I. FOREWORD

INTRODUCTION

Description of Study: The Pennsylvania Department of Environmental Resources, in response to Commonwealth of Pennsylvania Legislative Act 443 "Land and Water Conservation and Reclamation Act," authorized engineering surveys of a number of major watersheds in the Commonwealth. The purpose of these studies was to locate the sources of acid mine drainage pollution stemming from abandoned deep and strip mines, recommend abatement measures, and estimate the costs of abatement.

One of the major watersheds found to be affected by coal mining operations was the Raccoon Creek Watershed, located in Allegheny, Washington and Beaver Counties. The Raccoon Creek Watershed provides room for industrial and residential growth within the Greater Pittsburgh Metropolitan area. Moreover, the watershed contains Raccoon Creek State Park and Hillman State Park and State Gamelands 117, all of which are recreational facilities located within a 30 mile driving distance from downtown Pittsburgh.

Purpose: The purpose of this acid mine drainage survey of the study portion of the Raccoon Creek Watershed was to:

Perform field reconnaissance to define the water quality of streams and to determine the number and type of acid mine drainage sources.

Establish sampling and flow measurement stations along streams and at locations of acid mine drainage sources.

Sample and gauge identified streams and acid mine drainage pollution sources for a period of 12 months.

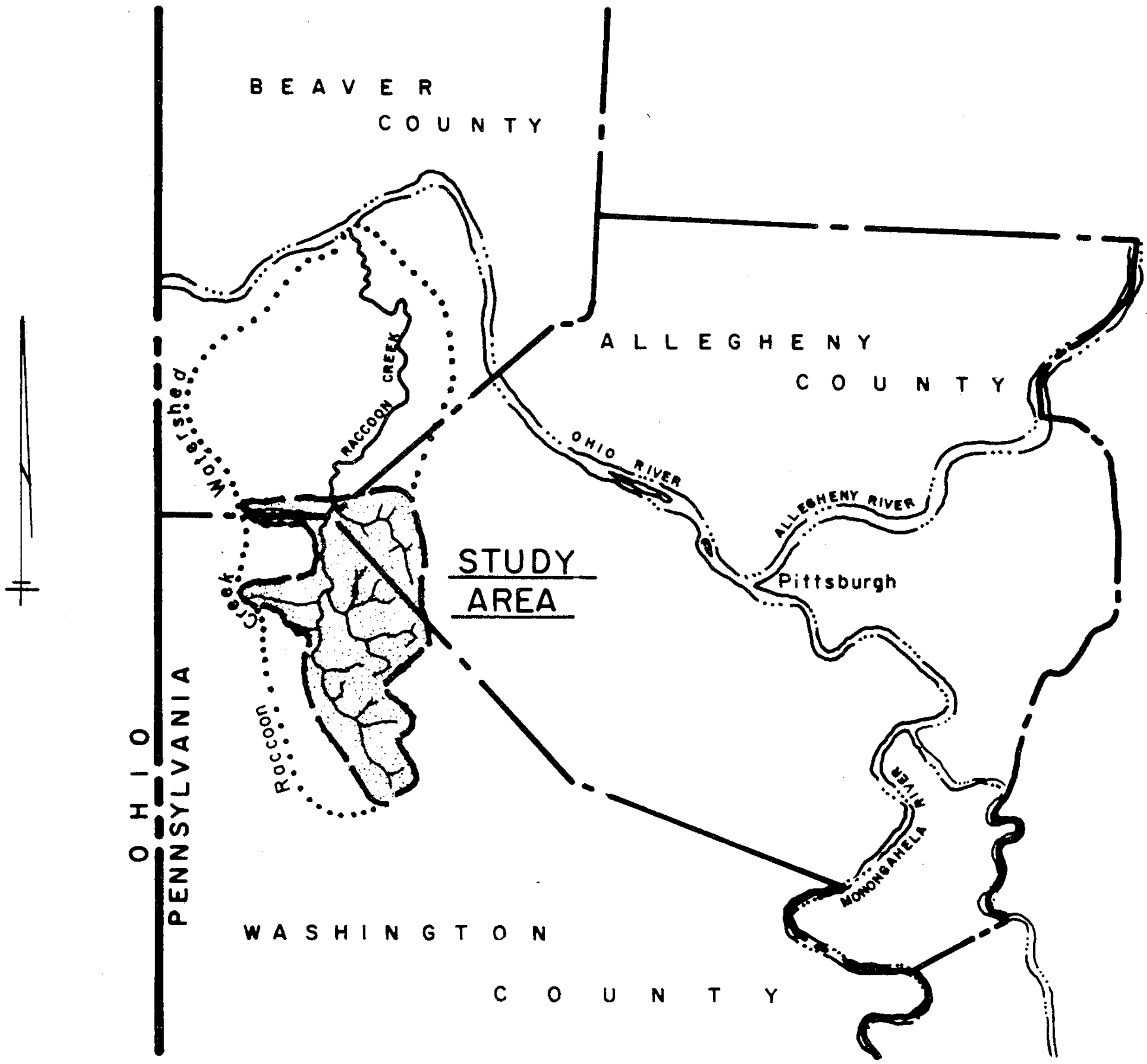
Collect geological, hydrological, mining and other data useful to study mine drainage conditions.

Determine feasible methods of abating acid mine drainage based on analysis of water quality results, study of mining and geological data, and field investigations.

Estimate costs for abatement of all major and minor sources of acid mine drainage.

DESCRIPTION OF THE STUDY AREA

Location of Basin: The Raccoon Creek Watershed lies within the Allegheny Plateau in Southwestern Pennsylvania. The watershed is drained by Raccoon Creek and ultimately the Ohio River. The Raccoon Creek Watershed is bounded on the east by Chartiers Creek, on the south and west by a number of minor Ohio River tributaries, and on the north by the Ohio River. The total watershed area is approximately 184 square miles. Only the southern portion of the Raccoon Creek Watershed contains sources of AND. Thus, the study area has been limited to a drainage area of approximately 45 square miles and approximately 115 stream miles. The watershed lies in Allegheny, Beaver and Washington Counties. Plate No. 1 shows the relationship of Raccoon Creek and the study area to Allegheny, Beaver, and Washington Counties.



LOCATION MAP
RACCOON CREEK STUDY AREA

Plate I

Location of Sub-watersheds Within the Study Area: For convenience of sample identification, water quality evaluation, and report presentation the Raccoon Creek Watershed study area was subdivided into its eight natural sub-watersheds. Plate No. 2 shows the boundaries of the study area and the eight sub-watershed boundaries.

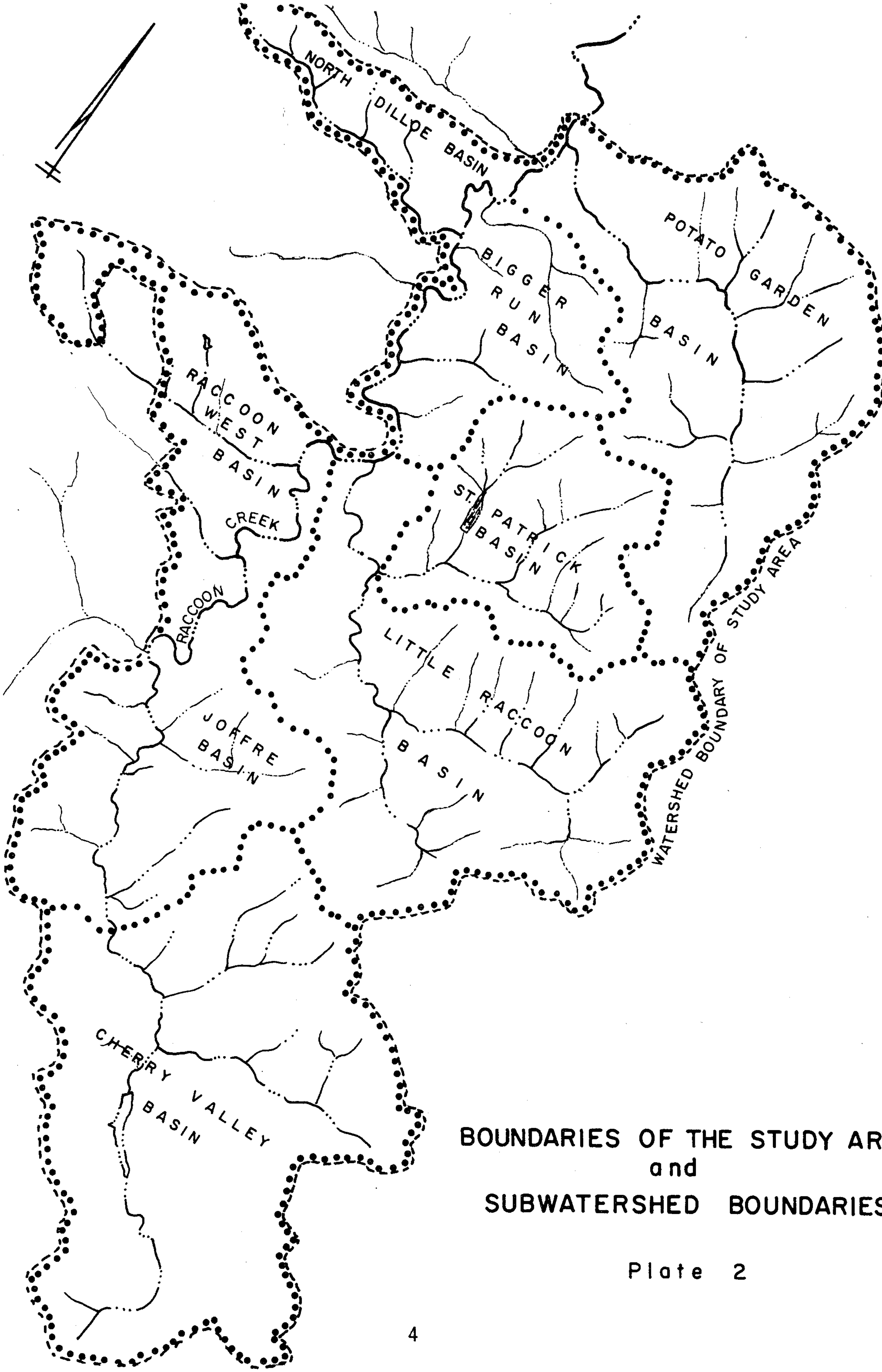
Relationship to Other SL Projects: Excluded from the Raccoon Creek Watershed study, in addition to the northern portion of the watershed, are Hillman State Park - Project No. SL 130-2, State Game Lands 117 - Project No. SL 130-1, and the Burgetts Fork Sub-watershed - Project No. SL 130. These areas have been, or are presently under separate study. The relationship of this study area to other SL projects is shown on Plate No. 3.

Topography: The Raccoon Creek Watershed study area is part of the unglaciated Appalachian Plateau physiographic province, a broad dissected upland underlain by essentially horizontal sedimentary rocks. Streams have dissected the area so that most of the plateau surface is no longer evident. The present surface consists mainly of broad rounded ridges and intervening valleys. The study area is located in what is known geomorphologically as a mature region. Such a. region is one in which the principal streams have eroded their valleys to a fairly uniform grade and the smaller tributaries have cut the uplands into numerous rounded off ridges. The result is a hilly topography. The maximum relief which exists over the study area is about 300 ft. Elevations near 1200 ft. predominate in Joffre Basin and Cherry Valley Basin while Raccoon Creek flows in the valley at about 1,000 ft. The northern part of the study area is predominantly at Elev. 1100 ft., with Raccoon Creek at about Elev. 900 ft.

The head waters of Raccoon Creek are in northwestern Washington County in Mount Pleasant Township. The creek then flows north some 46 miles to enter the Ohio River at a point about 30 miles downstream of Pittsburgh, Pennsylvania.

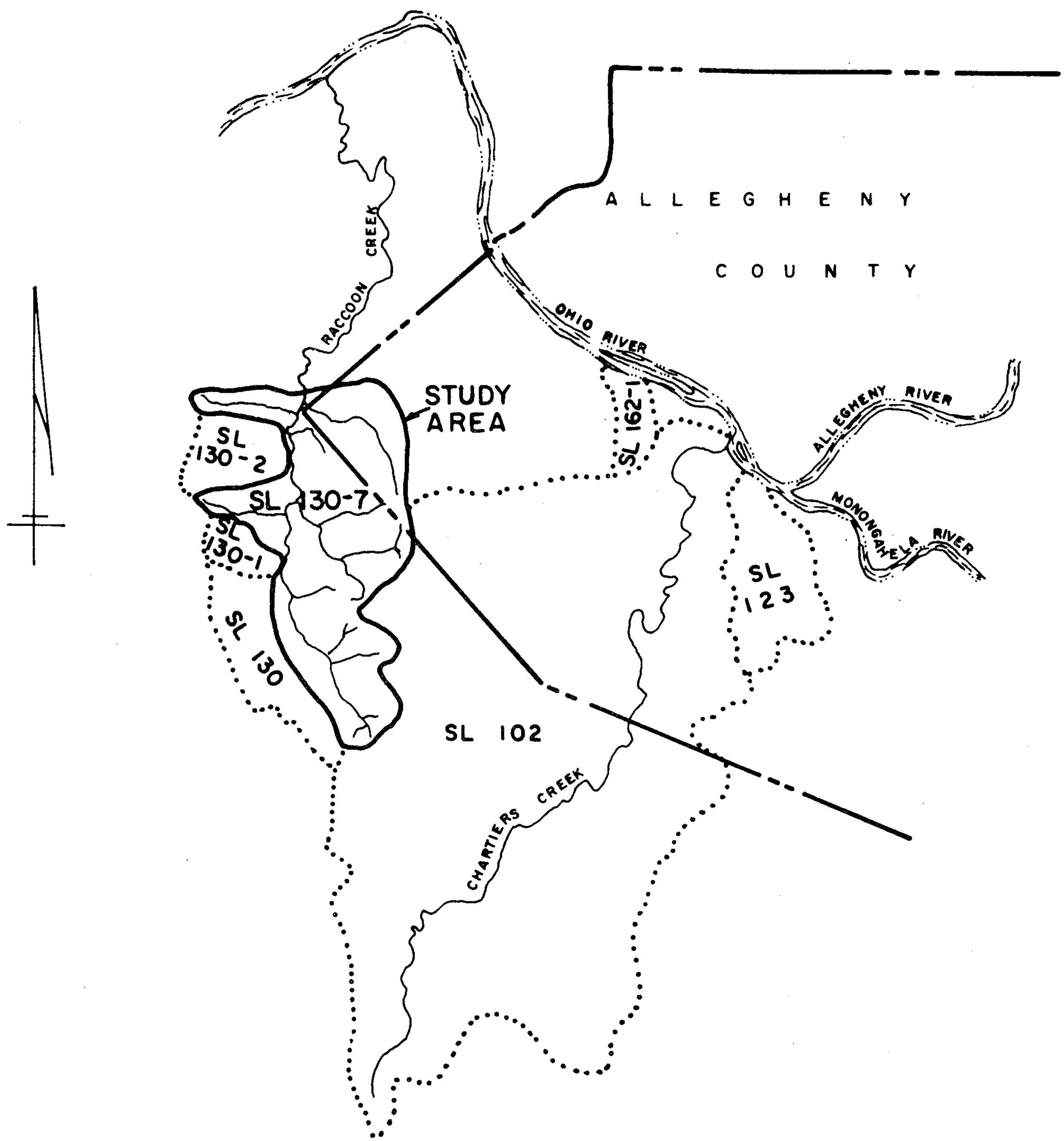
Surface Drainage: The whole Raccoon Creek Watershed is long and narrow in shape measuring about 26 miles in length and about 11.5 miles at its maximum width (east-west). Six major streams drain the study area and flow into Raccoon Creek. Those draining into Raccoon Creek from the eastern side are Potato Garden Run, Bigger Run, Little Raccoon Run, and Cherry Run, whereas, those draining from the western side are Dilloe Run and an unnamed tributary. The location of the streams to the study area are shown on Plate 4. Three additional tributaries flow into Raccoon Creek within the study boundary, but their sub-watersheds were not included in the study area. They are Burgetts Fork, Brush Run and Wingfield Run.

The Raccoon Creek study area is well-drained due to the hilly topography conducive to rapid runoff of the surface waters. This is indicated by the very few swampy areas within the study area. The slope of the main channel of Raccoon Creek varies from about 7 ft. per mile near the northern boundary of the study area to 15 ft. per mile in the extreme headwaters. The channels of the tributaries generally vary in slope from about 35 ft. per mile to 80 ft. per mile.



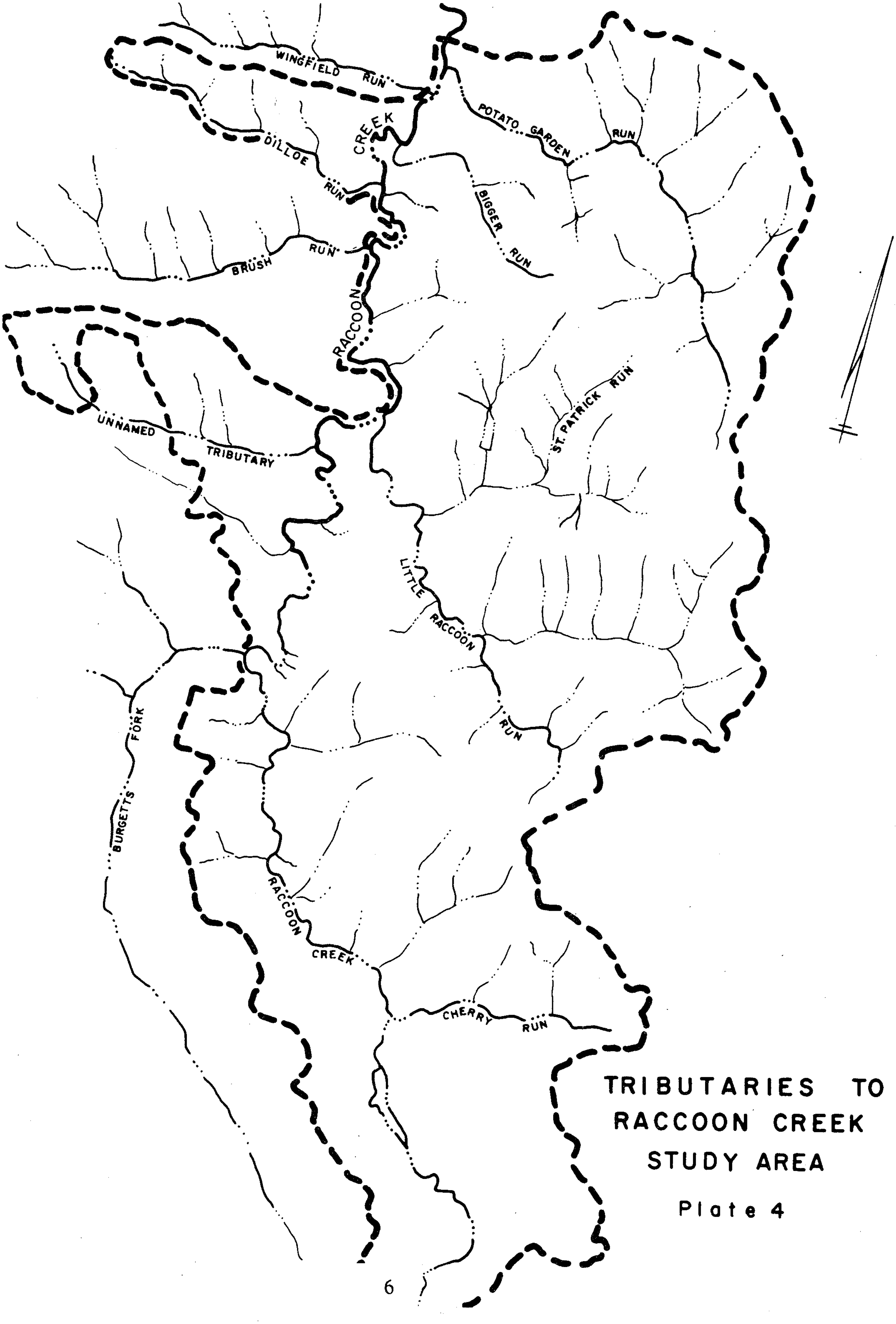
BOUNDARIES OF THE STUDY AREA
and
SUBWATERSHED BOUNDARIES

Plate 2



RELATIONSHIP OF THE STUDY AREA
TO OTHER SL PROJECTS

Plate 3



TRIBUTARIES TO RACCOON CREEK STUDY AREA

Plate 4

Precipitation: Precipitation in the area is normally well distributed throughout the year. Approximately 25% of the average total annual precipitation of 36 inches occurs during the winter months. The measured precipitation for the Raccoon Creek area during the period of study amounted to an annual total of 42 inches. This amount is approximately 17% more than the normal annual total. Precipitation data from 1969 through the study period is shown on Plate No. 5.

FLOOD FREQUENCY

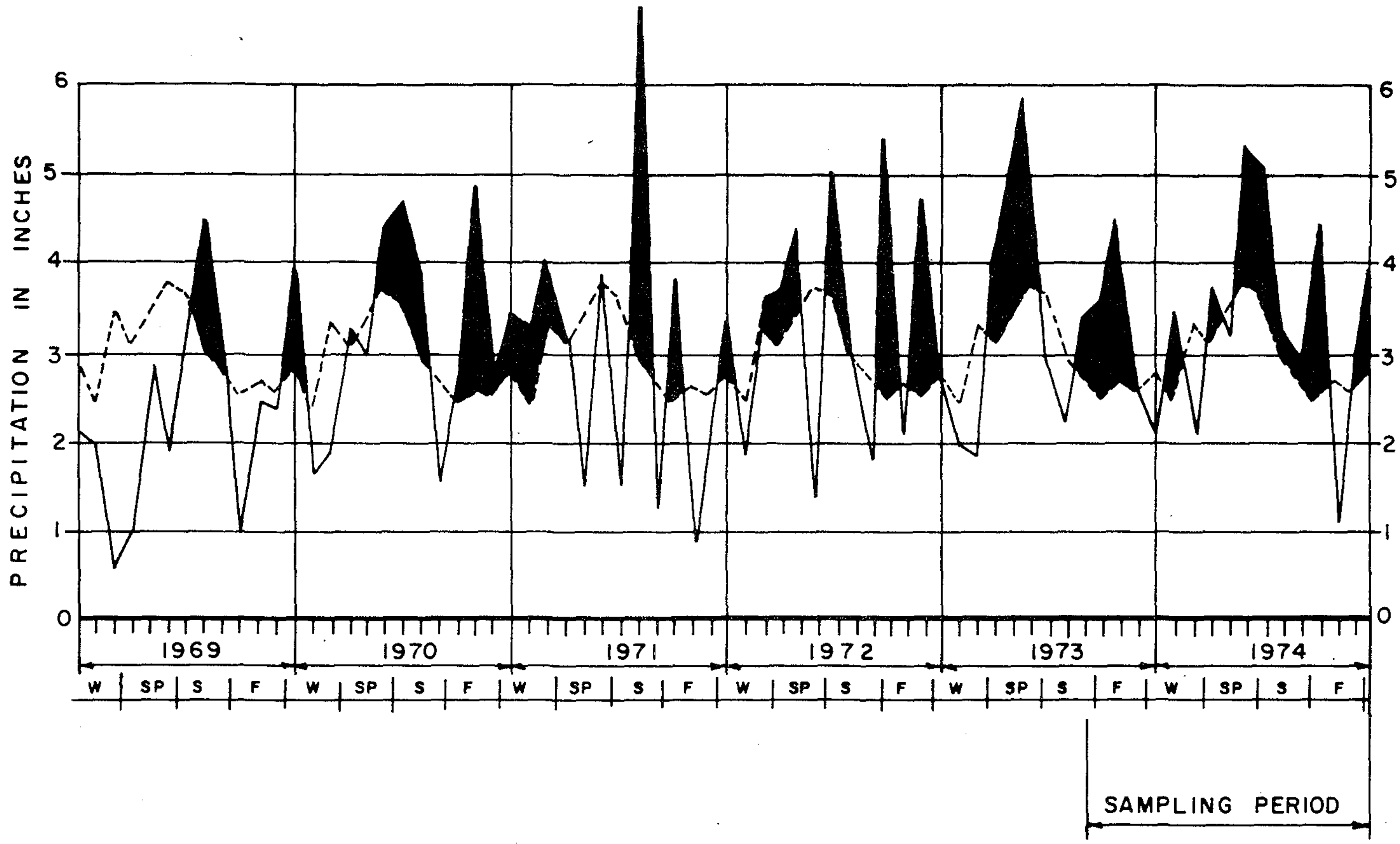
Flood frequency within the Raccoon Creek study area correlates with seasonal variations in the rate and amount of rainfall, subsequent seasonal variations in ground water level, degree of soil saturation, ground slope and cover, overall size and shape of the watershed, and ratio between stream channel length and area drained.

Rainfall Frequency and Intensity: The hydrologic year may be subdivided into two major seasons; one, from June through October characterized by irregular rainfall often in the form of intense storms; and the other, from November through May, characterized by more frequent, less intense rainfalls. Statistically, the months of maximum probability for intense one hour storms are July, August and September. Thus, "flash" flooding in response to quick heavy rainfall is most frequent in these months, while flooding due to prolonged rainfall occurs during other times of the year.

Base Flow of Raccoon Creek: The rate of discharge from the U.S.G.S. gauging station on Raccoon Creek at Moffatts Mill, for the hydrologic year from May, 1973 through April, 1974 indicates the same two hydrologic seasons. The dry season from June through October has an average discharge of 71.9 cfs, with a range from 16 cfs to 454 cfs. The drought months are July, August, and September when the average discharge is less than 50 cfs, and daily discharge rises above 100 cfs only 4 days during the drought season. The wetter season from November through May has an average discharge of 313 cfs with a range from 42 cfs to 1920 cfs. Comparison of rainfall data to discharge rates at Moffatts Mill shows an overall correlation between rainfall and discharge on a seasonal basis. Discharge tends to peak from 24 to 72 hours after a rainfall.

Soil Saturation and Ground Water Level: Previous rainfall may significantly affect runoff due to a particular rainfall. For example, a rainfall of .10 inch in a six hour period may cause relatively little increase in immediate stream discharge if the soil is not saturated. However, it may cause an appreciable surge in discharge if the soil is saturated. The ratios between evaporation, infiltration, and runoff may vary considerably with season and rate of rainfall, with evaporation hitting a peak during the summer months. Rainfall affects the ground water level over a longer time period than runoff.

Channel Gradient and Cover: Ground slope affects flood frequency in that it can change the velocity of runoff, thus changing the concentration time. Gradients for Raccoon Creek change from the headwaters to SR-67, the downstream station in the study area, and are generally less than 0.3%. Tributary gradients are higher generally and may be as great as 1.5%. Ground cover may serve to retard or inhibit runoff, reducing velocity and lengthening concentration time. Runoff from a stripped area will reach a stream channel much more quickly than runoff from a grassy area equivalently spaced. Ground cover also reduces the runoff coefficient, affecting the potential discharge immediately after an appreciable rainfall.



LEGEND

-------- = AVERAGE PRECIPITATION

——— = RECORDED PRECIPITATION

= DARK AREAS ARE ABOVE AVERAGE PRECIPITATION

Data from U.S. Dept. Of Commerce, Greater Pittsburgh Airport.

MONTHLY PRECIPITATION DATA

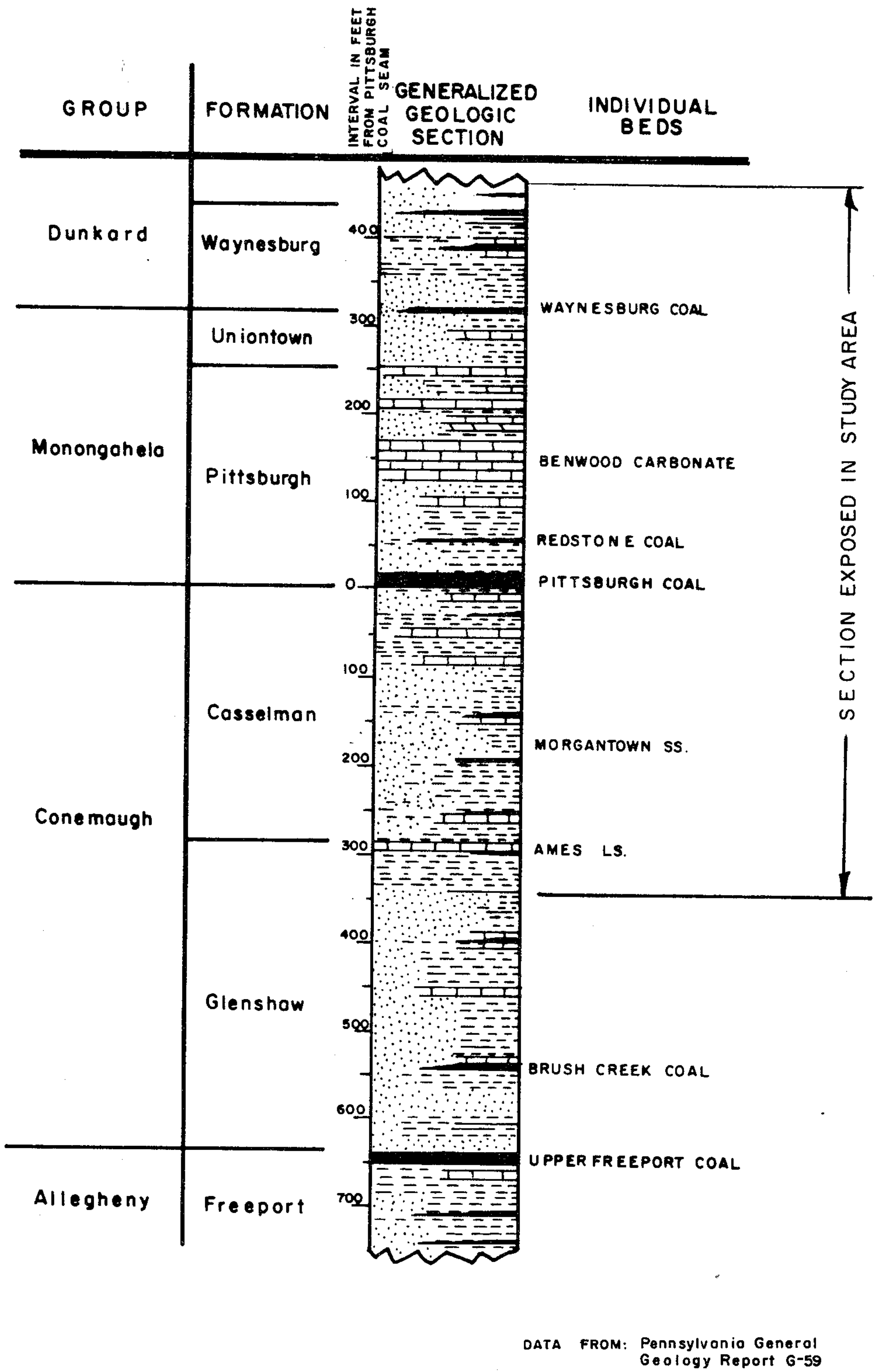
Plate 5

Overall Size and Shape of Watershed: The overall size and shape of the watershed affects the flood frequency of Raccoon Creek because of the distribution and size of tributaries along the main stream channel. A well-drained watershed with many short tributaries evenly spaced along the main channel will have a wide discharge peak because discharge from tributaries reaches the monitoring point sequentially. Thus, the flood risk is reduced. However, a watershed such as Raccoon Creek will have a higher flood potential because of large tributaries such as Potato Garden Run and Little Raccoon Run. A discharge peak of Raccoon Creek at the downstream part of the study area could show surges in discharge when the water from major tributaries reaches the monitoring point. This could increase the flood potential.

GEOLOGY

Structure: Raccoon Creek Watershed is contained within the physiographic province known as the Appalachian Plateau. The province is characterized by essentially flat-lying strata whose regularity is broken by low broad folds. The regional dip of the stratified rocks exposed in the watershed is to the southeast. The local geology is modified by two structural folds. The West Middletown Syncline is the fold which most predominantly affects the local geology of the Raccoon Creek study area. The north trending axis of the syncline crosses Raccoon Creek near Bavington. The closure of the syncline just to the northeast results in a basin-like structure within the main watershed area. This condition is evidenced by noting the circular pattern formed by the Pittsburgh Coal structural contours. The Cross Creek Syncline, which trends east-west across the Cherry Valley Sub-watershed, intersects the West Middletown Syncline west of the Cherry Valley Sub-watershed. The structure contour of the coal also indicates that a certain amount of acid mine drainage discharged into the Raccoon Creek Drainage Basin results from surface water entering outside the topographic boundaries of the basin. It is particularly true of the areas in North Dilloe and Potato Garden Sub-watersheds.

Stratigraphy: The bedrock strata exposed over various portions of the study area are members of the Dunkard, Monongahela and Conemaugh groups. The total stratigraphic thickness exposed is on the order of 800 ft. All of the strata are sedimentary in origin. The generalized columnar section is shown on Plate 6. The formations within the Dunkard, Conemaugh and Monongahela groups are comprised principally of shales and sandstones but also contain prominent limestone and coal horizons. The area of outcrop of the Monongahela Group is more extensive than that of any other group in the Raccoon Creek study area. The Pittsburgh Coal seam is the lowest bed in the Monongahela Group and rests disconformably on the Conemaugh Group. Below the Pittsburgh Coal there are generally a few inches to a foot of impervious gray underclay, below which is about 2 ft. of dark to light gray brecciated limestone. The main coal seam is approximately 5 to 6 ft. thick with some thickening and thinning in various areas. The upper part of the Pittsburgh Coal consists of alternating bands of black carbonaceous shales and boney coal 6 in. to 2 ft. in thickness for about 7 to 8 ft. above the main seam. Iron sulfide minerals (pyrite and marcasite) are generally associated with the coal and the black carbonaceous shales and sandstone overlying the coal bed. These minerals, upon oxidation, represent the principal source of coal mine acid.



GENERALIZED COLUMNAR SECTION OF RACCOON CREEK STUDY AREA

Plate 6

Iron sulfide minerals are also found in the main coal seam as horizontal shaley partings and as concretions known as sulfur balls. The iron sulfide minerals in these partings are generally in the form of flaky crystals and the concretions occur as black to brassy spheres of various sizes. The sulfur balls are irregular in distribution in the Pittsburgh Coal and their composition is largely pyritic. These sulfur balls are one of the sources of acid in the main coal seam.

Mining History: The Raccoon Creek Watershed is situated in parts of three counties, but the mining activities of the watershed primarily reflect the mining history and trends of Washington County, and to a lesser extent Allegheny County. By far, the most economically important coal to the Raccoon Creek area has been the Pittsburgh Coal seam. The first recorded instance of mining in the Pittsburgh Coal seam was 1761 in Allegheny County and 1781 in Washington County. By 1820, both counties were dotted with small mines for primarily domestic uses. Coal production from the Pittsburgh seam steadily increased until around 1923 when peak production was realized in the two county area. Employment in the coal industry generally paralleled the production trends, and also peaked around the same time.

In the 1940's the use of new earthmoving equipment made it economical to remove thin surface seams by strip mining. During the 1940's and 1950's, strip mining in the Raccoon Creek area was intense and much of the area was depleted of its shallow Pittsburgh Coal deposits by strip mining. However, reserves of Pittsburgh Coal still remain in abandoned deep mines and are being economically strip mined today. Current energy requirements indicate that coal will probably play an increasingly important role in our economy. Significant coal reserves in the Raccoon Creek Watershed are limited to Washington County. Deep coal reserves of the Pittsburgh seam are located in the Cherry Valley portion of the Raccoon Creek Watershed. Future deep mining in this area should occur and will be of economic importance. Coal seams which were once economically unfeasible to strip mine, such as the thinner seams above the Pittsburgh Coal, are being viewed as economically mineable seams. Thus, future strip mining of these thinner seams in the southern half of the Raccoon Creek Watershed is a possibility. Areas of the Raccoon Creek Watershed, where deep mining and strip mining occurred, as well as where the Pittsburgh Coal remains in place, are shown on the Inventory Maps.

Previous Work in Study Area: Previous studies performed by the Washington County Planning Commission and the Wheeling, West Virginia Field Station of the Federal Water Pollution Control Administration (FWPCA) in 1967 and 1968 identified 157 sources of mine drainage in the entire watershed with a total net acidity loading of 81 tons per day. During the present survey, 115 pollution sources contributing 24 tons per day of net acidity were documented. The Wheeling FWPCA pollution survey catalogued twenty-eight (28) mine drainage sources, each discharging more than 1000 lbs/day of net acidity (total acidity less total alkalinity). The combined acidity discharge of these 28 sources was 141,556 lbs/day (71 tons per day) or approximately 87 percent of the total AMD discharges measured.

Acid Load: The acid concentration as determined by laboratory tests weighted by the flow measured at the time of sample collection.

Air Seal: Barrier which keeps air from entering a deep mine but permits normal flow of water from the mine.

AMD: Abbreviation for Acid Mine Drainage.

Anticline: A fold in which the stratified rocks dip away from the axial plane.

Base Flow: (For this report) Defined at a stream monitoring station as the total of all surface drainage and ground water recharge not accounted for by flaw measurements of streams and pollution discharges upstream of the stream monitoring station.

Base Load: (For this report) Defined at a stream monitoring station as the total of all stream influents contributing a constituent load (e.g. acidity) not accounted for by sample analysis and flow measurements of streams and pollution discharged upstream of the stream monitoring station.

Department: Department of Environmental Resources.

D.E.R.: Abbreviation for Department of Environmental Resources.

Drift: An underground entry driven horizontally into the coal seam.

Dry (Surface) Seal: Barrier which closes deep mine entries where there is little or no hydrostatic pressure in the area of the seal.

FWPCA: Abbreviation for Federal Water Pollution Control Administration. Later became part of the Environmental Protection Agency (EPA).

Formation: Any assemblage of rocks which have some characteristic in common, such as origin, age or composition.

Highwall: The vertical working face of a strip or surface mine.

Hydraulic Seal: Barrier which closes deep mine entries and develops hydrostatic pressure in the area of the seal

Hydrologic Year: A 13-month period of time.

Major Source: A discharge of acid mine drainage which results in at least an average of 400 lbs. net acid load per day.

Minor Source: A discharge of acid mine water which results in less than 400 lbs. net acid load per day on the average.

pH: The negative common logarithm of the hydrogen ion concentration. Estimation of degree of acidity or alkalinity.

Pollution: (In this report) Refers to mine water or industrial waste effluents.

Priority Number: The relative order for recommended abatement of stream reaches affected by AMD.

Shaft: An approximately vertical entry driven into the coal seam.

Slope: An inclined entry driven into the coal seam.

Slugger: A source which produces a large net acid load in a short period of time.

Syncline: A fold in which the stratified rocks dip toward the axial plane.

U.S.G.S.: Abbreviation for United States Geological Survey.

WPA: Abbreviation for Works Projects Administration. Agency which compiled generalized deep mine maps from detailed coal mine working maps.

STUDY METHODS

Compilation of Data: Topographic maps of the Raccoon Creek Drainage Basin were obtained from the United States Geological Survey. These maps were of the 7? Minute Quadrangle series.

W.P.A. mining maps for the Raccoon Creek study area were obtained from the U. S. Bureau of Mines, Mine Map Repository. Detailed mine maps were obtained where possible from mining companies or individual private collections.

Field notes from the original FWPCA survey were obtained from the Environmental Protection Agency, Wheeling, West Virginia field station.

Aerial photograph enlargements dated 1967 of the Raccoon Creek area were obtained from the Southwestern Pennsylvania Regional Planning Commission.

Basin runoff criteria for the Raccoon Creek area were obtained from the Soil Conservation Service, U. S. Department of Agriculture, Pittsburgh, Pennsylvania.

Weather statistics for the area were obtained from monthly publications of the National Climatic Center, U. S. Department of Commerce, Ashville, North Carolina.

Flow data from the Raccoon Creek gauging station were obtained from the U. S. Geological Survey.

Location of Sources of Pollution: The location and identification of pollution sources was performed by the stream-walking method. This method requires walking the lengths of identifiable streams and tracing water flows to their points of origin. The search was initiated at the mouths of the major tributaries of Raccoon Creek and proceeded upstream into minor tributaries. In the process of stream walking, all pollution sources identified by pH were numbered in sequence in each sub-watershed for purposes of future study. Many sources were red-flagged so that subsequent field identification would be facilitated. Sampling stations were also set up on major streams, principal tributaries and large areas of ponded water. The locations of all stations are shown on the Inventory Maps.

The initial field reconnaissance for pollution sources began in September, 1973 and was completed during January, 1974. As the study progressed beyond January, 1974, a number of stations were added as additional pollution sources were identified. Some stations were deleted with the accumulation of information.

Sample Collection and Laboratory Testing: The pH, temperature, and flow of the discharge and streams were recorded in the field at each sampling station. The water at each sampling point was collected into two bottles. One of the bottles was acidified in the field to maintain the solubility of ferrous and ferric iron. The samples collected were shipped to the Department's designated laboratory and analyzed for alkalinity, acidity, total iron, ferrous iron, sulfates, and pH.

Monitoring: Samples of water and flow measurements were obtained once per month at all sources of ANA pollution and designated stream sampling stations during the 12 month period, January, 1974 through December, 1974. The locations of all sampling stations are shown on the Inventory Maps.

Weirs were constructed where feasible at sampling stations to facilitate flow measurements. Repairs were performed as necessary, after intervals of heavy flow or after periods of ice formation to keep the weirs operable over the study period.

Stream and discharge flows at each of the monitoring stations were measured by one of the following four methods: current meter, weir, surface velocity flow or timed bucket flow. Each is discussed below:

Current Meter: The current meter method of measurement was normally used where large flows were encountered. The measuring device was a Gurley Pygmy Type Current Meter (No. 625F). In this method, a measurement of the stream cross-sectional area is obtained and velocity rates are recorded with the Gurley Meter at small intervals across the stream. The product of area and velocity provides a measurement of flow.

Weir Flow: Where channel and discharge measurements were appropriate, a combination of sharp crested rectangular and 90^0 V-notch weirs were installed. Discharge was then calculated using the dimensions of the weir crest and the height of water flowing over the weir.

Velocity Flow: The surface velocity method was used to estimate flow on small streams or discharges where current meters or weirs could not readily be utilized. An estimate of the cross-sectional flow area was obtained and an average velocity was estimated using measured time intervals for floating stream particles. The product of area and velocity provided an estimated flow quantity which was then adjusted by an empirical correlation between surface velocity and mean velocity.

Timed-Bucket Flow: Timed-bucket flow measurements were used as frequently as possible throughout the project because of their inherent accuracy and ease of application, particularly in small streams and at pollution sources. This method consisted of determining the amount of time needed to fill a calibrated bucket.

Water Quality Evaluation: Water samples obtained at all sampling stations were analyzed by the Department's designated laboratory for pH, acidity, alkalinity, iron and sulfate content. Stream loadings and source loadings were calculated from the analyses and reported in pounds per day. The results of these tests, as well as calculated values of stream and source loadings, are tabulated in the Appendix of this report.

The quality of streams in the Raccoon Creek study area was evaluated at high flow and low flow periods. The principal criteria used for evaluation were pH and net acidity (acidity less alkalinity). Stream quality results are provided in this report and are shown on Plate Nos. 10 and 11. Evaluation performed during the course of study involved estimating the relative contributions of acid mine drainage from individual subwatersheds to the total study area, evaluating potential abatement methods, and estimating quantities of acid mine drainage which could be feasibly abated. Additional water quality tests were performed on selected pollution sources. The purpose of the additional tests was to evaluate whether the selected pollution sources were typical mine drainage discharges. The results of this additional testing can be found in Chapter IV under Abatement Plans 1 and 5.

Field Reconnaissance and Abatement Plan Development: General structure contours were constructed on the base of the Pittsburgh Coal to determine the direction of subsurface flow for the deep mines. The W.P.A. coal mine maps and available deep mine maps were used to establish the overall subsurface drainage trend of the basin.

Aerial photographs dated 1967 were used to locate strip mines and to calculate the area occupied by the strip mines. The strip mines were reviewed in the field by our personnel to verify the conditions noted on the aerial photographs. The major and minor sources were investigated in the field to determine the nature of the surface drainage in associated strip mines and the nature of the surface drainage in tributaries, valleys, and the ground surface above associated deep mines.

An abatement plan or combination of abatement plans was then developed to improve the water quality of polluted stream reaches to the minimum pH standard. Cost estimates were made for each recommended abatement plan based on our analysis of field conditions. The primary methods considered were surface reclamation, deep mine sealing, daylighting, fly ash injection, and treatment plants. In each case, however, the method chosen was the least cost per pound of acid abated.