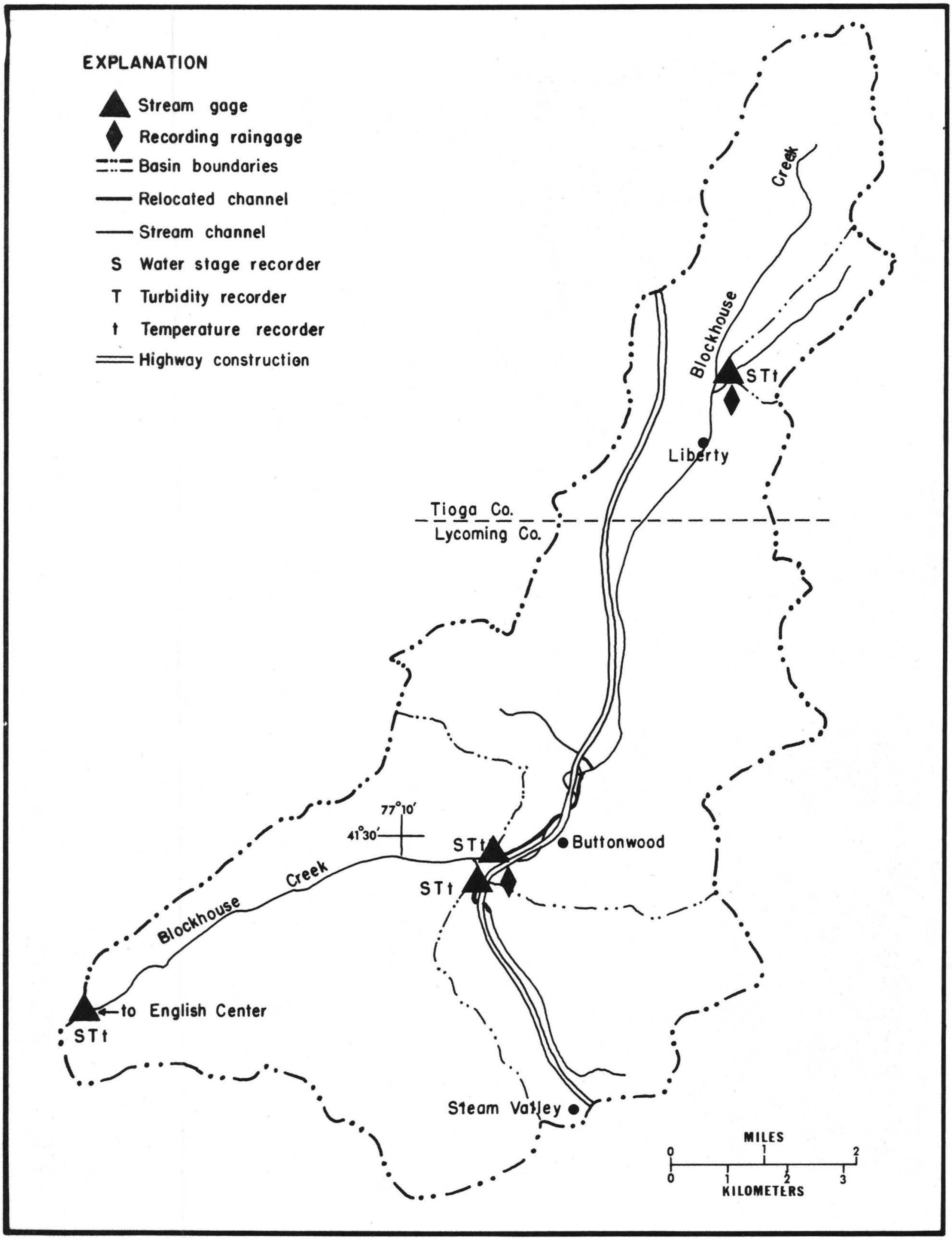

Figure 7.--Locations of gaging stations in the Blockhouse Creek basin and type of data collected at each station.

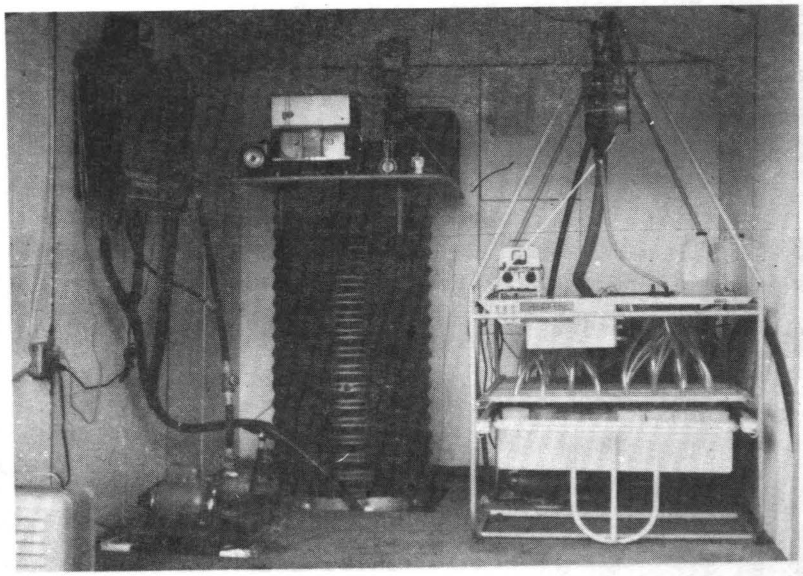

Figure 8.--Equipment installed in the station house on Steam Valley Run at Buttonwood.

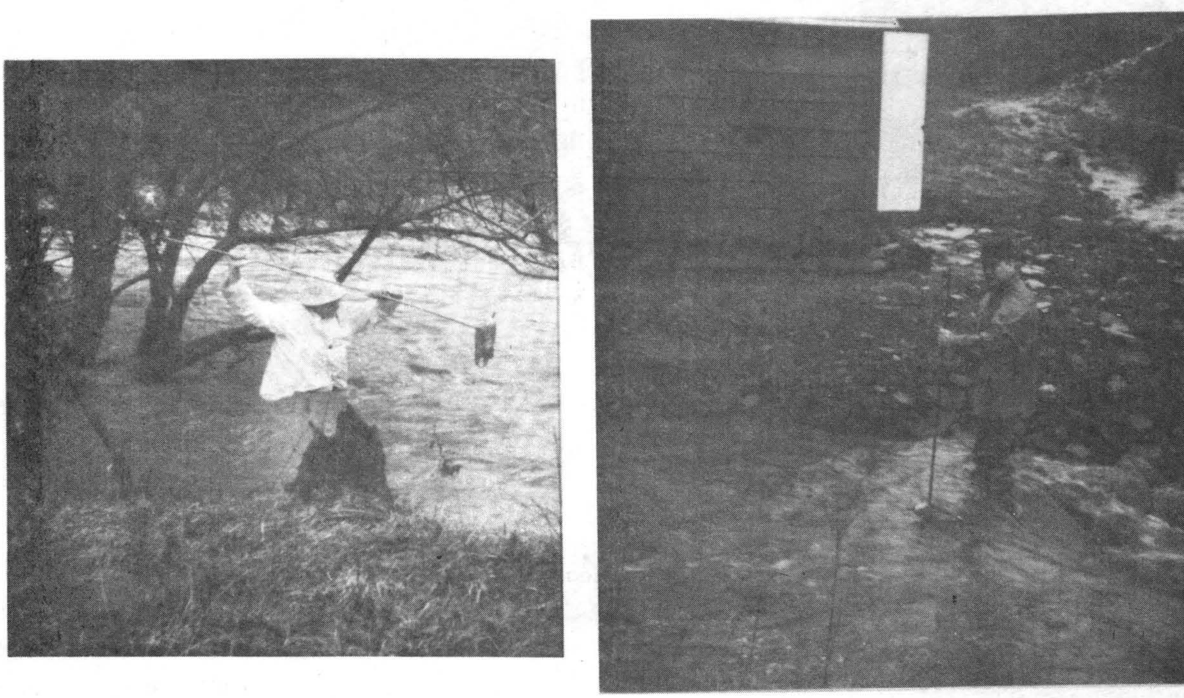

Figure 9.--Sediment sampling by hand with a DH-48 sediment sampler.

Using the sediment-discharge data at the control station, Blockhouse Creek tributary at Liberty, and sediment-discharge data from each station before and after construction, normal sediment discharge was computed for the downstream stations for the period they were affected by the highway construction. The computed sediment discharge represents the quantity of sediment transported by the streams if construction had not occurred. Differences between the measured load at the stations downstream from the construction and the computed normal load were the result of highway construction. The purpose of the data collection was to determine normal sediment loads and sediment loads caused by construction. The effectiveness of individual sediment controls was not determined.

All data are published in the annual U.S. Geological Survey basic-data reports "Water Resources Data for Pennsylvania" for the 1973-77 water years.

In addition to the hydrologic data collected by the USGS, the Pennsylvania Fish Commission made yearly surveys on fish populations in several sections of Blockhouse Creek before, during, and after highway construction.

HIGHWAY CONSTRUCTION

Highway construction involved a total area of 0.45 mi^2 or 290 acres of the 37.7 mi^2 drainage area. About $6\frac{1}{2}$ mi of the 15-mi stream length investigated were directly involved in the construction. Construction began in the spring of 1973 and was finished in the fall of 1975.

Clearing and grubbing began early in June 1973 at the north end of the Blockhouse Creek basin near Sebring and progressed southward to Buttonwood. The Steam Valley Run area was cleared and grubbed during 1974. Clearing and grubbing started in low-lying areas and progressed up the mountain to Steam Valley. Earth was moved at several locations in the northern Blockhouse Creek basin during 1973, in most areas of the basin during 1974, and was generally completed by April 1975. Seeding and mulching started in June 1974 and was completed in October 1975.

The construction area was 1.2 percent of the drainage area studied or about 290 acres. In the Steam Valley Run basin 82 acres, or 2.4 percent, of the drainage area was involved in construction. Figure 10 shows the sizes of the areas disturbed by the different phases of construction in the Steam Valley Run basin from October 1973 to October 1975. Figure 11 shows the areas disturbed by the different phases of construction in the Blockhouse Creek basin above Buttonwood from June 1973 to October 1975. During construction in this basin, 210 acres was disturbed. Generally, the maximum area exposed at one time in both basins was about half that involved in construction. This is partly because areas were reseeded as soon as possible and partly because they were not exposed until they were ready to be worked. Most of the earthmoving was completed by July 1975, when paving began. The decrease in revegetated areas shown on figures 10 and 11 is due to the vegetation of areas which were later paved. The roadway was completed by October 1975. Significant areas of soil were exposed about 14 months.

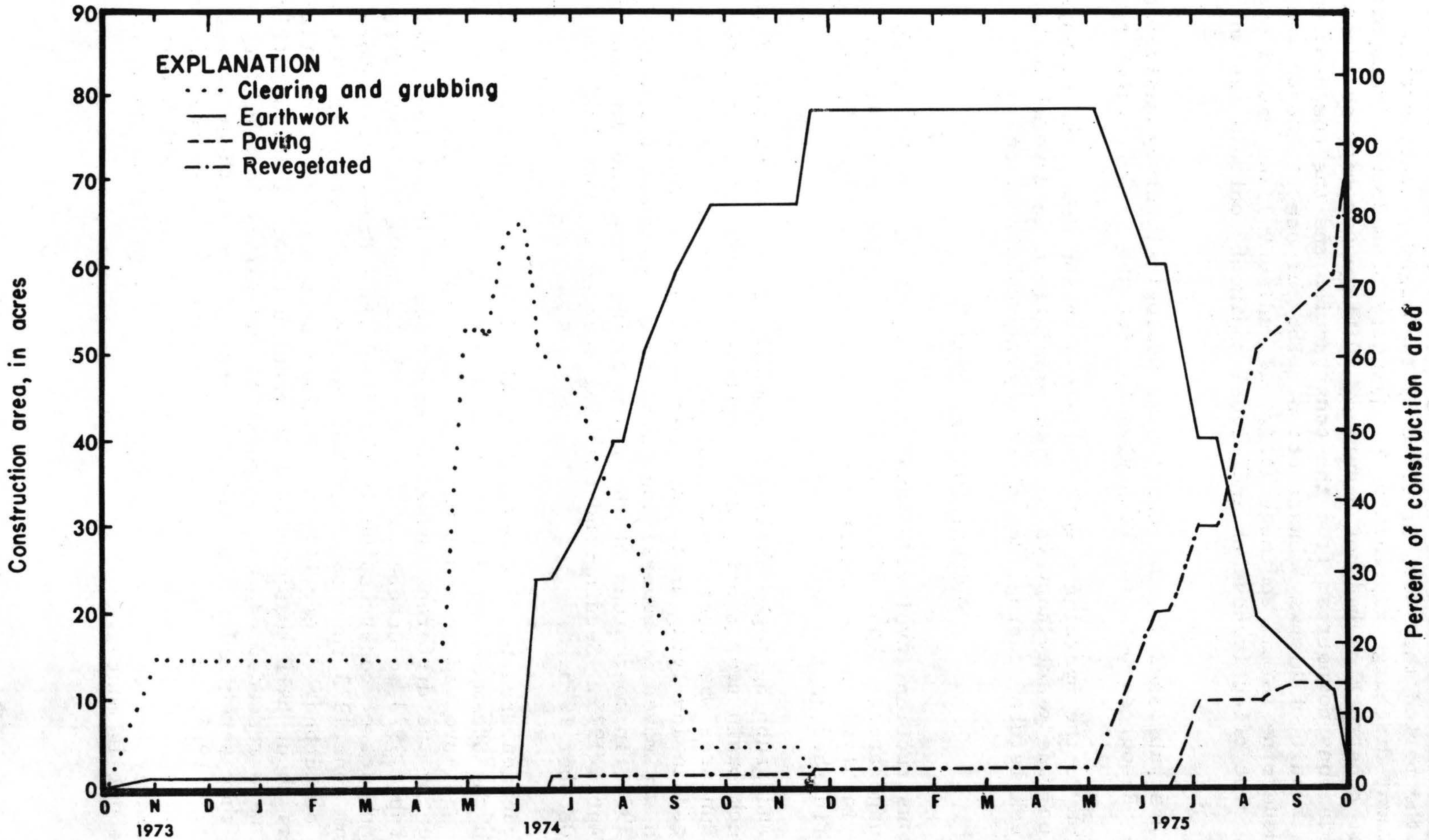

Figure 10.--Acreage and percentage of construction area involved during the indicated time period in the Steam Valley Run basin.

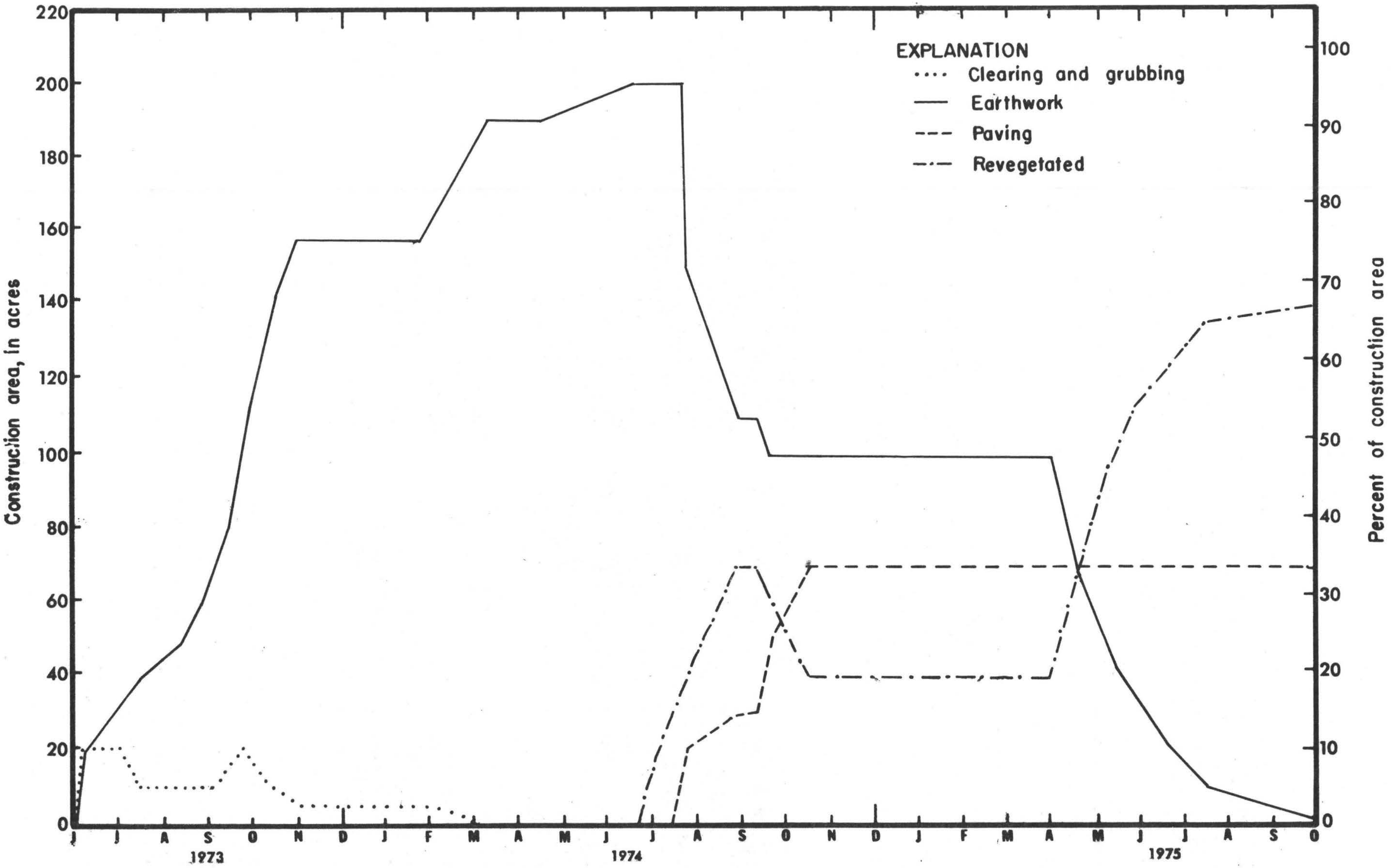

Figure 11.--Acreage and percentage of construction area involved during the indicated time period in the Blockhouse Creek basin.

SEDIMENT CONTROLS AND STREAM-RELOCATION METHODS

From the gaging station on Blockhouse Creek at Buttonwood to the basin divide between Liberty and Sebring, 34,000 ft, 6.5 mi, of highway was constructed. The first 2 mi of roadway in the Buttonwood area was built adjacent to the stream, and, in several places, the stream channel was relocated. About 7,700 ft of stream channel was diverted and relocated in nine areas of construction. The longest relocation was about half a mile. The remaining 5 mi of highway north of Buttonwood to the basin divide is a quarter to half a mile from Blockhouse Creek. The construction area along this section was 100 to 200 ft higher than the stream, and the channel along this 5 mi section was not relocated.

Where the construction was near the stream, rapid seeding and mulching of exposed areas, straw bales, and rock dams were used to limit the quantity of sediment transport. Seeding and mulching reduces sediment transport by preventing erosion. Straw bales and rock dams cause sediment deposition by reducing water velocities (Reed, 1978). Examples of these control measures are shown in figure 12. Most of the sediment controls are shown in the Pennsylvania

Figure 12.--Straw bales and rock dams used as sediment controls.

Department of Transportation Design Manual. Straw bales were normally anchored by rods into the streambed and reinforced with rocks. The bales were generally placed at regular intervals in the streams adjacent to areas where sediment erosion was anticipated.

Rock dams were also used to control sediment discharge by reducing the velocity of the stream. This allows more fine sediment to deposit in the streambed behind the dam, which, in turn, facilitates the physical removal of the eroded sediment. This type of control requires periodic maintenance to remove the deposited sediment.

Temporary culvert systems were placed in all waterways that had to be crossed with equpment. An example of a typical temporary crossing and culvert system are shown in figure 13.

Sediment discharge was also controlled by restricting clearing and grubbing in areas of potential stream sedimentation, especially during the high-runoff months of April, May, and June. In the area between Liberty and Sebring, clearing and grubbing included some relatively young dense stands of pine and hemlock. Branches from these trees were used as sediment traps in conjunction with rock dams, in streams, and waterways below the construction. The period during which significant areas of soil were exposed was about 14 months of the 30-month construction period.

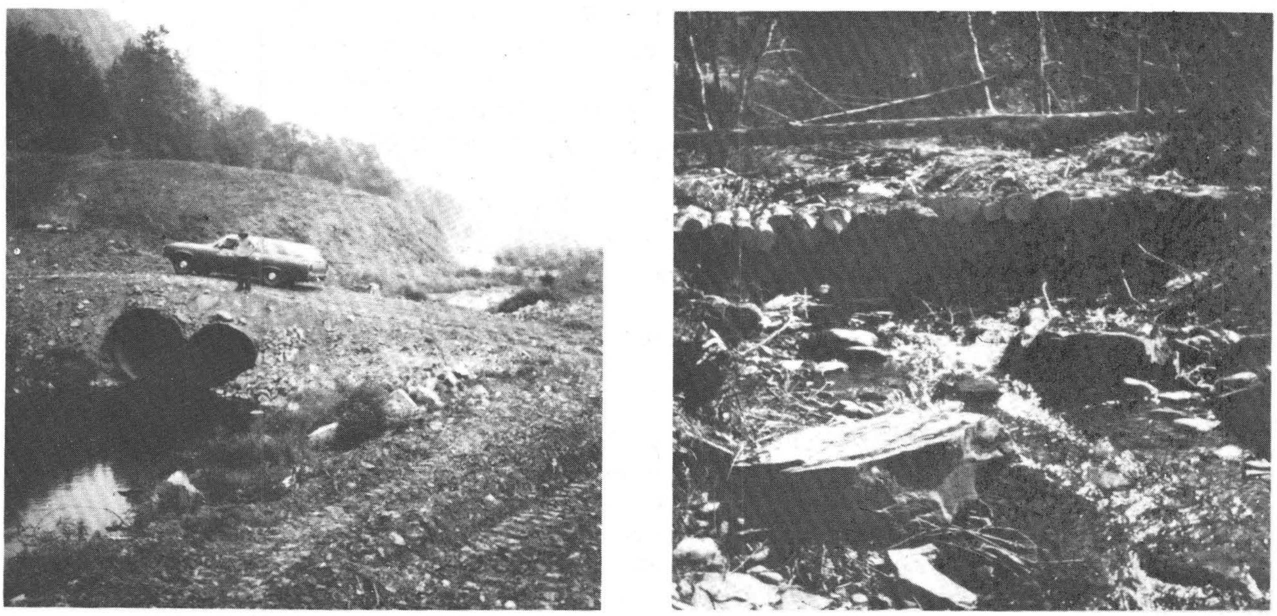

Figure 13.--An example of a typical temporary culvert system and a temporary crossing.

Just south of Liberty, two large sediment-control ponds (fig. 14) were installed on an overflow channel of a tributary to Blockhouse Creek during clearing and grubbing. The structures were located there to trap sediment from about half a mile of roadway and were designed to operate in two stages. Initially, water was filtered through a rock dam into an upper pond that had a capacity of about 0.25 acre-ft. This reduced the stream's velocity and allowed the sand part of the sediment that had not been removed by the rock dam to settle to the bottom. This material was removed by dredging a few times during the construction. A second, larger pond (about 6 acre-ft) received the flow from the upper pond. Silt and clay were to be removed here. Overflow from this pond was then returned to the tributary channel.

The ponds were effective in removing sand and coarse silt; however, the slow settling velocity of fine silt and clay reduced the effectiveness of removal, especially during relatively high flows. During such periods, the water traveled through the pond system quickly and returned to the stream before the sediment concentrations could be reduced significantly. Occasionally, after a storm, sediment concentrations in the pond outflow may be higher than in the stream. This situation has been observed in other similar studies (Reed, 1978). The ponds were effective in reducing sediment concentrations during storms that produced low to moderate streamflows.

Four stream diversions were made during construction. Where possible, these were made using existing overflow channels. Five stream relocations were also constructed--three on Blockhouse Creek, one on Steam Valley Run, and one on a small tributary to Blockhouse Creek. Channel length was shortened from 7,700 ft to 7,500 ft. On all relocations, single log, stone gabion and boulder dams, and deflectors were used wherever possible. Examples of these devices are shown in figure 15. These structures were built to increase the stream velocity locally, aerate the water, and create a suitable habitat for aquatic life by simulating the pool and riffle sequence of natural streams. All channel relocations were constructed, rock-lined, seeded, and mulched before any water was diverted. Water was diverted through these channels only after they had been given sufficient time to stabilize.

The 2,645-ft relocation just upstream from the gage on Blockhouse Creek at Buttonwood was constructed in the fall of 1973 and opened to flow (fig. 16) in March 1974. When the channel was opened, only a small sediment load was measured downstream from the channel relocation. The mean suspended-sediment concentration at the Buttonwood station on the day the channel was opened was 137 mg/L, and the mean turbidity level was 53 Jackson Turbidity Units (JTU). The instantaneous peaks for these two characteristics were 3,450 mg/L and 850 JTU. The mean turbidity level and sediment concentration for a March day are about 5 mg/L and 5 JTU. Even though these peaks are rather high, the sediment load was low due to the small flow at the time. The sediment load at the Buttonwood station on that day was 7.8 tons or about 2 percent of the total load for the month. Most of this sediment was introduced when the cofferdam was breached to allow the water into the new channel. Sediment concentration and turbidity values in this range are normally associated with light to moderate rainfalls. One week before the channel was opened, these levels were produced by a rainfall of 0.65 in. in 6 hours. The maximum 15-minute intensity of this rainfall was 0.2 in. per hour.

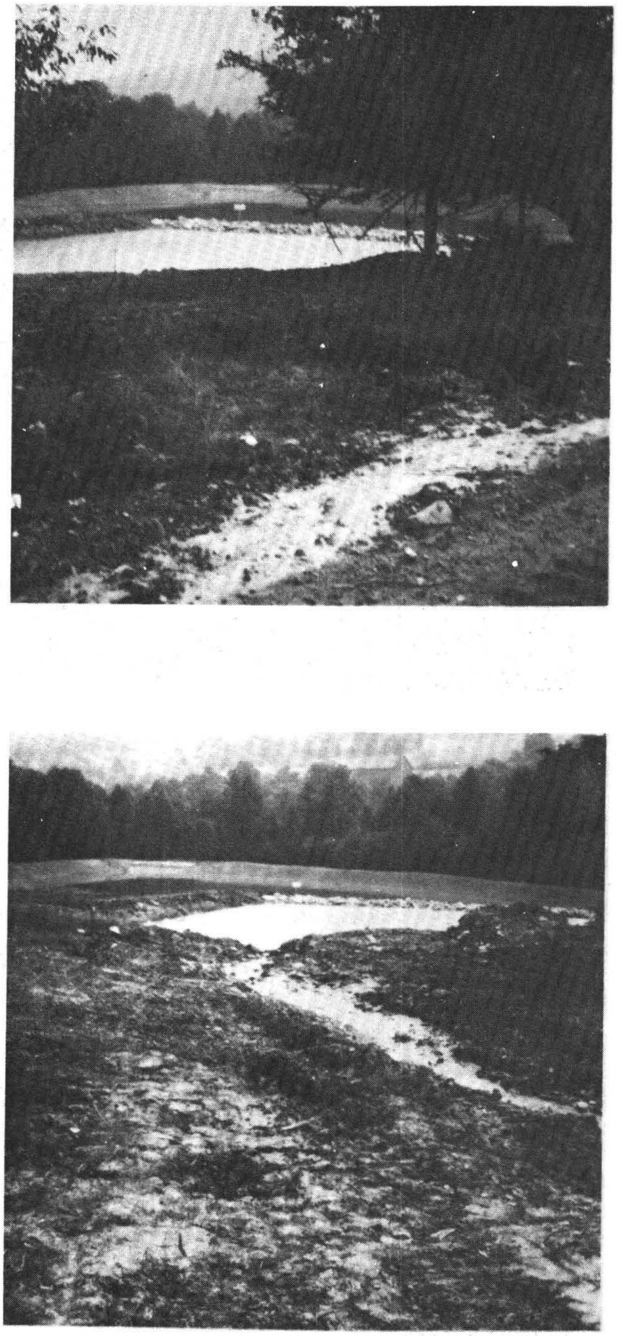

Figure 14.--Sediment-control pond installed directly south of Liberty.

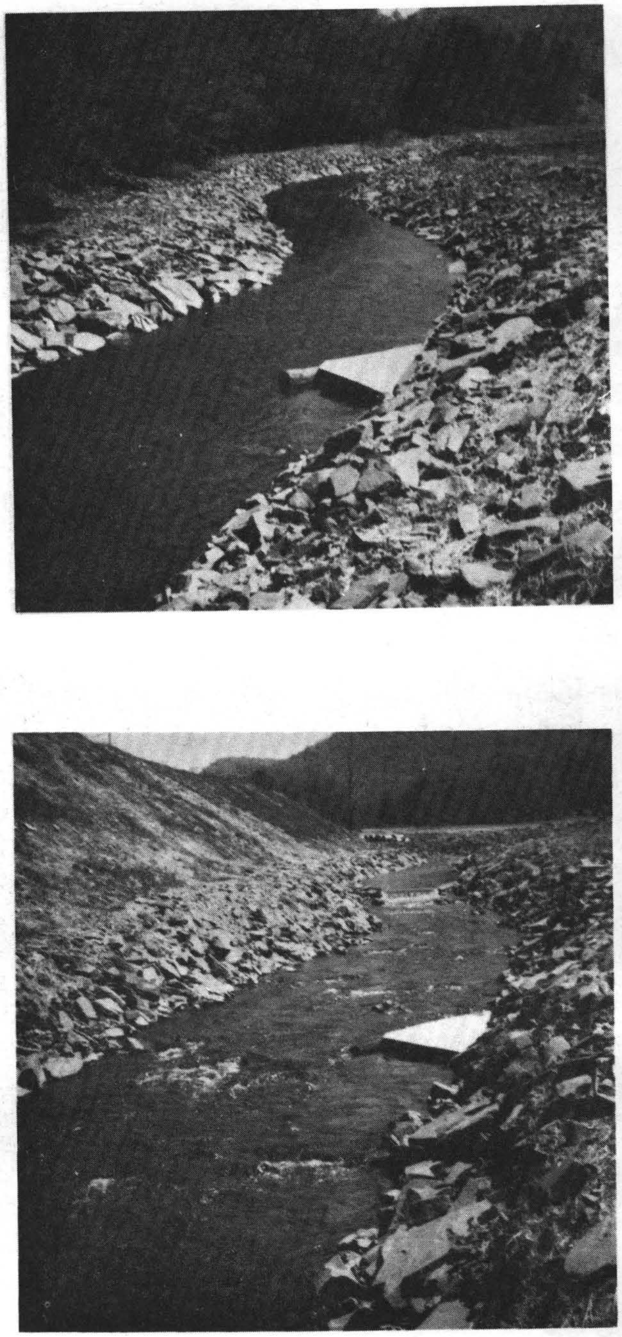

Figure 15.--Streamflow-altering measures built to create a suitable aquatic habitat.

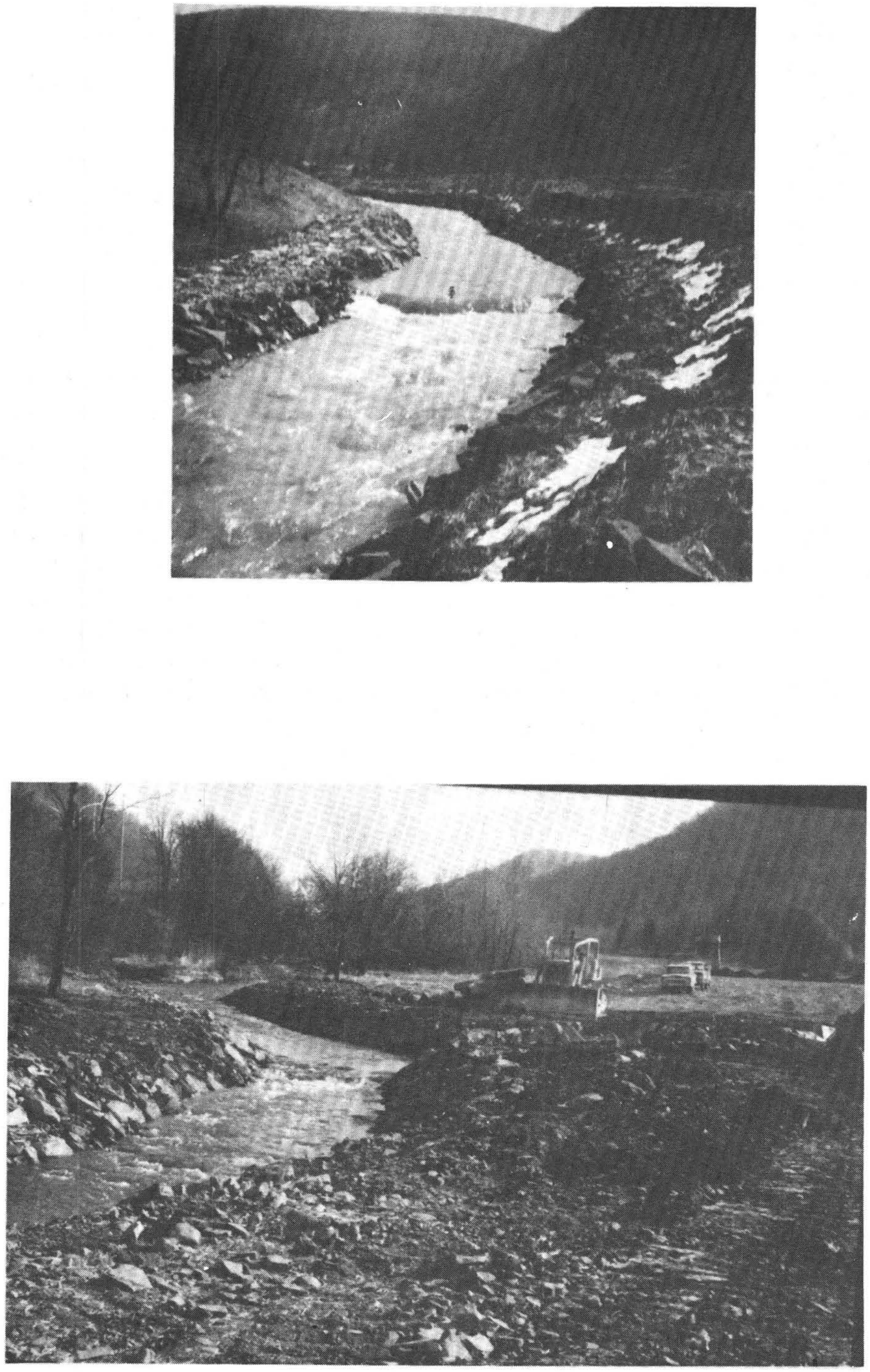

Figure 16.--The relocated channel constructed along Blockhouse Creek above the Buttonwood gage.

The sediment transported from the new channel at Buttonwood reached the English Center station about 7 hours later. The peak concentration was about 40 mg/L, and the peak turbidity level was about 35 JTU. The sediment load on this day at the English Center station was 0.5 tons, an insignificant quantity compared to sediment loads observed during storms. The relatively small sediment load transported due to the opening of the new channel and the occurrence of suspended-sediment concentrations that are exceeded several times during the year during storms suggest similar stream relocation methods could be used when necessary.

Sediment due to the opening of the new channel was 7.8 tons at Buttonwood, immediately downstream from the channel, and 0.5 tons at English Center, 6 mi, downstream. Sediment deposition in the channel between Buttonwood and English Center was 7.3 tons. As the channel area between the two sites is 21 acres, sediment deposition averaged 0.35 t/acre. Sediment deposition of this magnitude would be difficult to detect, even when the stream is waded.

Trout populations in the channel just upstream from the Buttonwood gage were sampled by the Pennsylvania Fish Commission in order to determine the effect of the stream relocations (J. Miller, Pennsylvania Fish Commission, oral communications, 1979). Samples were collected in August of each year from 1972-1977. The old channel was sampled in 1972 and 1973, flow was diverted to the new channel in March 1974, and the new channel was sampled four times from 1974 to 1977. When samples were collected from the old channel during 1972 and 1973, the trout population of the entire channel was 11.9 and 15.7 lbs., respectively. When samples were collected from the new channel during 1974 and 1975, the trout populations were 23.2 and 28.0 lbs, respectively. When samples were collected after highway construction was completed, 1976 and 1977, the trout populations were 46.1 and 54.0 lbs, respectively.

Trout populations in the new channel during 1976 and 1977 averaged 260 percent greater, when the samples were collected, than the populations in the old channel during 1972-73.

The old channel was 4,500 ft long and contained a surface area of 2.5 acres. The new channel is 2,645 ft long and contains 0.98 acres. Trout populations averaged 5.5 lbs per acre in the old channel and 51 lbs per acre in the new channel.

WATER DISCHARGE

A month-by-month comparison of the water discharge at the stations affected by construction with the discharge at the control station shows no significant changes in the normal flow by each station. Annual Discharge from the four sites ranged from 1.58 to 2.03 $(ft^3/s)/mi^2$.

Figure 17 shows the cumulative water discharge at Steam Valley Run and Blockhouse Creek at Buttonwood versus the cumulative water discharge at the Blockhouse Creek tributary at Liberty, the station unaffected by construction. The figure shows no appreciable difference between the discharge relationships of the control station and the two stations. Figure 17 also shows that Steam Valley Run at Buttonwood discharges about 25 percent more water than Blockhouse Creek at Buttonwood. The higher discharges could be caused by discharge from the underlying ground-water basin, which may be larger than its surface-water counterpart.

The major element of change in runoff is seasonal change. During the winter, soils in the basin freeze to depths of 2-3 ft. The winter freeze is commonly broken by periods of mild weather. Snow cover is normally continuous from December through February. Late winter and early spring is usually the period of greatest runoff. Late summer and early fall are usually the months of least runoff. During March and April, runoff may be greater than precipitation. This is caused by the storage of precipitation in the form of ice and snow, which melts quickly during a warm, rainy period and contributes to runoff.

STREAM TEMPERATURE

Stream temperatures were recorded at each of the four stations in the Blockhouse Creek basin to monitor changes in stream temperature due to the removal and addition of tree cover along the streams, as the stream was relocated or diverted. Daily maximum, minimum, and mean stream temperatures are presented in the U.S. Geological Survey report "Water Resources Data for Pennsylvania" for the appropriate year.

Figure 18 shows the relation of the monthly mean stream temperatures at the control station at Liberty to those at Steam Valley Run and Blockhouse Creek at Buttonwood. The temperature relation of the Blockhouse Creek tributary at Liberty and Steam Valley Run is linear. Blockhouse Creek at Buttonwood shows an increase in the monthly mean stream temperature of 0.5°C, which is within the limits of measuring error and is considered insignificant. This indicates that the mean stream temperature was not changed by construction.

The determination of changes in the rate of rise and fall of temperature during a 24-hour period is difficult. More data were needed for this analysis than were available. However, the insignificant change in mean temperature suggests that the rate of temperature change was probably not altered.

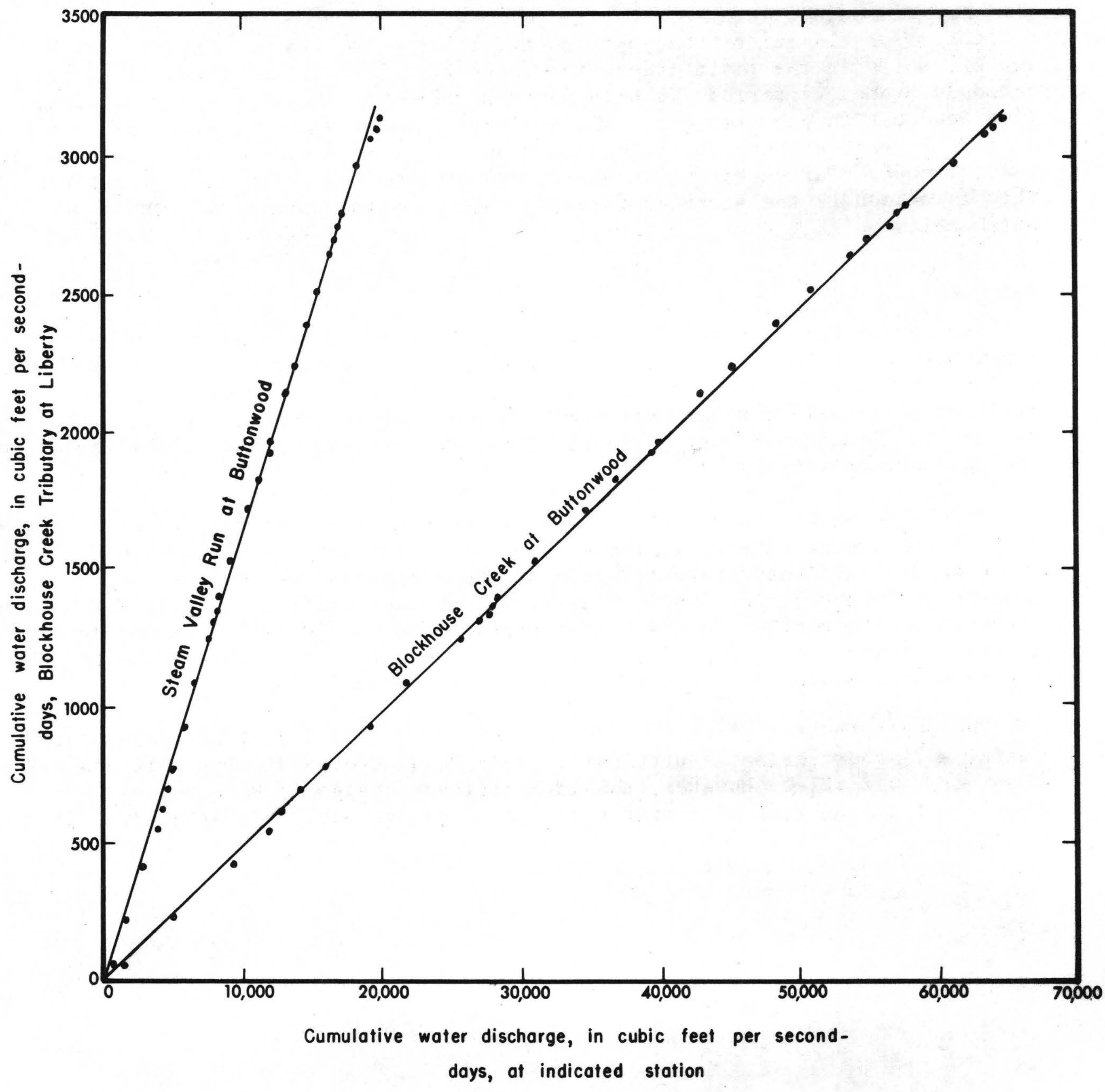

Figure 17.--The relation between cumulative water discharge at the control station and the two stations at Buttonwood.

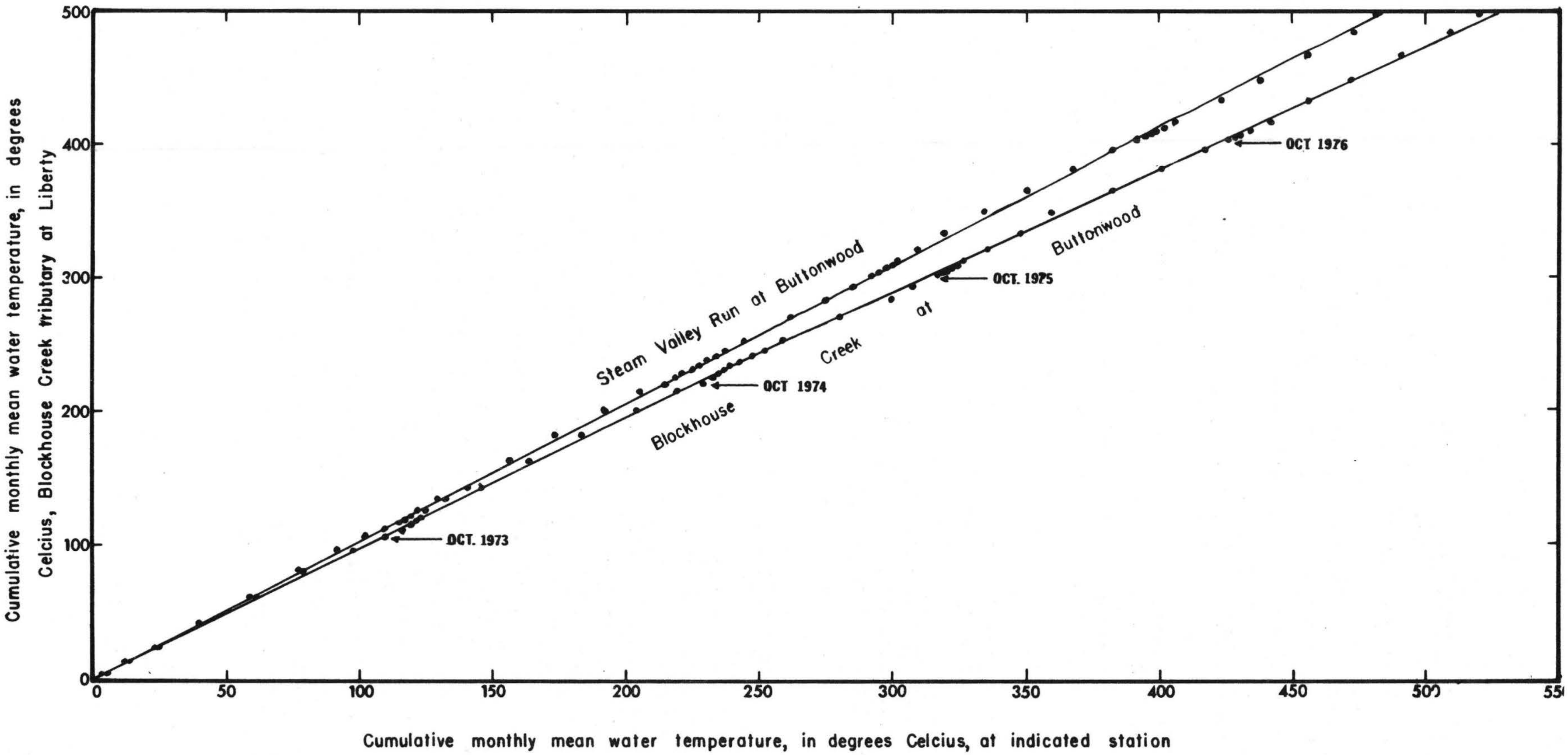

Figure 18.--The cumulative mean stream temperature at Liberty and the two stations at Buttonwood.

STORM SEDIMENT YIELD

Blockhouse Creek Tributary at Liberty

Suspended-sediment loads were measured at each sampling station before, during, and after the highway construction. Loads from the Blockhouse Creek tributary at Liberty, shown in figure 19, were extremely high early in the preconstruction phases of data collection. During February and March 1973, two abnormally large storms produced a sediment discharge of about 700 tons. During the March storm, sediment concentrations reached 30,000 mg/L. These heavy concentrations resulted from a storm that produced 1.4 in. of precipitation at a time when stream banks were thawing after a long winter freeze. The streambanks caved in at several places, and large blocks of soil eroded away. The stream was widened about a foot on each side in a relatively short time. This unusually high sediment discharge during the March storm was also observed at two of the other three sites, Blockhouse Creek at Buttonwood and near English Center.

From April 1, 1973, to the end of data collection, September 30, 1977, the sediment discharge-streamflow relation at Liberty has been fairly consistent. During the 4½-year period, about 700 tons of sediment was discharged from the 1.08 mi^2 basin, or about 145 $ton/mi^2/yr$. The sediment yield is slightly higher than that found by Williams and Reed (1972) for this area of Pennsylvania and may reflect, as Brune (1948) found, that sediment yields of small basins are largely dependent on land-use and individual basin characteristics.

Blockhouse Creek at Buttonwood

The sediment load of Blockhouse Creek at Buttonwood, with a drainage area of 22.3 mi^2, is shown on figure 20. From October 1972 to May 1973, before highway construction began, 15,000 tons of sediment was discharged. During two large storms in February and March 1973, 11,000 tons of sediment was discharged. During highway construction from May 1973 to October 1975, about 13,500 tons of sediment was discharged. After construction was completed, from October 1975 to October 1977, about 3,500 tons of sediment was discharged. If this 2-year period is considered average, then the normal sediment yield is about 80 $ton/mi^2/yr$ from the basin, a figure more in agreement with Williams and Reed (1972). When sediment yields after construction are compared with those during construction, about 7,700 tons or 150 $ton/mi^2/yr$ of sediment was discharged because of highway construction. This yield is similar to the yield from the largely agricultural control basin at Liberty and suggests that construction conditions are similar to conditions in agricultural areas. As sediment yield at Blockhouse Creek at Buttonwood is about 80 $ton/mi^2/yr$, the sediment yield due to highway construction was equal to that discharged in 4½ years. During the entire 5-year period a total of 32,000 tons of sediment was discharged by the Buttonwood station.

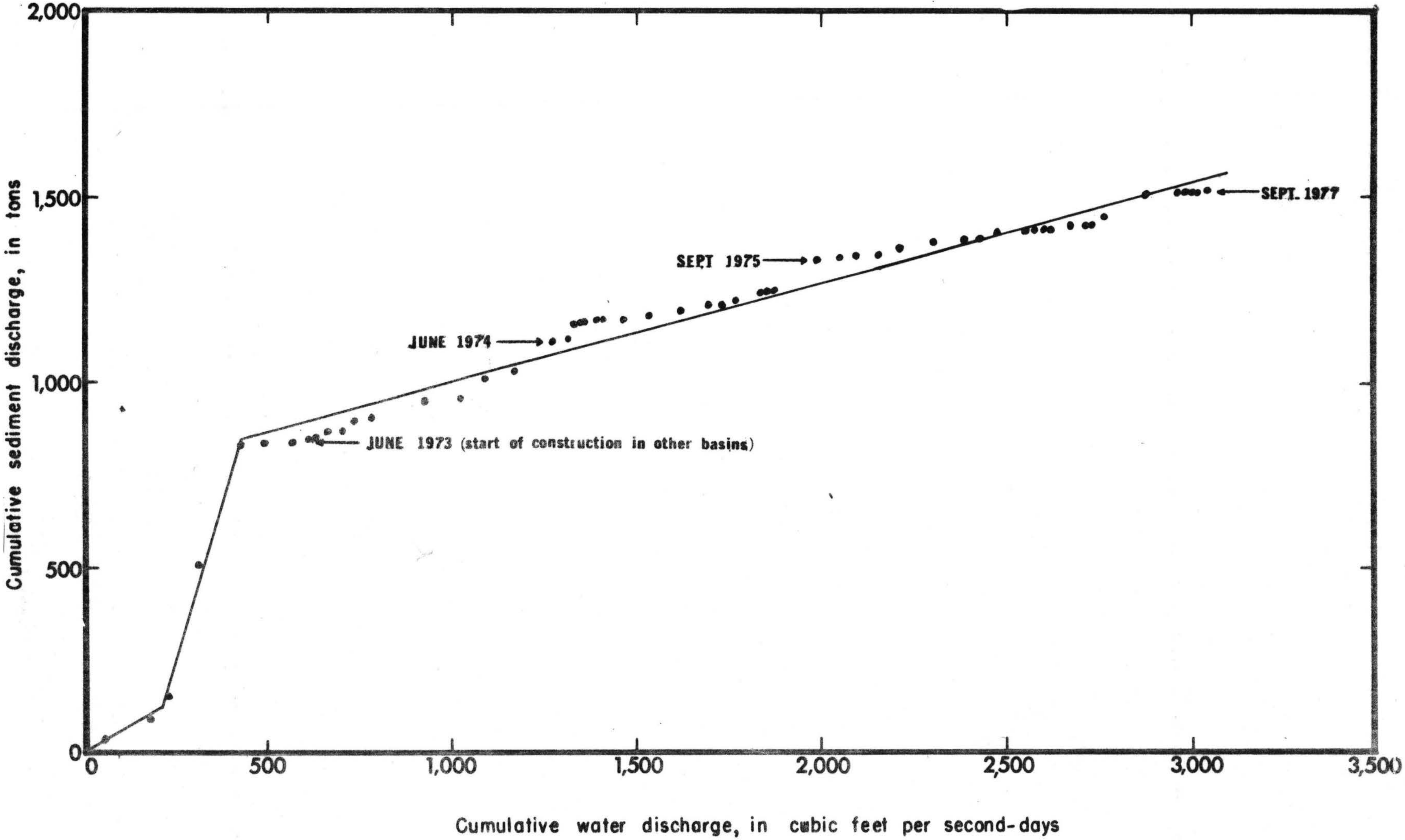

Figure 19.--The relation of cumulative water and sediment discharge by the control station at Liberty.

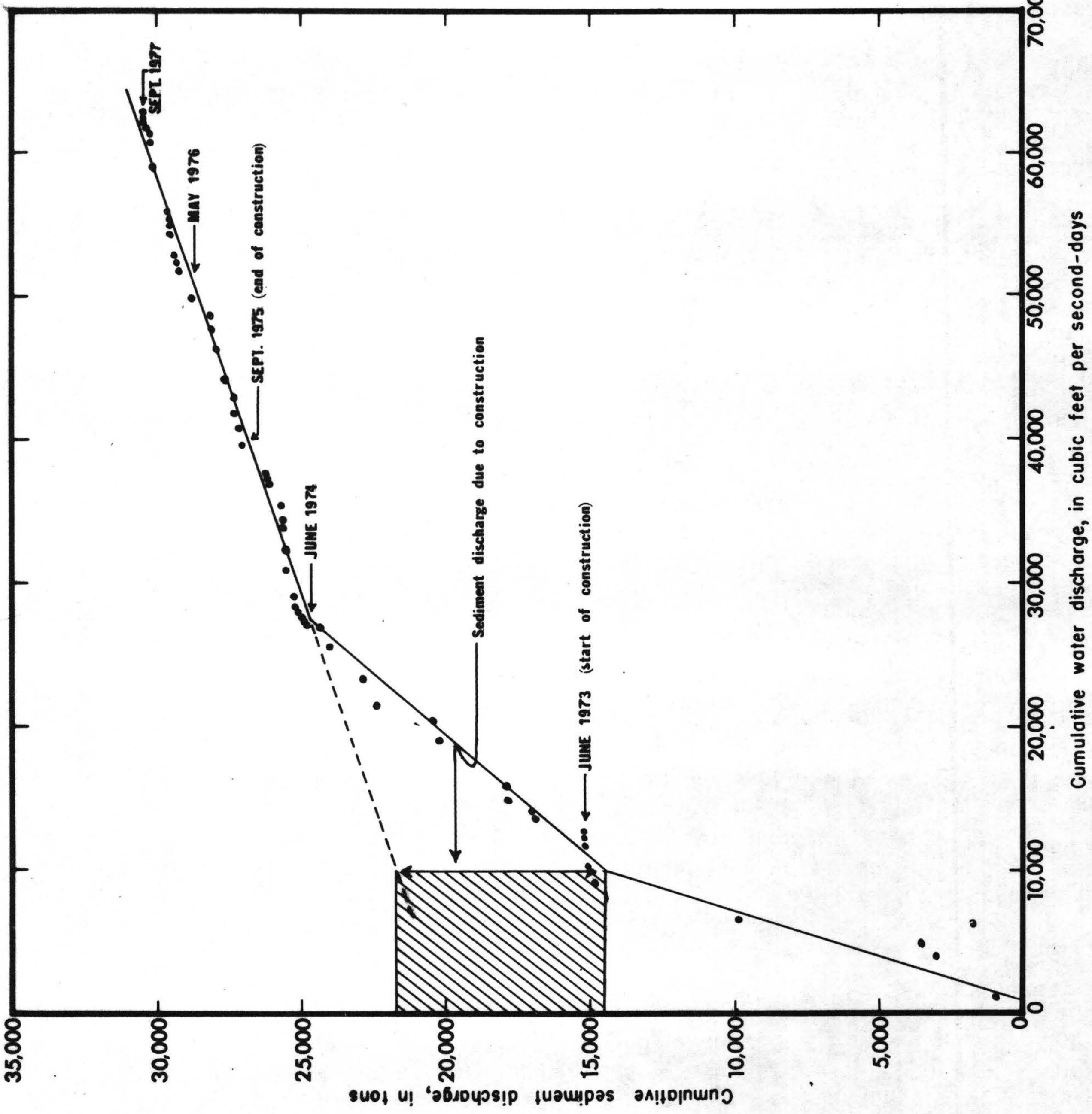

Figure 20.--Graph showing the cumulative relation of water and sediment discharge by the Blockhouse Creek station at Buttonwood

The sediment controls, the method of stabilizing the reconstruction channel, the brush barriers and rock dams, and the separation of the construction area from the stream in the north end of the basin, all contributed to reducing the sediment load caused by construction. The timely construction of the highway also helped to limit sediment discharge. When Hurricane Eloise struck in September 1975, the area had been paved, most of the seeding and mulching had been completed, and a good stand of vegetation was growing on most of the slopes along the highway. The effectiveness of paving and vegetation in the construction area are shown by the decrease in sediment load near the middle and end of the summer of 1974, when these operations began.

Steam Valley Run at Buttonwood

The sediment load from Steam Valley Run at Buttonwood, which has a 5.3 mi^2 drainage area, is shown on figure 21. The abnormally high sediment loads observed at the other sites during February and March 1973, were not observed in the Steam Valley Run basin. Suspended-sediment concentrations during the March 17, 1973, storm exceeded 30,000 mg/L at Blockhouse Creek near Liberty and exceeded 5,000 mg/L at Blockhouse Creek at Buttonwood, but only rose slightly higher than 1,500 mg/L at Steam Valley Run at Buttonwood.

During the 5 years of data collection, 3,500 tons of sediment was discharged by Steam Valley Run. Of this sediment load 1,400 tons was due to the highway construction. It equals the amount normally discharged in about $3\frac{1}{2}$ years and an increase in the sediment yield of about 250 percent for the period of construction. The remaining 2,100 tons may be considered the normal sediment load of the Steam Valley Run basin during the 5-year period. The sediment yield in the Steam Valley Run basin averaged about 80 $ton/mi^2/yr$, a figure similar to that in Williams and Reed (1972). Even though this yield is similar to the yields calculated in the other basins, it is higher than would be expected from a small basin with about 80 percent forest cover. Generally, such basins have low sediment yields. The high yield may be explained by the steepness of the terrain in the Steam Valley Run basin.

No sediment deposits in the bed of Steam Valley Run from construction were observed, probably due to the steep gradient of the stream and because the rock dams trapped most of the coarse material. The velocity of the stream was rapid enough to prevent deposition of the silt and clay part of the transported sediment.

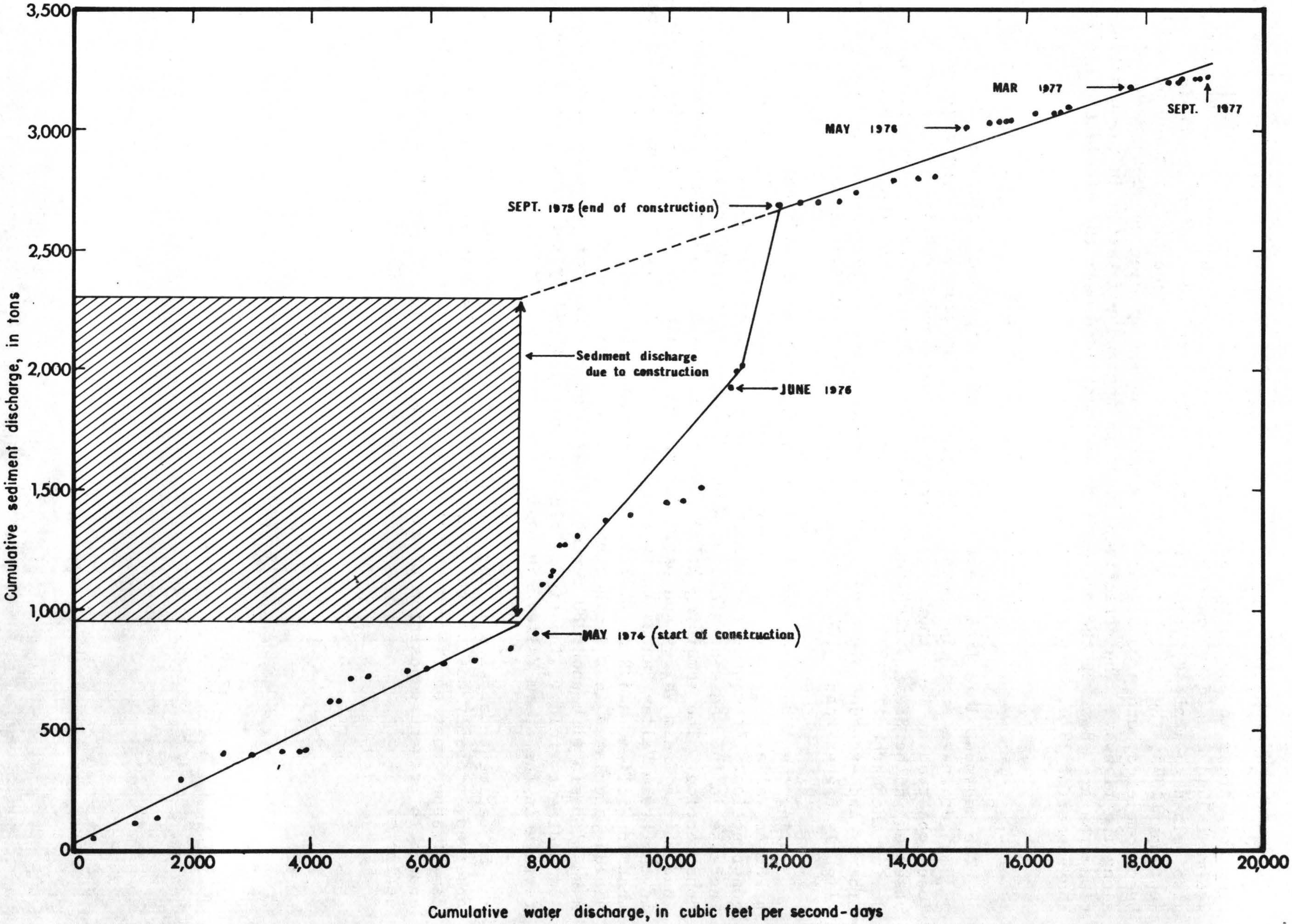

Figure 21.--The cumulative relation of water and sediment discharge by the Steam Valley Run station at Buttonwood.

After the active construction period, sediment discharge from Steam Valley Run returned to pre-construction levels or to a level slightly below the pre-construction values. This suggests the absence of a major change in the sediment-producing characteristics of the Steam Valley Run basin. For example, at Steam Valley Run on August 15, 1973, during the period before construction, precipitation of 0.9 in. produced a discharge increase of 17.2 ft^3/s and a daily sediment discharge of 0.3 tons. A similar storm of 1.04 in. on August 30, 1975, near the end of construction, produced a discharge increase of 15.0 ft^3/s and a daily sediment discharge of 10.8 tons. After the construction, 1.20 in. of precipitation on August 7, 1976, produced a discharge increase of 10.3 ft^3/s and a sediment discharge for the day of 1.0 ton. Assuming similar antecedent conditions, the differences in sediment discharge for the selected storms indicate the effect of the highway construction on sediment yield.

Blockhouse Creek Near English Center

Blockhouse Creek near English Center drains 37.7 mi^2 and is 5 mi downstream from the highway construction. The English Center station collected the drainage from 9 mi of highway construction. Drainage from 6.5 mi of highway construction passed Blockhouse Creek at Buttonwood, and drainage from the other 2.5 mi of construction passed Steam Valley Run at Buttonwood. Blockhouse Creek near English Center was sampled to determine the effects of channel distance on sediment loads due to highway construction. It was also sampled to determine the effects of storm magnitude on travel time and sediment deposition in the stream between Buttonwood and English Center. During the period of data collection, about 38,000 tons of sediment was transported past the Blockhouse Creek near English Center station. During the same period 35,000 tons was transported past the two stations at Buttonwood.

The drainage area between English Center and Buttonwood is about 10 mi^2, 95 percent of which is forested. If it is assumed that the sediment yield from this area was slightly less than from the undisturbed part of Steam Valley Run due to the increased forested area, then, over the 5-year period, abut 4,000 tons of sediment could be expected to be discharged. When this amount is added to the loads measured at Steam Valley Run and Blockhouse Creek at Buttonwood, a total suspended-sediment load of about 39,000 tons would be expected at the Blockhouse Creek near English Center station. This is close to the actual measured load of 38,000 tons.

The data collected at the English Center station is shown in figure 22. The figure indicates that about 8,000 tons of sediment was transported past the English Center gage because of construction. When the construction sediment from Blockhouse Creek at Buttonwood (7,700 tons) is added to that from Steam Valley run at Buttonwood (1,400 tons), the expected sediment load at English Center during construction (9,100 tons) is close to the measured values (8,000 tons). This indicates that, over the period, little sediment was scoured or deposited in the 5 mi channel between English Center and Buttonwood. Deposition probably did occur in the channel during some storms. However, during subsequent storms, these deposits were scoured and transported. Typically, deposition occurred during small but rather intense summer storms when streamflows were relatively low. During these low-flow conditions, the velocity of the water in the channel was not rapid enough to transport all the sediment. The slow-water velocity combined with long travel distance resulted in some material being deposited in the channels.

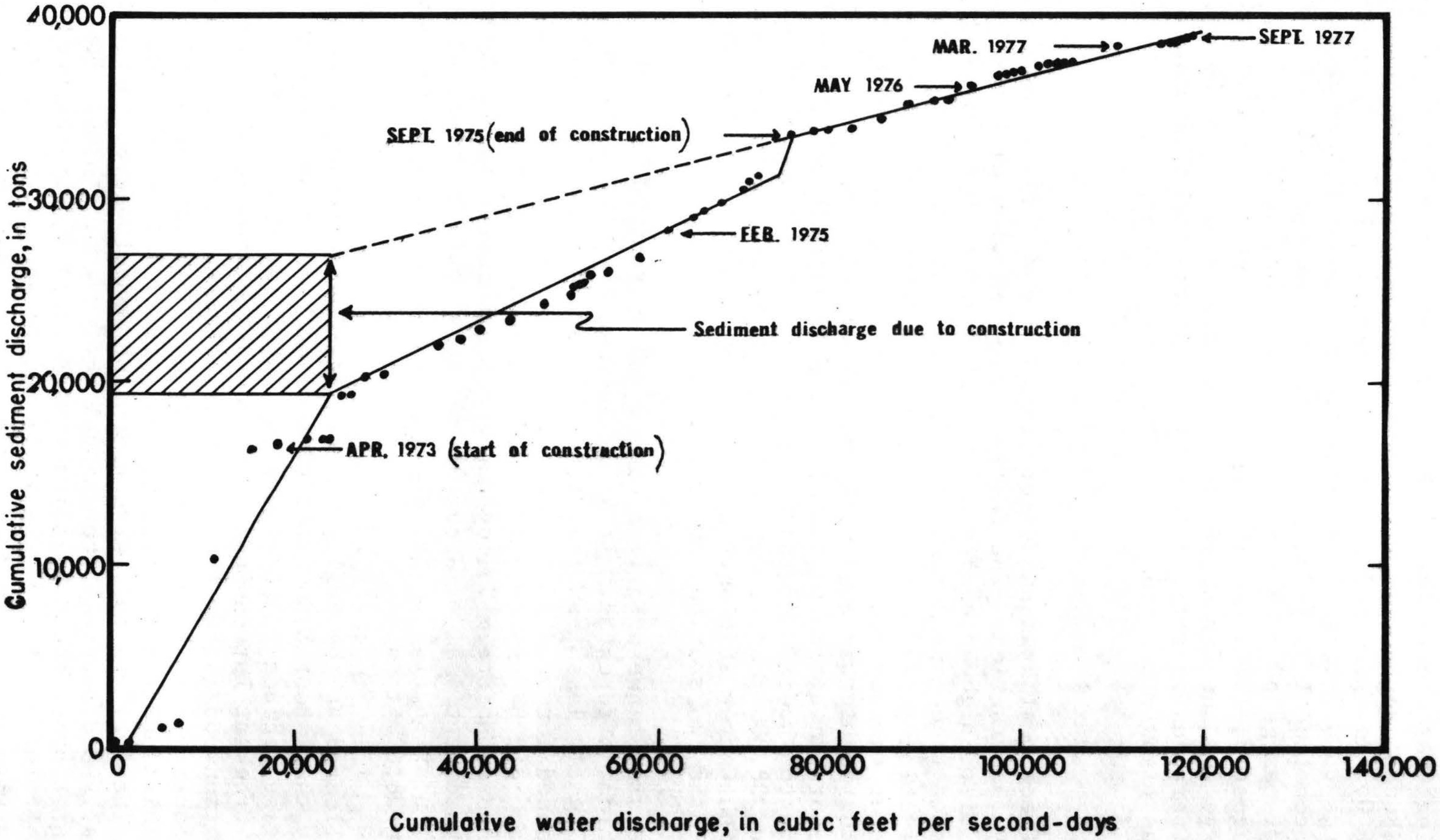

Figure 22.--The cumulative relation of water and sediment discharge by the Blockhouse Creek station near English Center.

During small intense storms in the summer, the lag time between the peak sediment concentration at the Buttonwood stations and the peak concentration at the English Center stations was as much as 12 hours. This period allows ample time for the coarse fractions of the suspended load to be deposited. Two examples of this type of storm are shown in figures 23 and 24. The storm shown in figure 23 occurred on August 15, 1973, and produced 0.9 in. of precipitation. Six-tenths of an inch fell in 30 minutes. Highway construction activity at that time was centered mostly in the headwaters of the Blockhouse Creek basin. About 60 acres of the area from Sebring to just south of Liberty had been cleared and grubbed and some sediment controls, such as brush barriers and small dams, had been installed. Highway construction in the Steam Valley Run basin was limited to about a 5-acre area just upstream from the gage. At this site, preparations were being made to install a box culvert. The culvert was constructed away from the main channel and was dry during construction.

The sediment discharges at Buttonwood, Steam Valley Run, and English Center were 7.9, 0.31, and 5.2 tons, respectively. The peak sediment concentration at the Buttonwood stations occurred about 5 a.m., and the peak of English Center occurred around 6 p.m., making the lag time about 13 hours. The sediment load passing by the two stations at Buttonwood was about 8.2 tons for the August 15 storm; however, only 5.2 tons was measured at English Center. The remaining 3.0 tons or 35 percent of the sediment load was deposited in the 5 mi channel between Buttonwood and English Center. Assuming the channel width averages about 35 ft, there is 21 acres of channel bottom between English Center and Buttonwood. Using this assumed figure, sediment deposits in the channel amounted to about 330 lb/acre or about 7.5 lb/1000 ft^2. This magnitude would normally be undetected, as it would produce only a thin coat of sediment on the stream bottom, which would go unnoticed when the stream is waded.

On September 6, 1973, 1.1 in. of rain fell in about 1½ hours. Construction at this time was in the earthmoving phase at Liberty and farther north. Clearing and grubbing was proceeding south of Liberty. Construction of the box culvert in Steam Valley Run was still underway.

Steam Valley Run sediment concentrations reached 420 mg/L and peaked about 1 a.m. on September 6. The suspended-sediment load at Steam Valley Run was about 2 tons. At Buttonwood, sediment concentrations reached 1,250 mg/L at 2 a.m., and the suspended-sediment load was 83 tons. Sediment concentrations at English Center did not peak until 6:30 a.m. and reached only 420 mg/L. The sediment load was 36 tons. The hydrographs and sediment-concentration curves for this storm are shown on figure 24. The suspended-load measured at the upstream sites was 85 tons. This indicates that at least 50 tons of sediment or 2.4 tons per acre may have been deposited in the channel. This amount of deposition would produce a thin coat of sediment on the stream bottom and could produce cloudy water when the stream is waded.

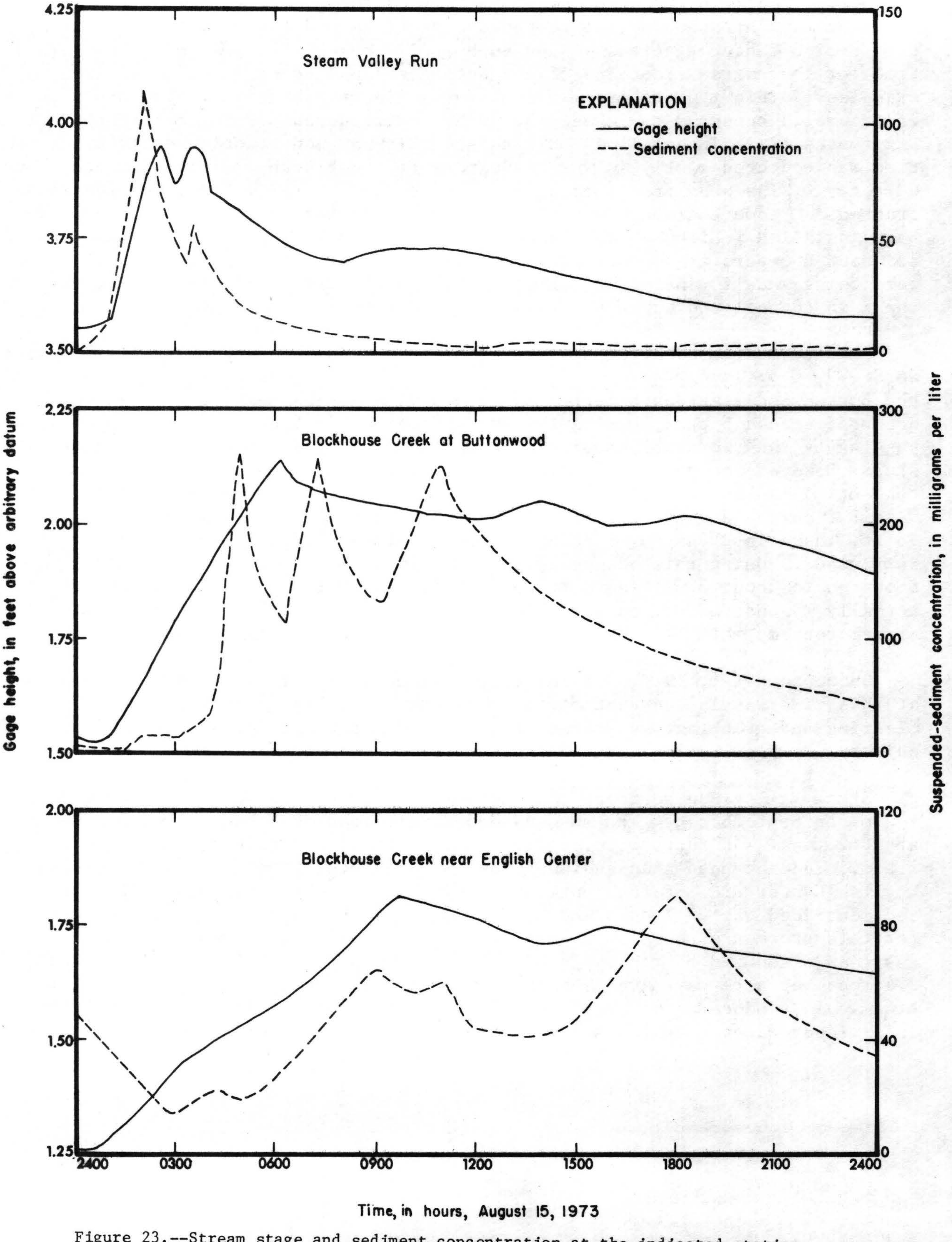

Figure 23.--Stream stage and sediment concentration at the indicated station for the storm of August 15, 1973.

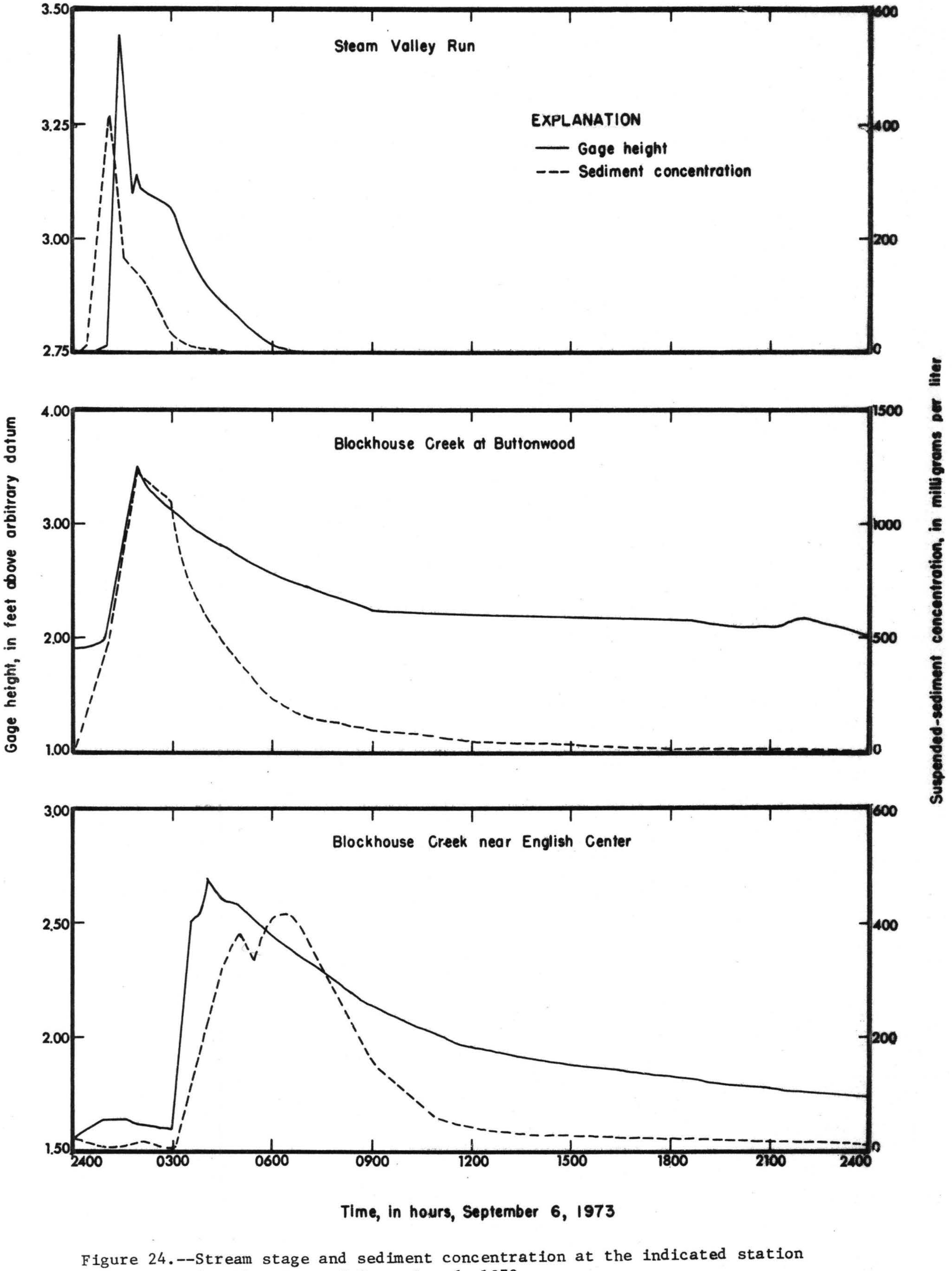

Figure 24.--Stream stage and sediment concentration at the indicated station for the storm of September 6, 1973.

The travel time of the peak sediment concentrations from Buttonwood to English Center was about 5 hours. Assuming that peak concentrations move at about the same rate as water velocity, their average velocity was 1.45 ft/s. If the sediment's settling velocity, the stream turbulence, and the average stream velocity are considered, most of the material that settled was probably coarse, although fine material may have been deposited in some areas. When larger storms occur, stream velocity and turbulence increase, and the material deposited in the channel is probably rescoured and transported downstream.

High stream stages, rapid velocities, and short travel times usually result in high sediment yields and little or no sediment deposition. On March 17, 1973, 1.2 in. of rain fell on soils that had recently thawed. The hydrographs for this storm are shown in figure 25. The sediment load at Steam Valley Run was 71 tons. Blockhouse Creek at Buttonwood discharged 4,690 tons. Assuming the sediment discharge into Blockhouse Creek between the Buttonwood and English Center stations was an additional 100 tons, then a suspended-sediment load of 4,860 tons could be expected to pass the English Center gage. The measured sediment load at English Center was 5,100 tons, about 5 percent more than expected, and could be from previously deposited material.

An intense storm occurred on October 29-30, 1973; stream stage and precipitation are shown in figure 26. Travel time for the sediment-concentration peak in the 5-mi channel was about 1 3/4 hours. This means that the water velocity averaged nearly 4 ft/s in the channel from Buttonwood to English Center. The sediment load measured at Buttonwood was 740 tons. On Steam Valley Run, the sediment load was 86 tons. If it is assumed that about 100 tons of sediment was supplied to Blockhouse Creek between Buttonwood and English Center, then a suspended-sediment load of 826 tons would be expected. However, a suspended-sediment load of 925 tons was measured at English Center. This 30 tons is about 3 percent more than was expected and is within the limits of measuring errors. Differences this small between expected and measured values cannot be reliably detected. However, the deposition levels found during previous smaller storms suggest that this difference is due to scour in the channel between Buttonwood and English Center.

Figure 27 compares the percentage of scour or deposition in the channel between Buttonwood and English Center and the approximate peak velocity for a particular storm at the English Center gage. Percentage of scour (-) or deposition (+) in the channel between Buttonwood and English Center was determined by the formula:

$$\frac{\text{tons by the Buttonwood stations}}{\text{tons by the English Center station}} \quad -1 \quad \times 100$$

The graph shows that as stream velocity increased (and travel time decreased), less deposition was observed. Figure 27 also indicates that scour develops above some threshold velocity. The graph suggests that as peak velocity at the English Center gage approaches 8 ft/s, scour may appear in the channel above the gage. At this velocity, the stream has enough force to disengage the sediment layer from the stream bottom and transport it along with the sediment introduced from the basin. Particle-size analyses of selected storm samples indicate that the sediment loads associated with storms of this magnitude have high percentages of sand.

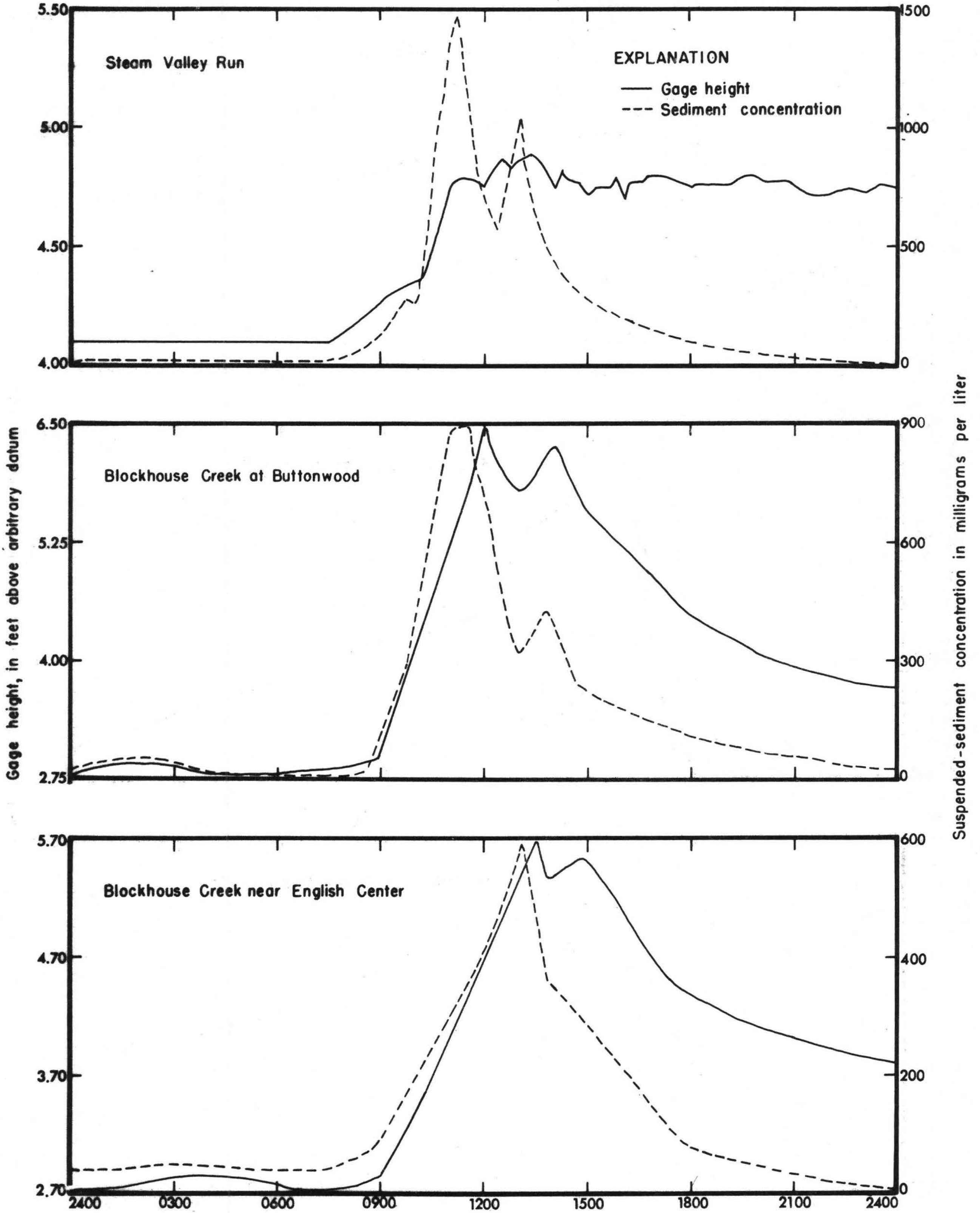

Figure 25.--Stream stage and sediment concentration at the indicated station for the storm of March 17, 1973.

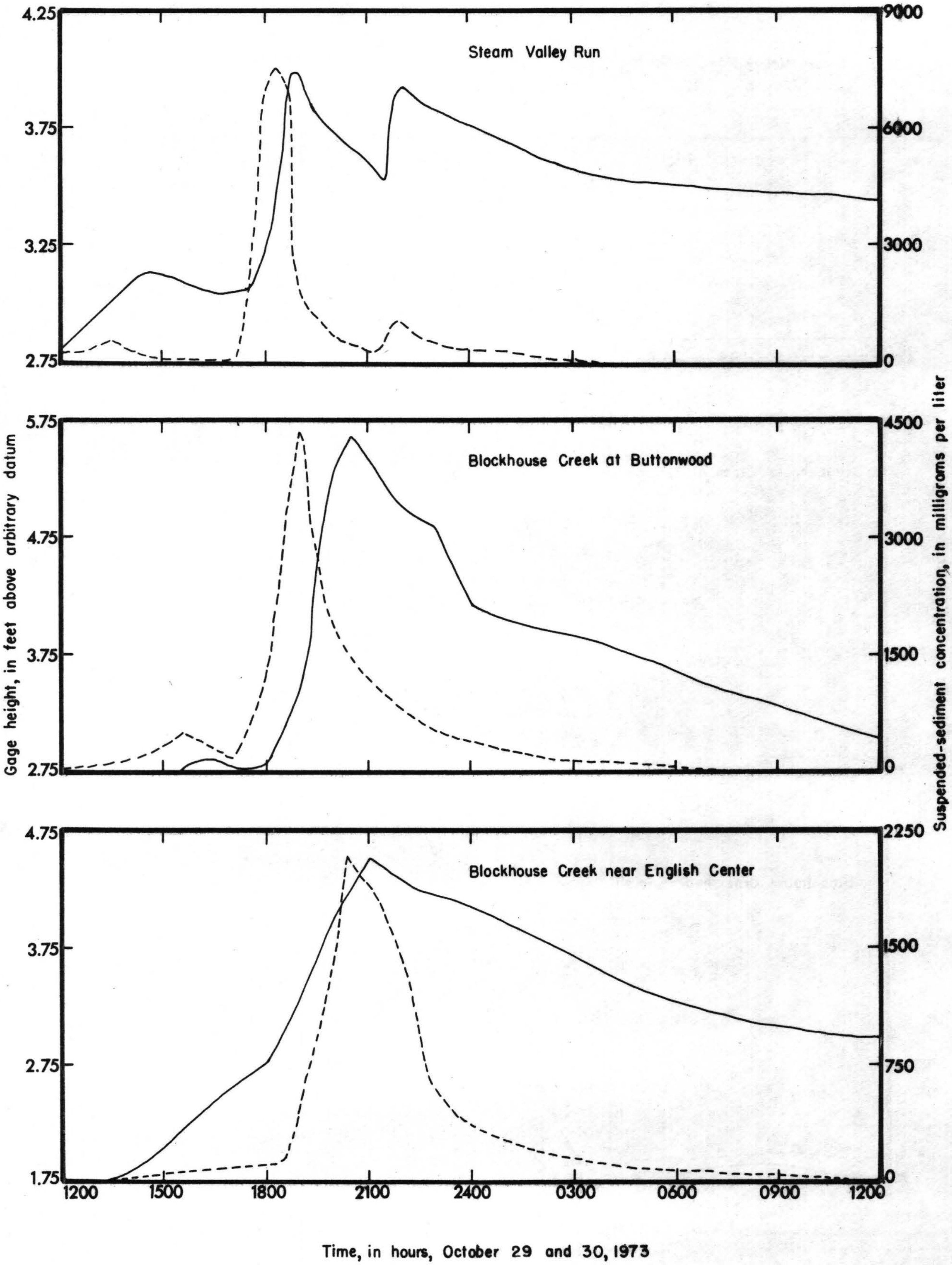

Figure 26.--Stream stage and sediment concentration at the indicated station for the storm of October 29-30, 1973.

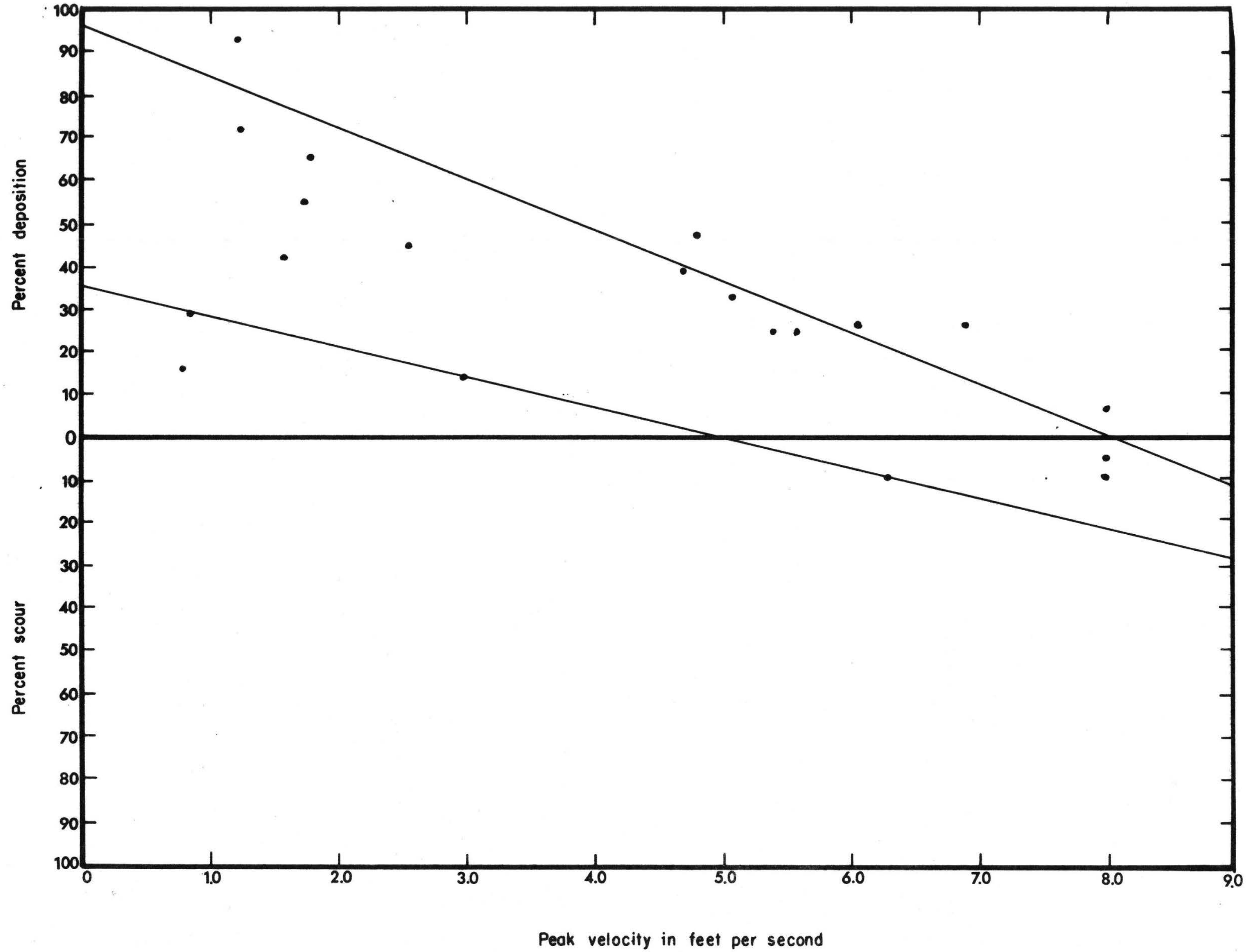

Figure 27.--The relation between peak velocity at the English Center station and the percentage of scour or deposition in the channel between the Blockhouse Creek stations near English Center and at Buttonwood.

Sediment deposition in the channel generally appears only during storms of small magnitude. Storms of high magnitude either scour the streambed or deposit and scour fairly equal amounts. During extremely large storms, streams normally transport most of their annual load (Helm, R. E., 1978; Eckhardt, D. A. V., 1976). Because the sediment loads are so high during these large storms, the sediment discharges from the highway construction area may be insignificant if compared to the total sediment discharge from the watershed. This suggests that sediment control methods need to be developed to control excess sediment discharges during small storms rather than those from large storms. The large storm sediment discharges appeared to be relatively unaffected by the sediment control method used in this study.

SEDIMENT YIELD DURING BASEFLOW CONDITIONS

About 2 percent of the suspended-sediment load due directly to construction of the highway was transported during baseflow conditions. In the stream whose drainage area was most involved in the construction area, about 5 percent of the suspended-sediment load was transported during periods of no storms. Other stations on the less-affected stream had less, but noticeable baseflow sediment loads.

Baseflow sediment discharge is defined as the sediment load carried by a stream or river during periods of little or no rainfall or snowmelt (Reed, 1976). Normally, this load is insignificant compared with the quantities of sediment discharged during storms. However, when an earthmoving activity, such as clearing or channel realignment, takes place near the stream or near an area from which the stream receives flow, the baseflow load may be a significant amount of the sediment discharge during the short period of active earthmoving.

Baseflow loads are determined by calculating sediment discharge during periods of no storms. Storm days normally occur about 20 percent of the year or 6 days per month. The remaining 24 days in the month were the basis for the calculations of sediment discharge during baseflow periods (Reed, 1976).

The most significant increase in baseflow sediment discharge was at the station on Steam Valley Run. This stream had considerable construction in its basin and was disturbed by earthmoving. The average baseflow discharge at this station for the 42-month nonconstruction period was 1.8 tons per month. Using this figure for the 18-month construction period from April 1974 to September 1975, the expected baseflow sediment load is 33 tons. The actual baseflow load for the construction period was 101 tons. This means that 68 tons or about 5 percent of the 1,400 tons introduced to the stream by construction was due to earthmoving near or in the stream, rather than to soil erosion from the construction area. The 68-ton sediment load is equivalent to 0.85 tons per acre of construction area in the basin. Flow through the relocated channel on Steam Valley Run, which opened in January 1974, contributed an insignificant amount of sediment to the baseflow load. Figure 28 shows the change in the baseflow loads due to construction. The figure also shows that about half the sediment-load increase was during the first 6 months of the 18-month construction period. This is probably due to the active earthmoving associated with the initial phases of clearing and grubbing.

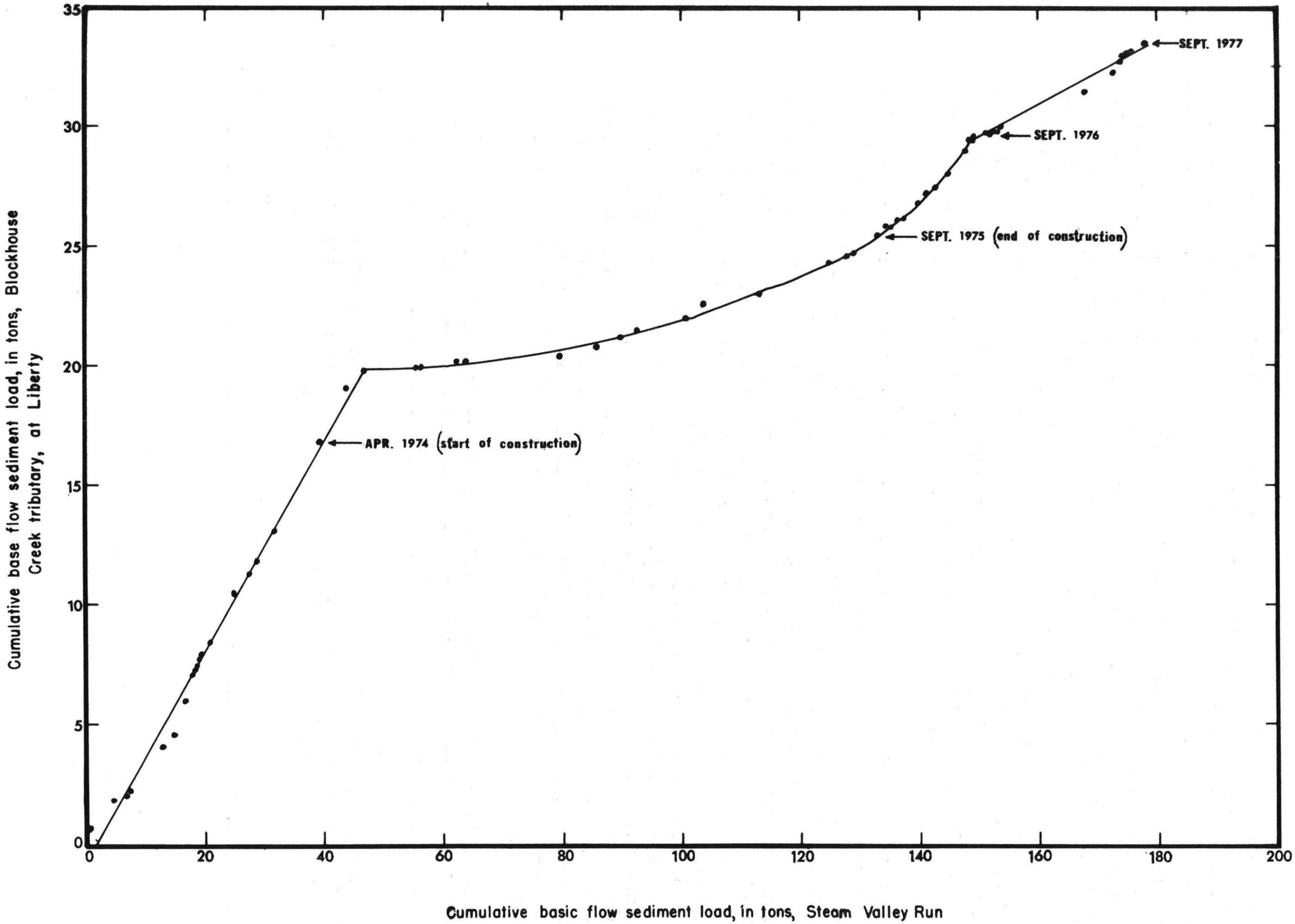

Figure 28.--The cumulative relation between the baseflow sediment loads of the control station at Liberty and the Steam Valley Run station at Buttonwood.

The station on Blockhouse Creek at Buttonwood also showed an increase in sediment discharge during baseflow conditions. Construction near this station produced a sediment load of 7,700 tons. By using the same methods as above to determine the baseflow increase, 88 tons of the 7,700 tons was baseflow sediment discharge due to construction in the immediate area of the stream. At this station, slightly more than 1 percent of the suspended-sediment was discharge during baseflow, compared with the 5 percent at Steam Valley Run. The smaller amount may be attributed to the small amount of construction adjacent to Blockhouse Creek north of Buttonwood. The baseflow load of 88 tons is equivalent to the loss of 0.4 tons per acre of sediment from the construction area, about half the loss in the Steam Valley Run basin. The opening of the relocated channel on Blockhouse Creek above Buttonwood in March 1974 contributed 7.8 tons of sediment or almost 10 percent of the calculated baseflow sediment load. Most of this was introduced when the cofferdam was breached. Figure 29 shows the changes in the baseflow loads at Buttonwood due to construction.

A significant amount of sediment also passed the station on Blockhouse Creek near English Center during baseflow periods. The increase in baseflow sediment discharge at this station was 155 tons, or close to the 156-ton total at the Buttonwood and Steam Valley Run stations. The sediment contribution of the stable forested drainage area between the Buttonwood and English Center stations is assumed to be negligible during baseflow. The 155-ton increase is about 2 percent of the 8,000 tons contributed by construction. The agreement of the figures from the upstream and downstream stations suggests that the sediment discharged during baseflow consists mainly of fine sediment. Only very fine particles will travel the 5 mi between the stations without being deposited. This conclusion is supported by the particle-size analysis shown in table 3. The sample was taken at the Buttonwood gage on the day the new channel on Blockhouse Creek was opened, a day of high baseflow sediment discharge. The analysis shows little sand and large quantities of silt and clay. Clay particles have a fall diameter less than .004 mm, silt particles have a fall diameter between 0.004 mm and 0.062 mm, and sand has a fall diameter greater than 0.062 mm.

Table 3.--Particle-size distribution of baseflow sediment sample from Blockhouse Creek at Buttonwood on March 28, 1974

INSTANTANEOUS DISCHARGE (ft^3/s)	SUSPENDED SEDIMENT CONCENTRATION (mg/L)	SUSPENDED SEDIMENT percent finer than indicated size, in millimeters .002	.004	.008	.016	.031	.062
27	860	30	33	52	73	92	99

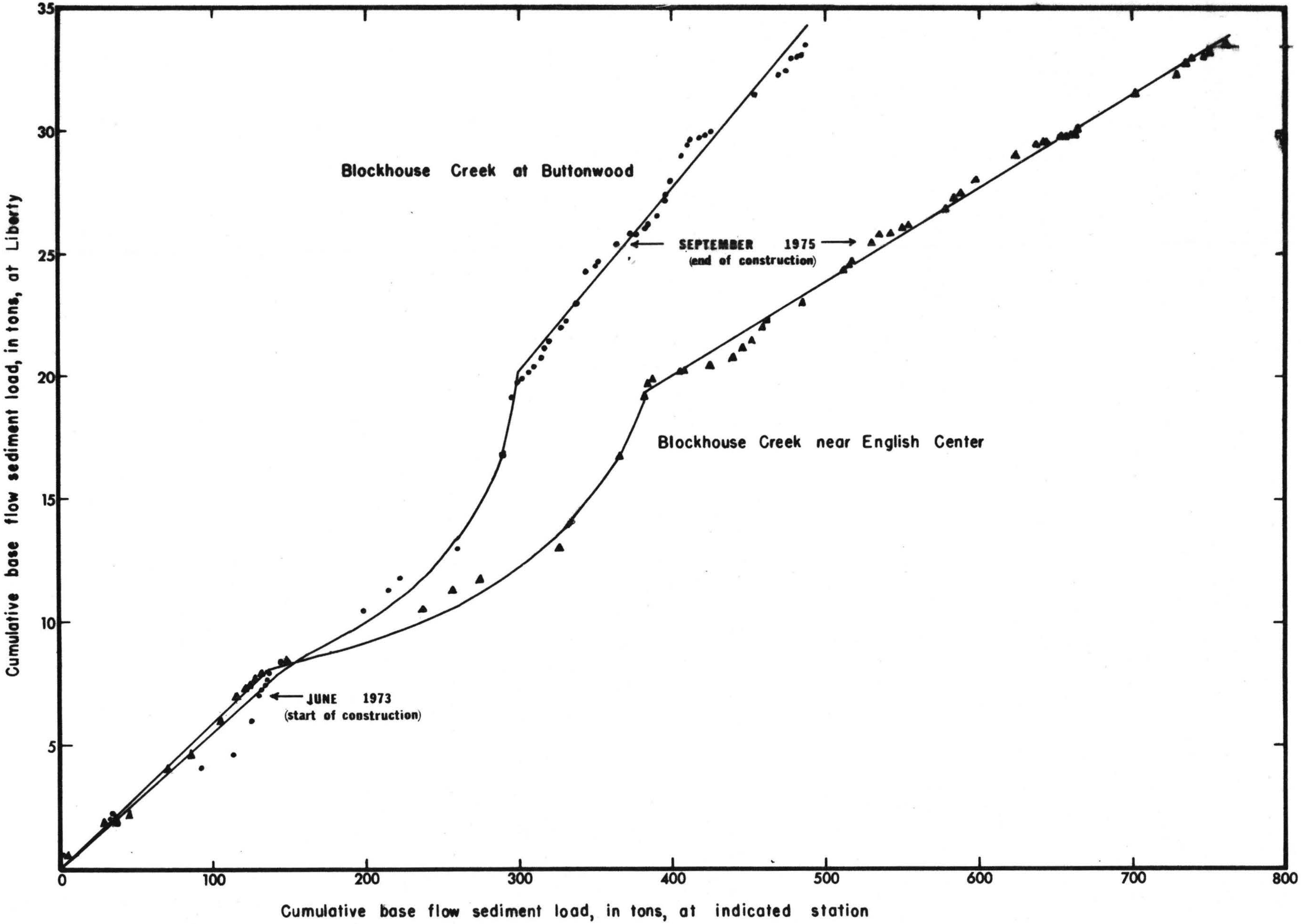

Figure 29.--The cumulative relation of the baseflow sediment loads of the control station at Liberty and the Blockhouse Creek stations near English Center and at Buttonwood.

A slight delay was noticed, after construction began, before an increase in baseflow-sediment discharge reached either Blockhouse Creek station. However, by October or November 1973, sediment discharge had increased. The trend continued until about March 1974. For the next 5 months, the sediment discharge was generally less than the rates before construction. Around July 1974, the sediment discharge rates returned to near the preconstruction rates. This pattern was also found at the Steam Valley Run station and is due to the construction procedure. During clearing and grubbing, some subsoil is exposed. This consists of the clay found in the baseflow samples. After clearing and grubbing, earthmoving begins. This requires transporting large quantities of subsoil and rock, and may involve the disturbance of the fine sediments in the subsoil. Therefore, some of the increase in baseflow sediment discharge is explained by the extensive soil disturbance by clearing and grubbing and the hauling of soil in cutting and filling.

The conclusion from this analysis is that some sediment, as much as 0.85 tons per acre in this study, may have been lost during baseflow periods when the area was being prepared for construction. The sand part of the sediment is removed fairly well by controls or deposition, but silt and clay are transported downstream.

SUMMARY

Approximately 9,000 tons of sediment was discharged from the 300-acre area during the construction period. Sediment controls used during construction were found to be fairly effective in limiting the sediment discharge. Sediment was not deposited permanently in the stream channels, and stream temperature appeared to be unaffected by the stream relocations and diversions. Limiting the amount of time that construction acres were exposed definitely reduced the amount of sediment discharged.

Nine miles of highway was constructed from May 1973 to September 1975, in the Blockhouse Creek basin from Steam Valley to just south of Sebring. Two and one-half miles of roadway was constructed parallel to Steam Valley Run. Along Blockhouse Creek or within 1/4 to 1/2 mile of Blockhouse Creek, 6 1/2 miles of roadway was constructed. Figures 10 and 11 show the major phases of construction in both basins. Major earthmoving began in the Blockhouse Creek basin above Buttonwood in July 1973 and in the Steam Valley Run basin in June 1974. Construction ended in both basins in September 1975. Most soils were stabilized during 1975 at both sites.

Sediment loads due to construction were 1,400 tons from the Steam Valley Run basin and 7,700 tons from the Blockhouse Creek basin. Of the 1,400 tons discharged by the Steam Valley Run station, 68 tons was during baseflow conditions. Of the 7,700 tons discharged by the Blockhouse Creek at Buttonwood Station, 88 tons passed the sampling station between periods of significant rainfall.

On a per-acre-of-construction basis, the sediment load of 7,700 tons at the Buttonwood station averaged 37 tons per acre of disturbed area. Assuming soil weighs 85 lb/ft^3, the average soil loss from the disturbed area was about 0.25 in. A total of 80 acres was disturbed in the Steam Valley Run basin. In this basin, 1,400 tons was discharged due to construction, a yield of 17 tons per acre. The difference between these two sediment yields is due mainly to the shorter time that the Steam Valley Run basin soils were exposed by construction. Blockhouse Creek basin soils were exposed for about 28 months; Steam Valley Run basin soils for about 18 months. After the period of construction, the basins' sediment yields returned to the levels found before construction.

Measured sediment yield at the Blockhouse Creek station near English Center indicated that temporary deposition did occur in the 5 mi section of Blockhouse Creek from Buttonwood to the English Center station. Most of the deposition was on a storm-to-storm basis and was probably scoured and transported during subsequent high flows. Due to the small quantities of sediment involved in this deposition and the large quantities of sediment discharged during storms with scouring potential, detection of the deposited sediment was difficult.

Stream-temperature data were collected at each of the four stations in the Blockhouse Creek basin in order to monitor changes due to the channel relocations and diversions. No change was found in the mean stream temperature at the two stations directly downstream from the relocations on Steam Valley Run and Blockhouse Creek. The lack of a change in the mean stream temperature suggests that the rate of temperature change also remained stable.

Sediment-control measures included strict limits on construction near flowing streams. Rock dams and straw bales were used to trap excess sediment in several areas, and a large offstream pond was constructed to trap sediment from slightly more than half a mile of constructed roadway. Most streams were crossed with temporary culverts, and all channel relocations were constructed under dry conditions before the stream was diverted. The channel constructions were lined with rock, seeded and mulched, and allowed to stabilize for 6-12 months before the stream was diverted.

The most effective sediment control was the limitation of the active construction period. This reduced the length of time during which sediment-erosion rates were increased. For instance, the heavy rains associated with the passage of tropical storm Eloise in September 1975, fell after the paving was finished and after most of the area had been stabilized by seeding and mulching; otherwise, large quantities of sediment might have eroded from the construction area.

Sediment controls were fairly effective in reducing the amount of coarse sediments discharged during storms and during earthmoving periods. Their effect on the silt and clay part of the sediment was noticeable only during baseflow conditions. Sediment controls need to be designed to control sediment discharge during the earthmoving periods and during small and medium storms. The increase in sediment discharge from the exposed construction area during large storms is insignificant and basically uncontrollable.

The data collected for this investigation suggests that the most effective method of sediment control used in the construction of this highway was the limiting of the amount of time that the construction area was exposed. This was accomplished most effectively by clearing only small areas at a time and following this operation with the finishing and paving operations as soon as possible. Physical sediment controls did not control sediment erosion caused by major storms, but were most effective in controlling sediment discharges due to lower magnitude storms and from earthmoving activities. Erosion was minimized, where stream relocations were made, by constructing new channels several months before the diversion, seeding and mulching them immediately after their construction, and allowing them to stabilize adequately. By combining these sediment control features, a reduction can be realized in the sediment discharge from an area of highway construction.

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