INTRODUCTION

PURPOSE AND SCOPE

Skelly and Loy, under contract to the Pennsylvania Department of Environmental Resources (hereafter referred to in this report as the Department), and with the cooperation of various Federal, State, and private groups, has conducted an acid mine drainage feasibility study in the Newport Creek Watershed, Luzerne County, Pennsylvania. The principal objectives of this study were to: 1) locate and monitor all mine drainage discharges and their affects on stream water quality; 2) locate surface water losses to deep mines; 3) describe the origin and cause of AMD formation; and 4) offer abatement recommendations to eliminate or reduce AMD pollution in the Newport Creek Watershed.

In the initial phases of this study, a network of sample stations was developed following field reconnaissance. The method of flow measurement (V-notched weirs or cross sections), was designated during field exploration. The original sampling stations were established during low flow conditions and new sample stations were added where required as the study progressed. Two samples were taken at each station on a monthly basis. One of the two samples was acidified with hydrochloric acid in the field. The samples were tested for pH, acidity, alkalinity, total and ferrous iron, and sulfate. Flows and AMD loadings were calculated after each sampling round.

Initial reconnaissance and subsequent detailed field explorations located the major pollution sources. These sources were evaluated to determine the nature and extent of pollution. Five (5) months after initiation of the study abatement plans were formulated for those sites where relatively high benefits will accrue, and where sufficient data had been collected. Each of these pollution sources and abatement plans is described and the cost of abatement estimated. The effectiveness of the abatement projects was evaluated on the basis of cost per pound acid abated. Any additional side benefits are also presented. Additional abatement projects were developed following the twelve month sampling period.

The estimated costs and effectiveness of these abatement projects are also presented in this report.

ACKNOWLEDGEMENTS

The authors are particularly grateful for assistance extended to project personnel by the staff of the Pennsylvania Department of Environmental Resources. Our appreciation is further extended to the following individuals for their substantial contribution toward the effective execution of this project: Jerrald Hollowell, Susquehanna River Basin Commission Ronald Temple, President, Susquehanna Coal Company Charles Zink, Vice President, Blue Coal Corporation

THE STUDY AREA

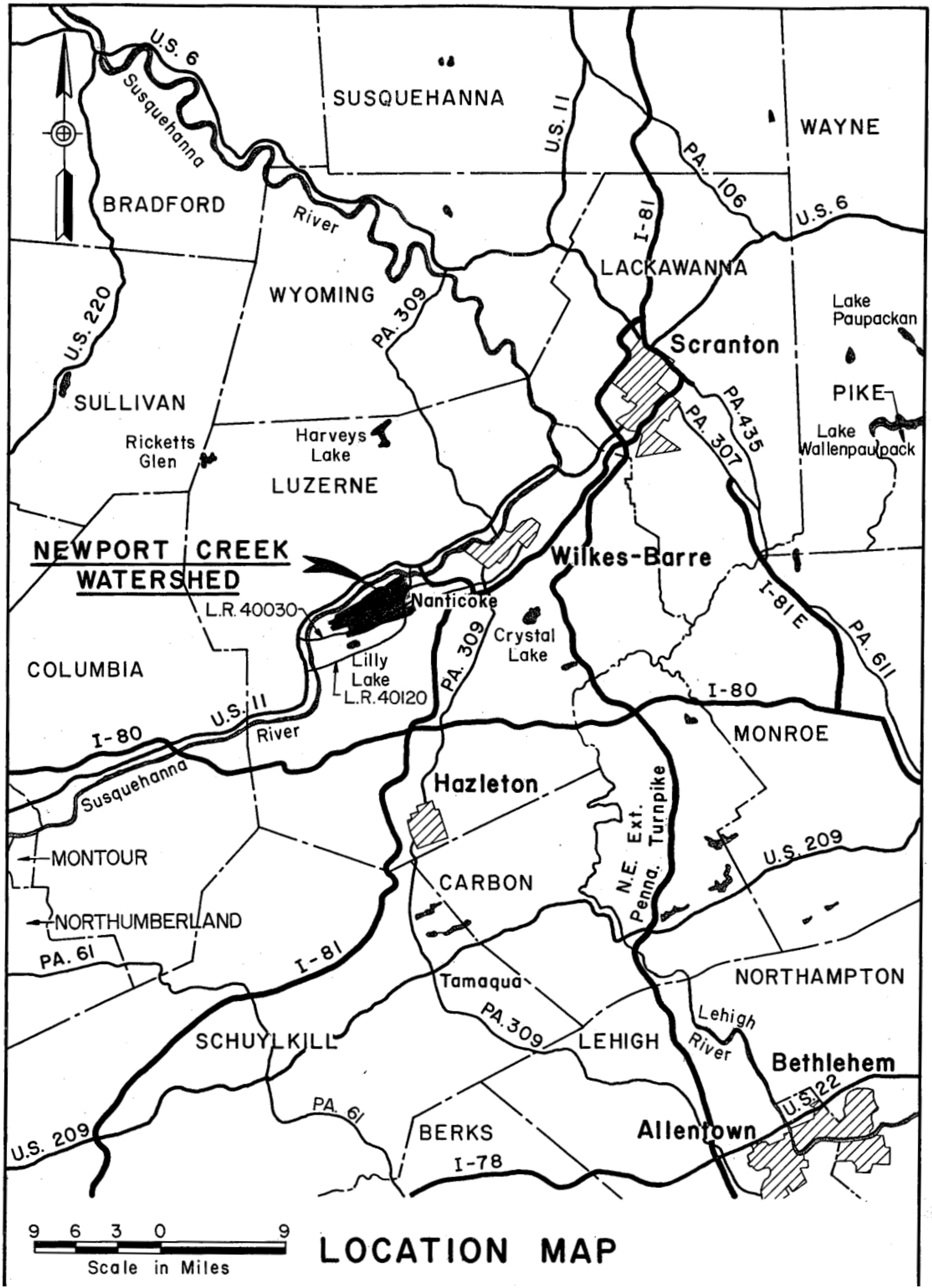
GEOGRAPHY

The Newport Creek Watershed is located in the central portion of Luzerne County, Northeastern Pennsylvania as illustrated on the following location map. The 15 square mile study area is bounded by Penobscot Mountain on the South and by Retreat Mountain (local nomenclature) along the Susquehanna River on the north. The watershed extends a maximum of 6.5 miles from Nanticoke (eastern limit) to the Black Creek Watershed (western limit) with a maximum width of 3.5 miles.

The watershed encompasses the communities of Glen Lyon, Wanamie, Newport Center, Alden Sheatown and a portion of Nanticoke. The center of the watershed is 9 miles southwest of Wilkes-Barre and 15 miles north of Hazelton. The North Branch Newport Creek has no tributary streams, while the South Branch Newport Creek receives flow from only two small streams. These tributaries are the Fairchild Pond and Wanamie Reservoir discharges.

PHYSIOGRAPHY

The Newport Creek Watershed lies within the intensely folded Appalachian Mountain Section of the Valley and Ridge Province. Differential weathering and erosion of various folded lithologies produced the present topography of the watershed. Extensive strip and deep mining has superimposed additional relief to the already rolling land surface.



LOCATION MAP

The watershed attains a total relief of approximately 1 , 110 feet. Elevations vary from a high of 1,620 feet on Penobscot Mountain to a low of 510 feet at the Susquehanna River.

Erosion resistant sandstones and conglomerates of the Pottsville and Pocono Formations underlie the topographic highs while the topographic lows are underlain by the Llewellyn Formation. More rapid erosion of the less resistant shales and sandstones of the Mauch Chunk Formation produced a valley between Little Wilkes-Barre Mountain of the Pottsville Formation and Penobscot Mountain composed of the Pocono Formation. This high mountain valley acts as a collecting basin for mountain spring runs forming Najaka Pond, Kielar Lake, Wanamie Reservoir, and Fairchild Pond. At one time most of these waters drained into either the North Branch Newport Creek or the South Branch Newport Creek. However, intense mining has altered flow patterns--intercepting drainage from all of these sources except Wanamie Reservoir and intermittent flow from Fairchild Pond. As previously mentioned, both of these discharges drain into the South Branch Newport Creek.

Stream courses in the watershed are influenced by the numerous geologic folds. North and South Branch Newport Creek flow roughly parallel to the major northeast striking folds and the combined flows join the Susquehanna River at Nanticoke.

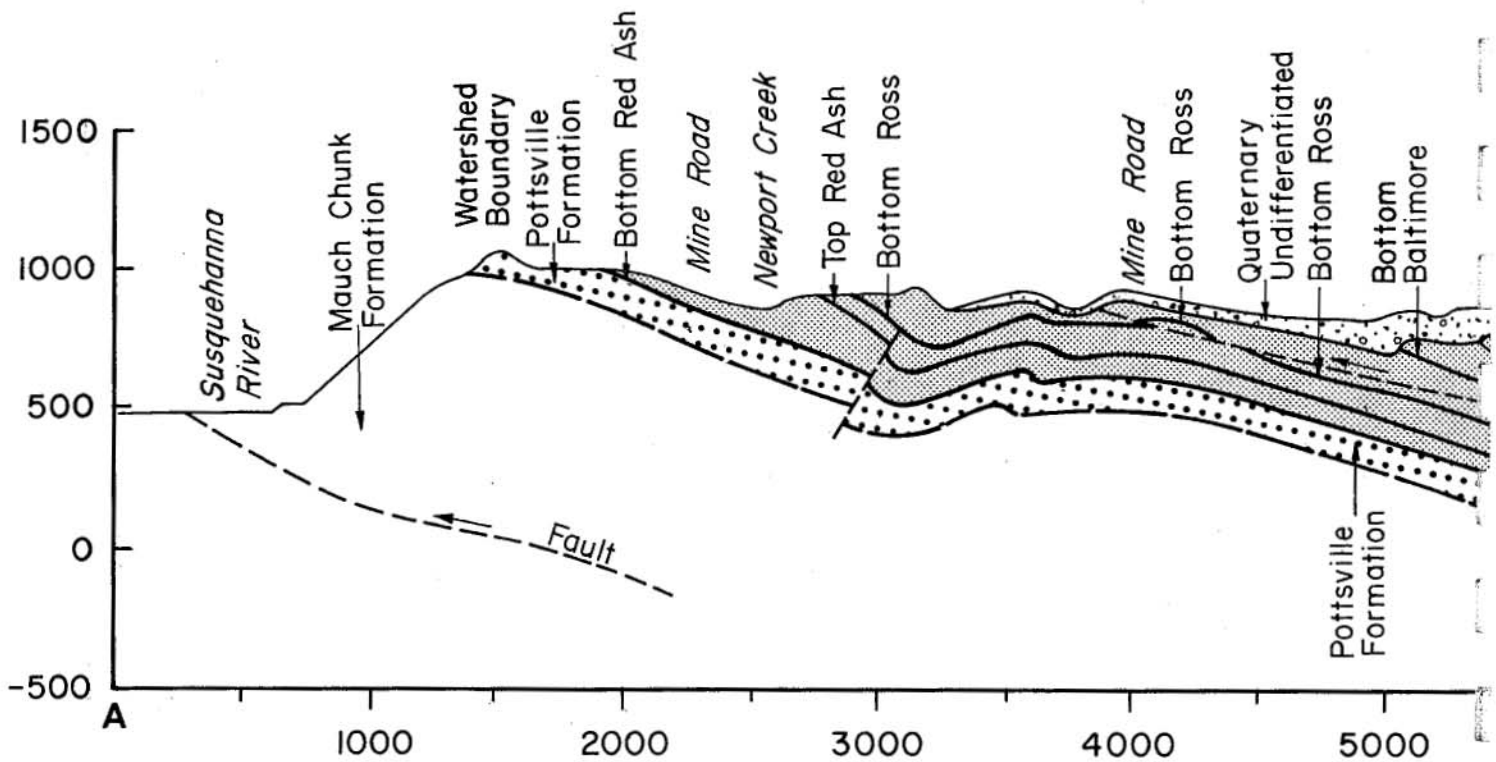
GEOLOGY

The study area lies within the southwestern portion of a long, narrow canoe-shaped synclinorium which encompasses the Northern Anthracite Coal Field. The Northern Field is 62 miles long and 5 miles wide at its broadest point. A geologic structure called the Moosic Saddle near Old Forge, Pennsylvania, separates the Northern Field into the Lackawanna and Wyoming Coal Basins. The study area is located in the Wyoming Basin and is characterized by numerous local synclines and anticlines with accompanying and related faults. The geologic folds that influence the surface topography of this watershed are part of a large structural basin. This complex folding and faulting is shown on the geologic cross sections (pp. 8-10), as well as, on the mine development and pollution source map. These synclinal and anticlinal folds generally trend N. 80 E. and plunge at a low angle to the east.

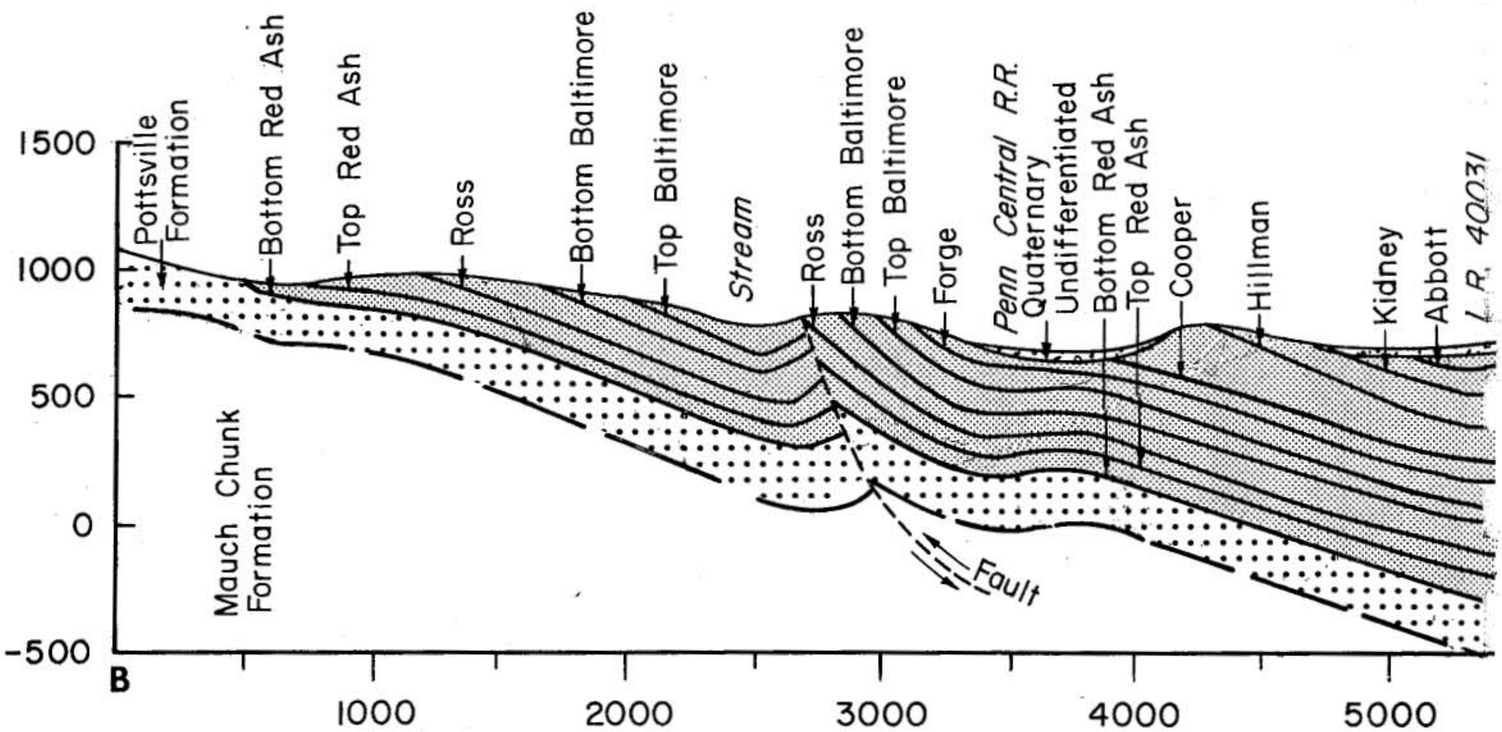
The stratigraphy of the surface formations in the Newport Creek Watershed is illustrated by the following generalized stratigraphic column (pg. 11). Included in this column are approximately 1 , 100 feet of coal bearing units of lower Pennsylvanian and 1,300 feet of Mississippian strata.

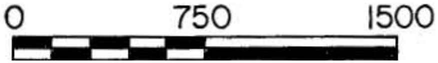
Vertical distances between formation members on the stratigraphic column represent average separations of these units in the study area. In some instances, coal beds represented on the stratigraphic column as top and bottom splits may actually join within the study area forming a single seam.

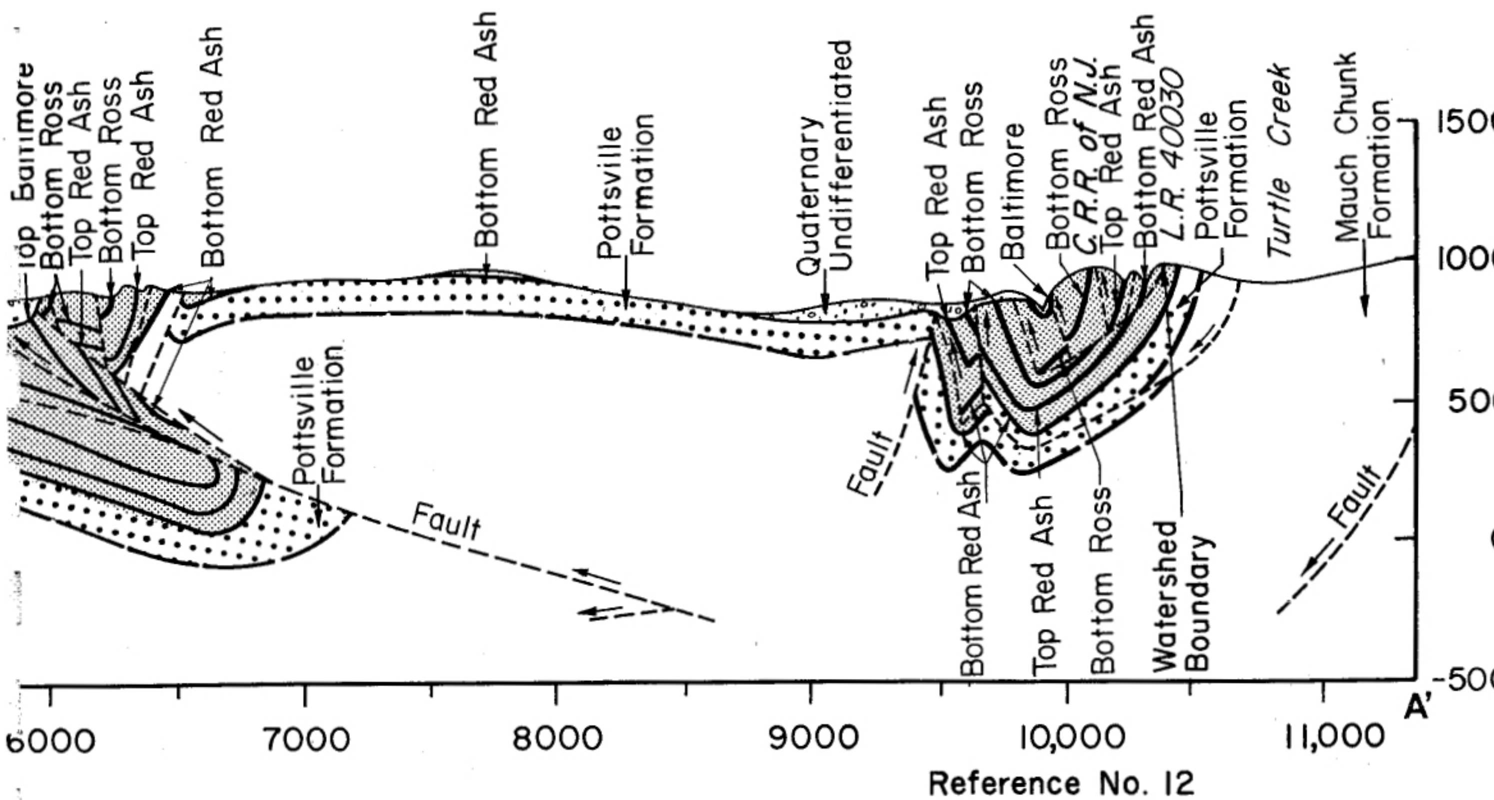
Mississippian outcrops in the study area include nearly 300 feet of the Pocono and 1,000 feet of the Mauch Chunk Formations. Complete exposure of these formations occurs along the southern watershed boundary. At this

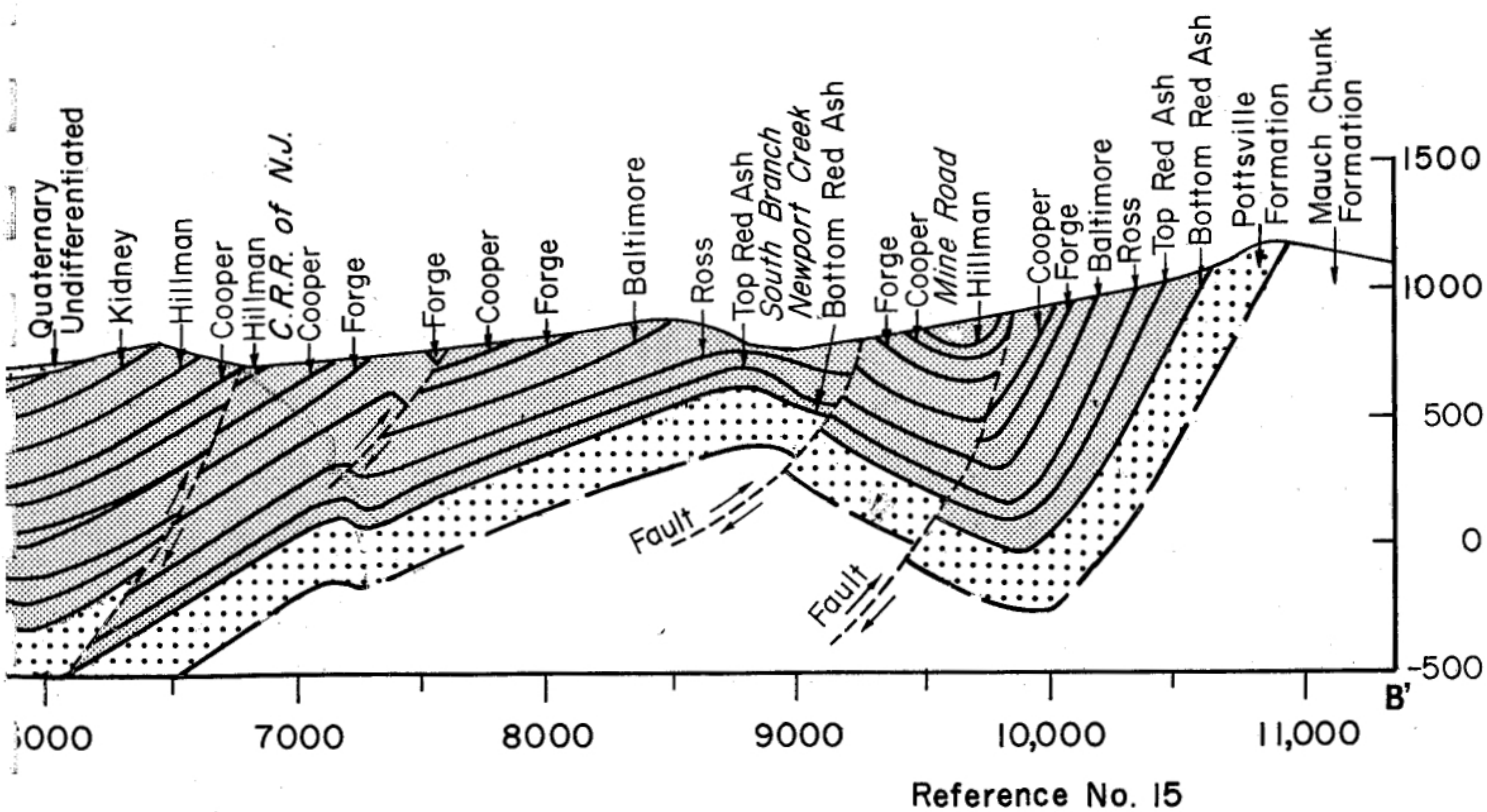


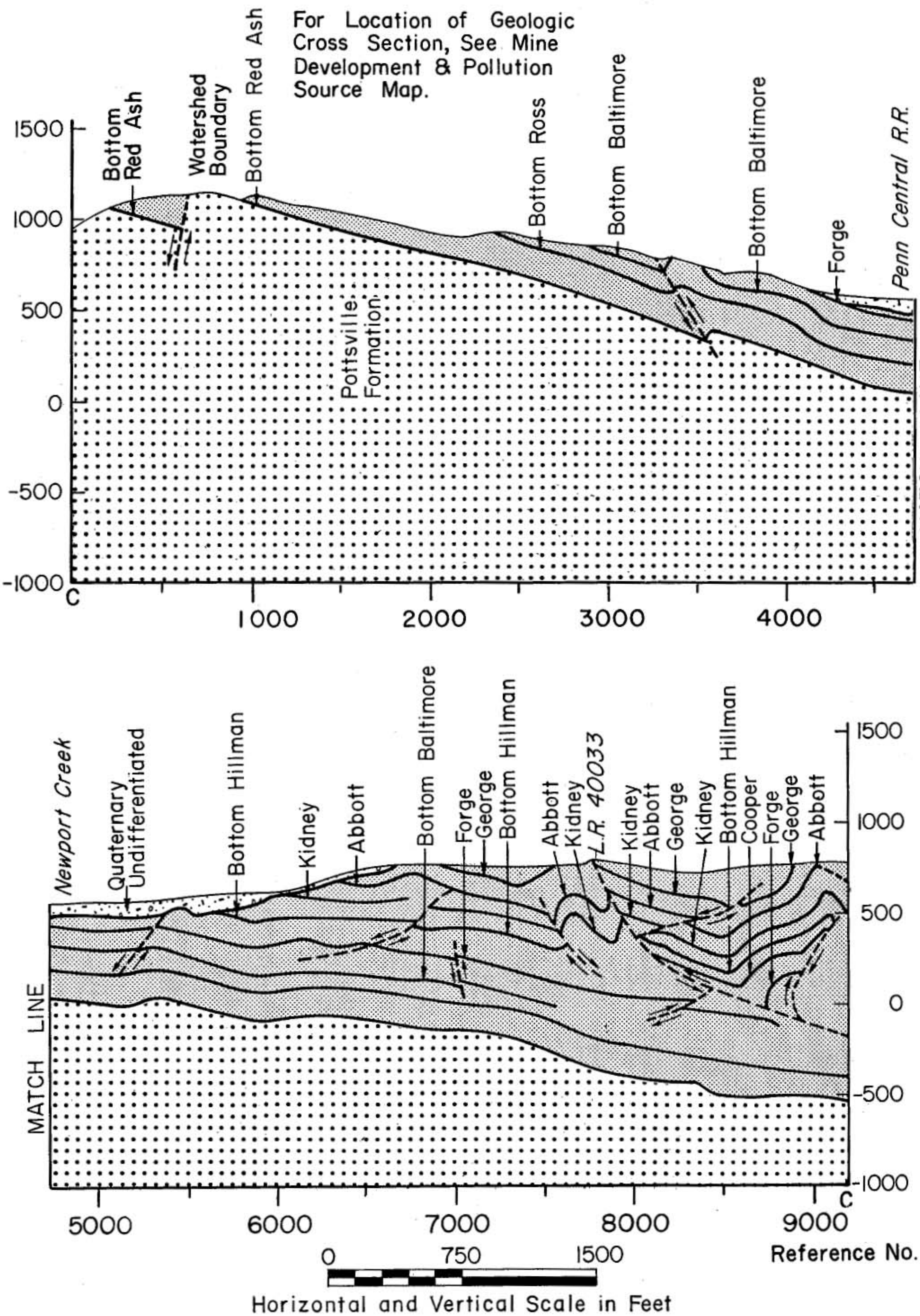
For Location of Geologic Cross Section
See Mine Development & Pollution Source Map



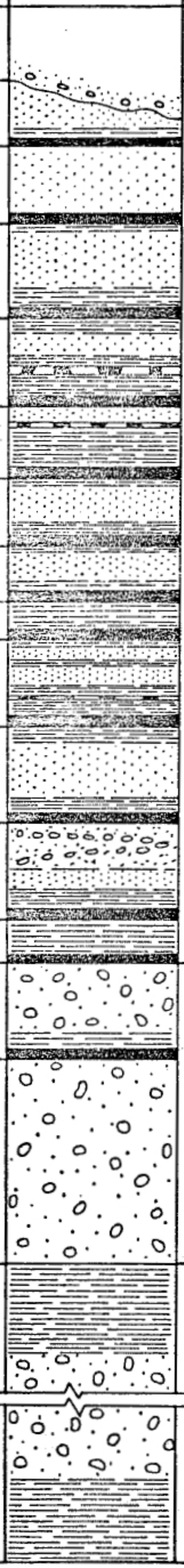



Top Baltimore
Bottom Ross
Top Red Ash
Bottom Ross
Top Red Ash
Bottom Red Ash
Bottom Red Ash
Pottsville Formation
Quaternary Undifferentiated
Top Red Ash
Bottom Ross
Baltimore
Bottom Ross
C.R.R. of N.J.
Top Red Ash
Bottom Red Ash
L.R. 40030
Pottsville Formation
Turtle Creek
Mauch Chunk Formation
Pottsville Formation
Fault
Fault
Fault
Bottom Red Ash
Top Red Ash
Bottom Ross
Watershed Boundary
1500
1000
500
0
-500
A'
6000
7000
8000
9000
10,000
11,000
Reference No. 12

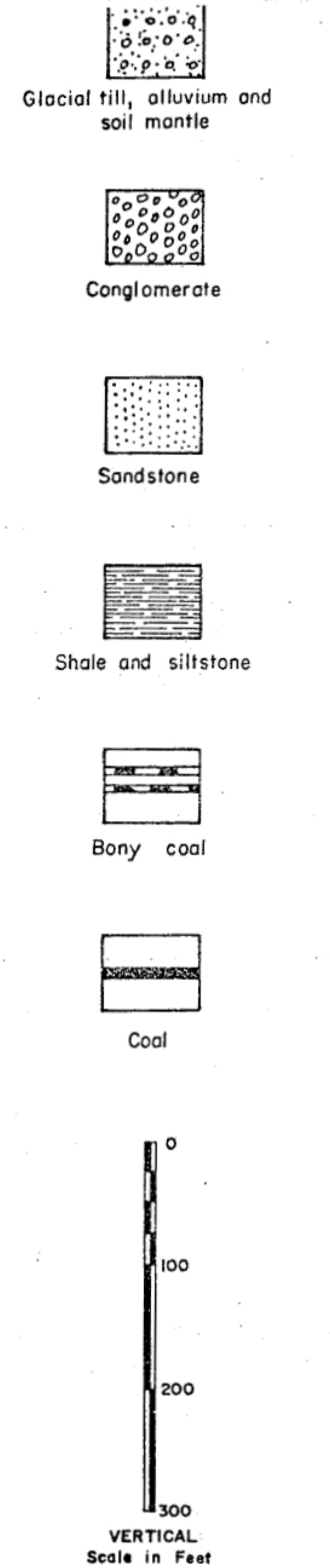

Quaternary Undifferentiated
Kidney
Hillman
Cooper
Hillman
C.R.R. of N.J.
Cooper
Forge
Forge
Cooper
Forge
Baltimore
Ross
Top Red Ash
South Branch
Newport Creek
Bottom Red Ash
Forge
Cooper
Mine Road
Hillman
Cooper
Forge
Baltimore
Ross
Top Red Ash
Bottom Red Ash
Pottsville Formation
Mauch Chunk Formation
Fault
Fault
1500
1000
500
0
-500
B'
6000
7000
8000
9000
10,000
11,000
Reference No. 15



Reference No. 14



SYSTEM	FORMATION	COAL MEMBER	SECTION	GENERAL STRATIGRAPHY OF FORMATION
		QUATERNARY		GLACIAL DRIFT OF PLEISTOCENE AGE AND STREAM ALLUVIUM TALUS, SOIL MANTLE.
PENNSYLVANIAN	LLEWELLYN (POST POTTSVILLE)	GEORGE		INTERBEDDED, LIGHT TO DARK-GRAY LIGHT-YELLOW TO LIGHT-BROWN SANDSTONE, SILTSTONE AND CLAYSTONE BEDS WITH MINOR AMOUNTS OF LIGHT TO DARK-GRAY, QUARTZ-PEBBLE CONGLOMERATE AND CONGLOMERATIC SANDSTONE AND AT LEAST TWELVE PERSISTENT THIN TO THICK COAL BEDS.
		(Orchard) ABBOTT		
		(Mills) KIDNEY		
		HILLMAN		
		(Bottom Hillman or Pittston) COOPER		
		(Pittston) FORGE		
		TOP (Twin) BALTIMORE		
		BOTTOM (Twin) BALTIMORE		
		TOP ROSS		
		BOTTOM ROSS		
		TOP RED ASH		
		BOTTOM RED ASH		
	POTTSVILLE	DUNMORE NO. 4		LIGHT TO DARK-GRAY, FINE TO COARSE-PEBBLE CONGLOMERATE, CONGLOMERATIC SANDSTONE, SANDSTONE AND CARBONACEOUS SHALE
		?		
MISSISIPIAN	MAUCH CHUNK			RED OR RED-BROWN SHALE, SILTSTONE AND SANDSTONE ALTERNATING WITH GRAY, AND GRAY-GREEN PEBBLE AND COBBLE CONGLOMERATE, CONGLOMERATIC SANDSTONE AND SANDSTONE



Data based on information in United States Dept. of Interior, Flood Control Project No's. 32, 37 and 39, and from mining interests in the area.

Adapted from Reference No. 15

GENERALIZED STRATIGRAPHIC COLUMN

location the units have been folded such that the Pocono Formation has high pitched to vertical dips forming the northern slope of Penobscot Mountain.

The Pennsylvanian System in the study area is represented by the Pottsville and Llewellyn Formations. The average thickness of these formations is 180 feet and 950 feet respectively. The Wanamie Reservoir discharge flows in a narrow valley eroded through near vertical outcrops, providing excel-lent exposure of portions of these rock units.

The Llewellyn Formation contains all of the economically important coals in the study area. At least twelve persistent anthracite coal seams are present. All of the coal seams located within the study area have been mined to some extent by either strip or underground mining methods. Seam thicknesses vary from less than one foot to as great as twenty feet. Laterally, individual seams may split or pinch out into sandstone or shale units. In addition to the persistent seams, several other coals are locally mineable. All coals have relatively low sulfur content ranging from 0.6% to 0.8% with an average value of 0.7%. The sulfur content in most coal refuse rarely exceeds 1.2% (reference 29). These low sulfur values appear to be inconsistent with high acid loadings recorded in the Newport Creek Watershed. This anomaly may be explained either by a high percentage of reactive pyrite or from the large amount of surface area exposed by the mining.

Surficial materials overlying the Llewellyn Formation consist of Pleistocene age glacial drift and stream deposits, soil, and strip and underground mine waste of Recent age. Bedrock of the Wyoming Valley was eroded by glaciers during the Ice Age. The resultant erosional depression has since been filled by moraines from the retreating glaciers and alluvial deposits from the Susquehanna River and its tributaries. This great trough is termed the "Buried Valley of the Susquehanna River."

Glaciofluvial deposits found in the study area consist of alternate layers of sand, clay, gravel and boulders in various orders of stratification. Much of these deposits are masked byculm piles and strip mines. However, exposures of glaciofluvial deposits can be seen on several ridges within the watershed. The valley fill is usually extremely permeable, allowing infiltration of surface waters into underlying bedrock. Fracturing induced by extensive underground mining provides avenues for transfer of infiltrating waters through bedrock into underlying mine voids. The deep mines were excavated well below the elevation of the Susquehanna River. Thus all abandoned deep mines are flooded and active deep mines were forced to pump large volumes of water. Periods of intense rainfall may have caused water levels in abandoned mines to rise above barrier pillars and flow through fractures and alluvial material into adjacent active workings. This added further strain to already increased pumping loads in the active mine.

This water flowing through fractures and mine voids acts as a transport medium for soluble pyrite oxidation products. Oxidation of the iron disulfide mineral pyrite is the main source of acid in coal mine drainage. The pyrite oxidation reaction is complex and not fully understood. Two reactants, water and oxygen, are involved in the oxidation of pyrite. Certain bacteria are also influential in this reaction.

The general reaction is:

Reactive Pyrite + Water + Oxygen = Sulfuric Acid + Ferrous Sulfate

$2FeS_2 + 2H_20 + 70_2 = 2H_2SO_4 + 2FeSO4$ (reference 10).

The abatement of acid deep mine drainage is accomplished three ways

1) reduce or eliminate the oxygen supply, thereby slowing down the reaction.

2) reduce or eliminate the quantities of transporting medium (water).

3) chemical treatment of mine water.

Reducing the quantity of water entering deep mines is the most practical abatement technique for the study area. This technique and any measures suggested to ameliorate acid pollution of surface waters are explained in the Evaluation of Abatement Methods Section of the report.

Although most water in the mined areas is polluted, local clays of relatively low permeability retard ground water infiltration, producing perched water tables. Numerous isolated ponds reflect these clay lenses. Pond levels fluctuate with rainfall and evaporation rates. These waters are void of mine drainage pollutants found in most streams flowing through the valley.

Flooded deep mines present problems in the entire Wyoming Valley.

Approximately 45 percent of the precipitation within the Wyoming Valley Coal Basin enters underground mines either by direct infiltration or from surface runoff that enters the mines through the strip mines, crop falls, and streambed infiltration. Mine pumping records show significant water level rise in all deep mines immediately after heavy precipitation. In the past, mining companies installed pumps with capacities ten times the annual average rate of pumping to handle this surge water. Pumps were operated at full capacity for several days to remove the surge inflows produced by heavy rainfall.

With only one exception, excessive operating costs caused the few remaining Wyoming Valley deep mine operations to cease production by October 1967. The Glen Nan mine located within the watershed was the only remaining active deep coal mine in the Wyoming Coal Basin at the initiation of this study.

Tropical Storm Agnes had resulted in continuous near capacity pumping to maintain production in the Glen Nan mine. Sample data collected during ten sampling rounds from July, 1973, through April, 1974, indicates that an average of 6.44 cfs is discharged to the North Branch Newport Creek from two holding ponds as the Glen Nan mine (Sample Station N5). In addition, an average of 8.75 cfs of water was removed from the Glen Nan Forge workings by a borehole pump and discharged into the North Branch Newport Creek (Sample Station F2). However, the Glen Nan mine was closed and pumping stopped prior to the eleventh sampling round.

The flow pattern of water within a mine is usually complex, and in many cases it is unknown. However, it is thought that the longer the deep mine water flow route, and subsequent longer retention time, the higher the pollution levels. Thus, waters collecting in lower seams generally display a greater degree of deterioration.

Interflow between adjacent mine complexes in the Wyoming Valley is somewhat controlled by the barrier pillars separating individual mines. Mine pools are partially isolated, but flow occurs where the barrier pillars have been robbed or bored through for drainage during mining, or have been breached by fractures caused during subsidence, or where pool levels overflow barrier pillars. Numerous studies have been conducted to determine interflow patterns between deep mines in the Wyoming Basin. The Department is presently monitoring mine pool levels. The major objectives of these studies are: 1) to lower and stabilize mine pool elevations, thus minimizing the potential for surface subsidence and; 2) to determine what measures are required to provide better quality mine-water discharges in the Wyoming Valley. The nature and extent of interbasin flow via deep mine pools is evaluated in the "Hydrologic Balance" section of this report.

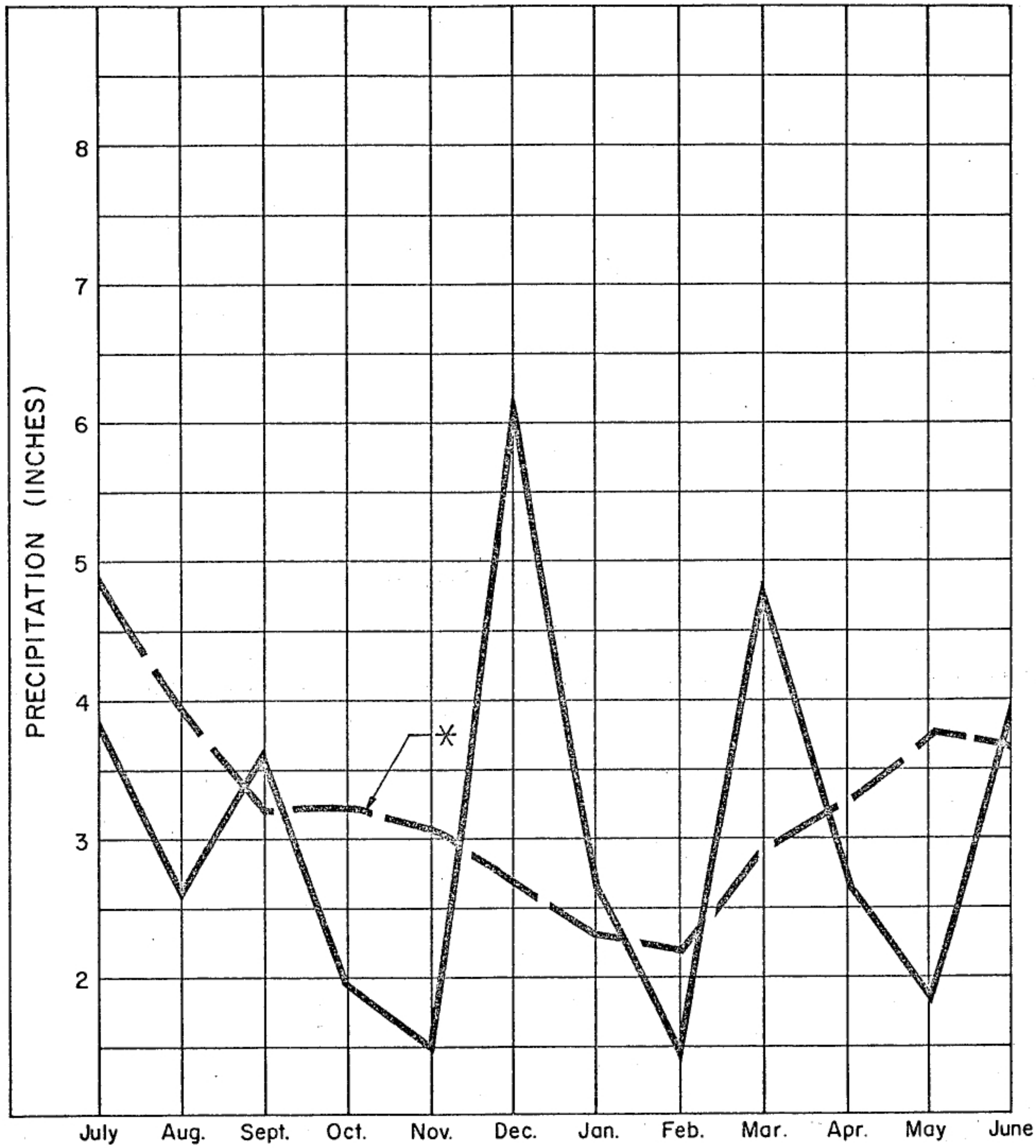
CLIMATOLOGY

Climatological data is required for computation of potential stream flows. Rainfall minus evapo-transpiration losses equals the amount of water that should be present is surface flow. The loss of surface water to deep mines can then be computed for any given subwatershed area.

The National Weather Service maintains a recording station located approximately 18 miles northeast of the Study Area it the Wilkes-Barre-Scranton WSO Airport. The maximum and minimum daily temperatures is well is the total precipitation are recorded. This information is published monthly by the National Oceanic and Atmospheric Administration. Data from the WSO Airport was applied is representative of the study area.

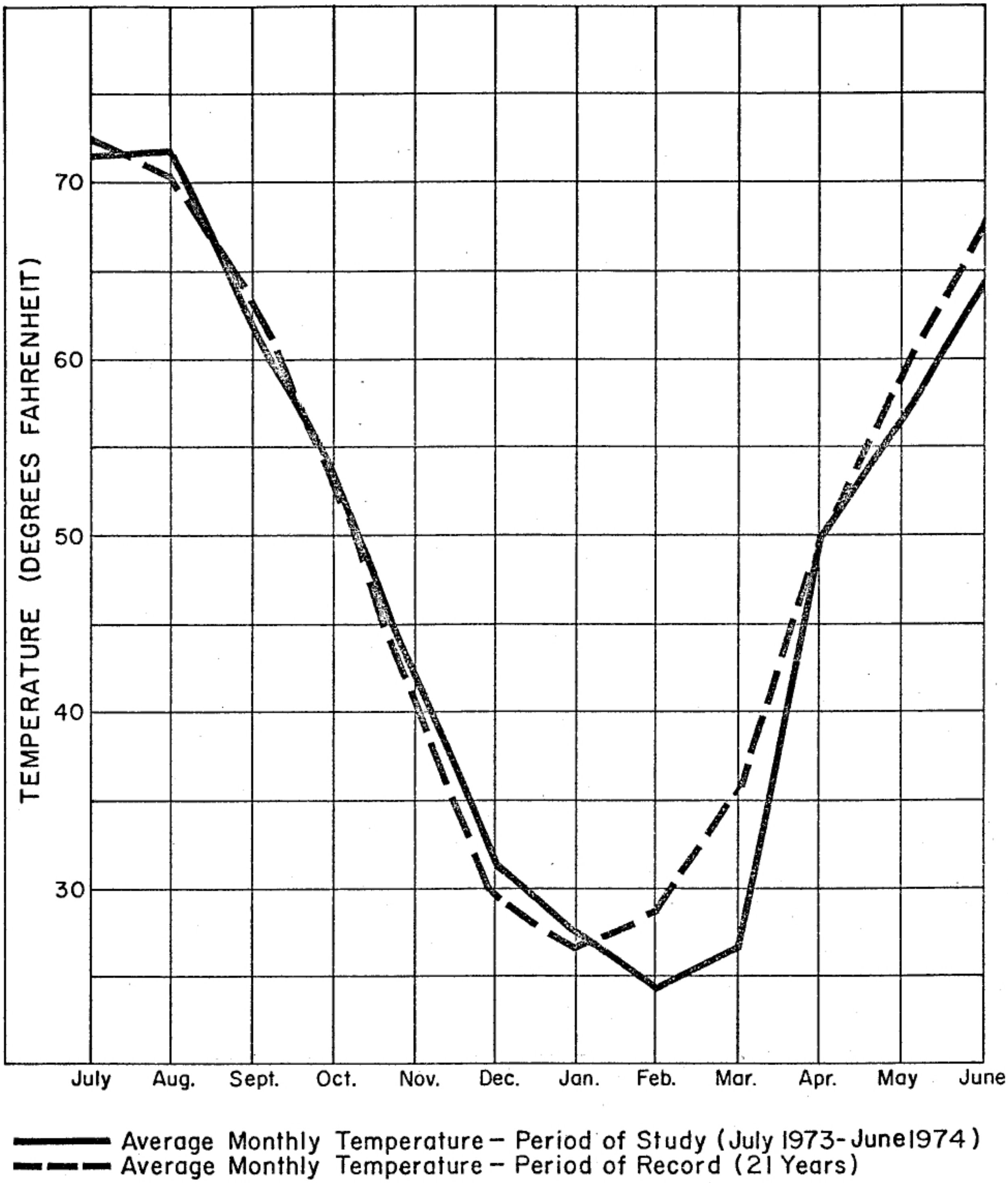
The average annual precipitation, temperature, and snowfall for the area are 39.1 inches, 49.6 degrees F, and 33.3 inches respectively. The precipitation for the study area is 1 .64 inches below the yearly average for central Pennsylvania. However, precipitation in the study area is about 3 inches above the north-central Pennsylvania yearly average. Total Snowfall is 16.7 inches less thin the average for north-central Pennsylvania.

The total precipitation and the average temperature for the study period were 36.98 inches and 49.0 degrees F respectively. Thus the precipitation was 2.12 inches below the average for the area and the temperature was 0.6 degrees cooler. The monthly precipitation and average temperature deviations from selected record periods is illustrated on the Monthly Precipitation and Monthly Temperature charts (pp. 18-20). Examination of these charts indicates that during the study period precipitation varied sharply from the thirty year average while the average temperature closely conformed to a twenty



Monthly Precipitation - Period of Study (July 1973 - June 1974)
Mean Monthly Precipitation - Period of Record (30 Years)
* Wilkes Barre Weather Station (1931 to 1960)

MONTHLY PRECIPITATION
Wilkes Barre - Scranton Weather Station



MONTHLY TEMPERATURE
Wilkes Barre - Scranton Weather Station

DAY	DAILY PRECIPITATION IN INCHES	1973						1974					
		JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE
1			1.21			0.17		0.05		0.08		0.08	0.43
2			0.36		0.17				0.14	0.12	0.03		
3		0.14				0.02		0.30	0.04		0.01	0.18	0.18
4		0.02			0.24						0.08		
5		0.44			0.15	0.02	0.75			0.07	0.88		
6				0.57		0.01			0.01			0.07	
7									0.11	0.01			
8					0.03					0.74	0.28		
9							1.03	0.24		0.34	0.28	0.08	
10			0.42				0.02	0.29		0.03	0.04	0.11	0.56
11			0.03				0.03	0.24	0.01				
12								0.02				0.90	0.01
13		1.15			0.02		0.10				0.04		
14			0.06	1.28	0.01		0.06				0.14		0.06
15		0.40	0.41		0.11	0.22							
16			0.05			0.09	0.12			0.78			0.40
17							0.32						0.22
18				1.03	0.08			0.14					
19								0.21	0.31	0.09	0.31		
20							0.94						0.14
21		1.14				0.01	1.57	0.65		0.79			0.20
22				0.45					0.80		0.09		
23				0.21				0.04			0.01	0.22	0.15
24						0.22						0.04	0.18
25						0.35	0.02		0.04				0.10
26		0.18				0.01	0.66	0.04				0.01	
27		0.14	0.01			0.14	0.14	0.01					
28		0.26				0.24	0.21	0.43	0.02				0.19
29				0.08	1.16		0.03			0.74	0.01	0.10	0.10
30										0.60	0.51		0.93
31			0.06				0.07			0.36		0.10	

DAILY PRECIPITATION

Wilkes Barre - Scranton Weather Station

one year average.

POPULATION AND LAND USE

Climate has a strong influence on land use in the Wyoming Valley. A short growing season, in addition to poor soils, limits crop farming by some of the twenty-three thousand inhabitants of the greater Nanticoke community area. Extensive mining has also reduced the land available for farming, A majority of the working population is employed in local factories. A steady decrease in coal production since 1950 has left the once majority coal mining work force with only a small portion of the total working population. Past and future population trends are presented in the following table.

Recorded and Estimated Population for the Nanticoke Area (reference 11)

1950 - 32,953	1960 - 25,467	1970 - 23,2534	1980 – 23,630
1990 - 24,930	2000 – 26,050	2010 - 27,170	2020 - 28, 280

Population trends reflect decreases due to job losses as mines closed and an expected future increase as new industries provide additional jobs in the area. The following "Mining History" section illustrates the decline of anthracite coal production.

MINING HISTORY

Mining history for the study area roughly parallels the history of the anthracite coal region. Underground coal mining in the watershed began in the early 1800's followed by the first independent strip mining operations about 1940. Total coal production in Luzerne County rose to a maximum of 35 million tons in

1924. Production dropped slightly after this peak and remained relatively constant until 1950 when production began a continuous decline to present production levels.

The Glen Nan Mine was the only remaining active major deep coal mine in the Northern Anthracite Coal Field. However, as previously noted this mine was abandoned during the later stages of the study. Most of the deep mines located in the study area were closed in the 1950's. The Susquehanna #7 and Stearns mines were abandoned in 1953 while the Glen Lyon mine remained open until 1959.

At the completion of this study the major coal producer in the watershed, the Blue Coal Corporation, had ceased all coal mining. Thus, the only production in the watershed at this time was limited to deep mining (11 or 12 man operation) from the Wanamie #18 slope. Strip mining is expected to resume in the near future. However, considering the loss of production from all of the Blue Coal Corporation's anthracite mining operations a reduction of between 10 and 20 percent of the Nations total anthracite production will occur until the new mines are operating, (reference 29).