I. INTRODUCTION

BACKGROUND INFORMATION.

Acid Mine Drainage (AMD) from abandoned deep mines and strip mines is the major pollution source of the streams in the Wyoming Valley. These streams subsequently flow into the Susquehanna River, degrading river water quality which, at times, results in fish kills.

Activities associated with deep mining caused a significant change in the position and direction of the groundwater flow within the coal basin. Dewatering of deep mines by pumping and drainage tunnels had lowered the groundwater table that surrounded the mined areas. The groundwater table was lowered to a considerable depth below the bed of the creeks that overlie the mined-out areas. Consequently, the creeks within the coal basin lost the groundwater recharge or "base flow" that prevailed prior to the lowering of the groundwater table. Moreover, the lowering of the table below the levels of the streams resulted in streambed losses into the deep mines which necessitated additional pumping to dewater the active mines.

Most deep mine pumping was stopped in 1967 and the mines were abandoned. The cessation of pumping altered the balance between inflow and outflow from the deep mines causing the water level in the mines to rise. The flooded mines, through interconnection (tunnels and breached barrier pillars), formed two major recognizable mine pool complexes in the Wyoming Valley; the South-East Complex and the North-West Complex.

The flow of water through the abandoned mines is controlled by the various outlets within the two major complexes. When the inflow into the mines exceeds the rate of outflow, the mine pool levels rise. The rise in the mine pool levels increases the discharge rate at mine pool outlets until a balance is reached with the inflow. Similarly, when the rate of outflow from the mine pools exceeds the inflow, the mine pool levels drop until a new balance is reached.

The inflow into the mine pools consists of surface water losses, pipeline losses and groundwater recharge. The Wyoming Valley coal basin underlies and is surrounded by numerous watersheds. The South-East mine pool complex Underlies the Nanticoke, Warrior, Solomon and Mill Creek watersheds. The headwaters of these watersheds are outside of the coal measures. Recharge of the mine pools by surface water sources is through streambed losses and interception of runoff into strip mines ad surface area infiltration. When the streams that originate in these watersheds cross the coal measures into the coal basin, they begin to lose water into the deep mines. Under extreme runoff conditions such as during the floods of 1972, the rate of inflow into the mine pools exceeded the rate of outflow causing a considerable rise in the mine pool levels. The rise in the pool levels increased the pressure in the flooded portion of the mines under the low-lying urban areas, causing basement flooding. Subsidence in the low-lying areas is also partially attributed to extreme fluctuation of the mine pools. Reduction of pool fluctuations should reduce subsidence.

Reduction in mine pool fluctuation can be achieved by decreasing the rate of inflow into the mines, or by increasing the rate of outflow. The latter method can be achieved by drilling boreholes into the mines at selected locations. The drilling of the Askam Borehole and the three South Wilkes-Barre Boreholes reduced the fluctuation in the South-East Mine Pool Complex. Consequently, flooding and related subsidence problems in the area were considerably reduced. However, the water dischargedd from the boreholes is acid mine drainage (AMD). The Askam Borehole discharges into the Nanticoke Creek and the South Wilkes-Barre Boreholes into the Solomon Creek above their confluences with the Susquehanna River. Since the annual outflow from the mine pools is related to the annual inflow, the boreholes reduced the fluctuation in the mine pool levels with no material change in the annual volume of AMD discharges. The present outflow from the mine pools is predominantly through the borehole outlets. Prior to the installation of the boreholes, the mine pools discharged through other uncontrolled outlets.

The drilling of the boreholes enabled the outflow from the mine pools to be measured, thus facilitating the quantitative evaluation of water losses into the deep mines. Quantitative analysis of surface water losses was therefore made in the Nanticoke, Warrior and Solomon Creeks*. This analytical comparison indicated that in the

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case of Solomon Creek, the volume of outflow from the mine pools exceeded the volume of water losses. The excess outflow from the mine pools within Solomon Creek watershed was therefore attributed to mine pool recharge from the adjacent Mill Creek watershed.

PURPOSE OF THIS STUDY.

The purpose of this Study was to locate major surface water loss areas in the Mill Creek watershed; evaluate the magnitude of such '. losses; and assess their impact on the recharge and subsequent discharge of AMD from the Southeast Mine Pool Complex through the three South Wilkes-Barre Boreholes. On the basis of the findings above, recommend feasible solutions to reduce present water recharges of the mine pools and thereby eliminate or effect a considerable reduction in the AMD discharges from the South Wilkes-Barre Boreholes.

SCOPE OF STUDY.

To achieve the purpose outlined in the foregoing, the study consisted of the following major items:

1. Collection and compilation of available information related to the topography, geology, climatology and data on mining operations in the study area.
2. Selection and installation of stream monitoring stations including major AMD discharge points. Collection of water samples add stream flow measurements at the selected stations.
3. Evaluation of pollution sources including water losses to the deep mines.
4. Recommendation of feasible pollution abatement measures within the study area.

To establish a quantitative relationship between water losses and discharges from the deep mines, data on mine pool fluctuation was collected and continuous records were kept on discharges from the mines. These data were collected on all known major mine pool discharges in the Wyoming Valley for the following purposes:

a. Mine pool fluctuation in the study area had to be supplement ed with data on pool fluctuation in the adjacent Solomon Creek watershed and correlated with measured discharges from the South Wilkes-Barre Boreholes. This information was essential for the evaluation of water losses recharging the South-East Mine Pool Complex and the determination of their magnitude and source.

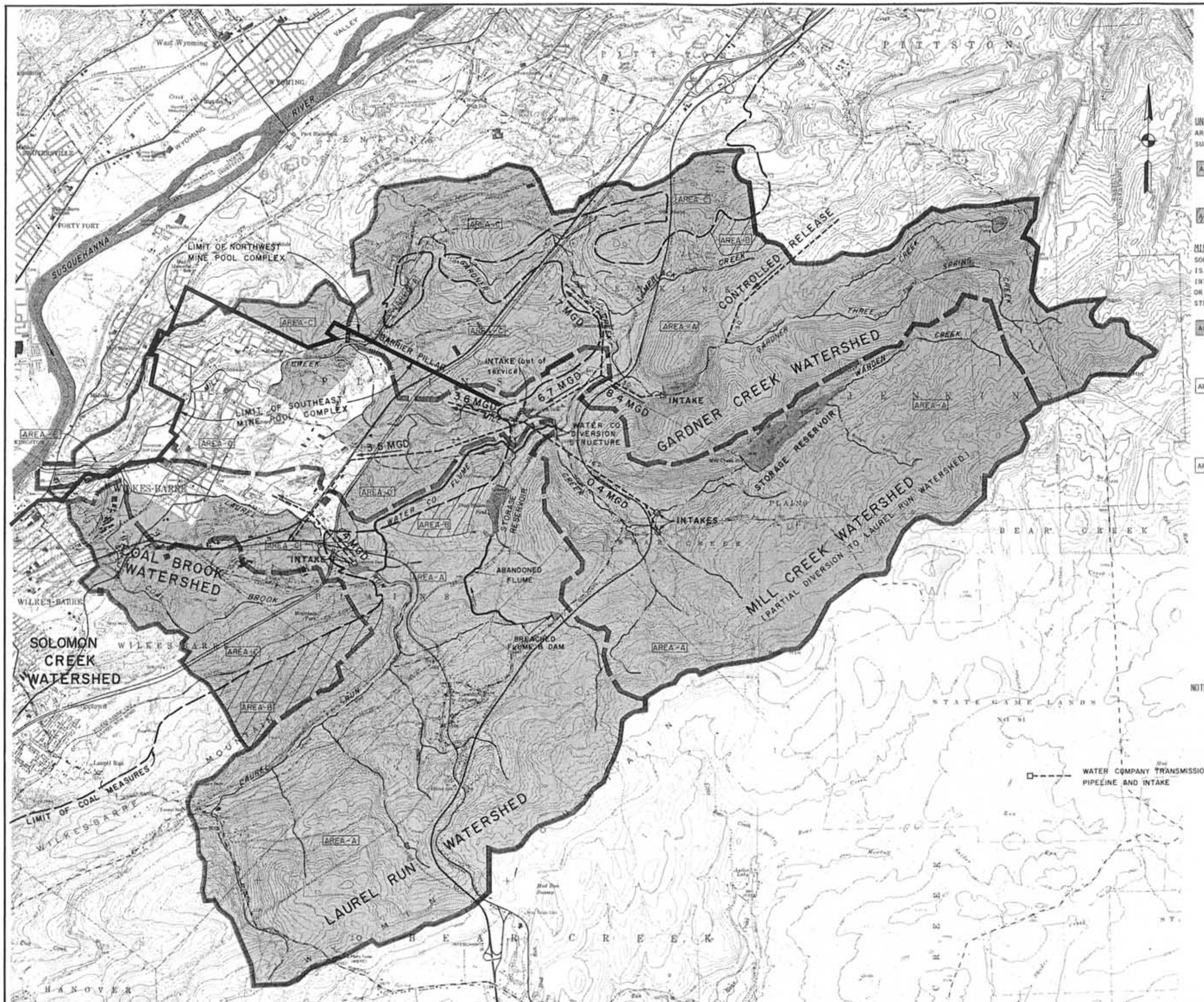
b. The study area overlies both major mine pool complexes and therefore the contribution. of water losses from the study area to the AMD discharges from the North-West Mine Pool Complex could also be evaluated. Data collected by the Department on the fluctuations of the North-West Complex was summarized for the duration of the study as well as the AMD discharge measurements from this Complex (Buttonwood Tunnel and the Plainsville Borehole outflow).

c. Data on fluctuations of the Upper Mine Pools within the South-East Complex and AMD discharges from the Askam Borehole were also recorded for the study period. This information was used for a comparison of the AMD discharges during the study period with previously recorded discharges.

Although analysis and interpretation of data collected for purpose b. and c. is not within the scope of this study, the data was essential for the evaluation of mine pool discharges in the entire Wyoming Valley. Consequently, data collected during the study could be used in future studies to determine the magnitude and locations of water losses that recharge the North-West Mine Pool Complex.

INVESTIGATIVE TECHNIQUES.

The initial phase of the study consisted of collection and review of pertinent data compiled by others such as topography, aerial photography, climatology, hydrology, geology, mining operations, County planning and Land Use Studies. A topographic map showing the 36 square mile watershed, the limit of the coal measures and other related watershed characteristics is shown on page 5. A map of basic geologic features is shown on page 7. Field reconnaissance was conducted to evaluate the quality and flow of surface water and to investigate geologic and other watershed features and conditions related to AMD. Based on these investigations, a total of thirty (30) monitoring stations were established in Mill Creek watershed. As the study progressed, twelve (12) additional stations were established



CHARACTERISTICS OF WATERSHED SUB-AREAS

UNMINED AREAS: BOTH AREAS A & B ARE OUTSIDE THE COAL MEASURES. THESE AREAS ARE CHARACTERIZED BY RELATIVELY STEEP SLOPES AND TREE COVER. SURFACE RUNOFF CONTRIBUTION TO STREAMS IS HIGH AND ESSENTIALLY "CLEAN".

AREA A SURFACE RUNOFF FLOWS INTO EXISTING STREAMS UPSTREAM OF THE COAL MEASURES. SOME OF THIS WATER IS INTERCEPTED AND LOST IN AREAS C & D.

AREA B SURFACE RUNOFF FLOWS DIRECTLY INTO AND IS PARTIALLY INTERCEPTED BY STRIP PITS AND SUBSIDENCE DEPRESSIONS IN AREA C.

MINED AREAS: AREAS C, D AND E ARE WITHIN THE COAL MEASURES AND CONTAIN SOME URBANIZED AREAS. IN AREAS C AND D, THE GROUNDWATER TABLE (MINE POOL) IS BELOW STREAMBED LEVELS RESULTING IN LOSSES FROM RUNOFF AND STREAM FLOW INTO THE DEEP MINES. IN AREA E, THE GROUNDWATER TABLE (MINE POOL) IS AT OR NEAR STREAMBED LEVELS. STREAM RECHARGE OCCURS AND THERE IS NO LOSS OF STREAM FLOW TO THE DEEP MINES.

AREA C THIS AREA HAS BEEN EXTENSIVELY STRIP MINED AND DEEP MINED. MOST OF THE PRECIPITATION AND RUNOFF IN THIS AREA IS INTERCEPTED BY STRIP PITS AND SUBSIDENCE DEPRESSIONS OR INFILTRATES FROM STREAMBEDS INTO THE DEEP MINES.

AREA D THIS AREA IS URBAN AND SUBURBAN WITH EXTENSIVE DEEP MINING AND LIMITED STRIP MINING OPERATIONS. PRECIPITATION AND RUNOFF IN THIS AREA IS INTERCEPTED IN LIMITED AREAS BY MINING OPERATIONS. MOST RUNOFF IS COLLECTED BY STORM DRAINS AND RUNOFF CONTRIBUTION TO STREAM FLOW IS MODERATE. SOME STREAM FLOW IS LOST BY STREAMBED INFILTRATION INTO THE DEEP MINES.

AREA E THIS AREA IS LIMITED TO THE STREAM CHANNEL ALONG THE LOWER REACHES OF MILL CREEK. THERE ARE NO STREAMBED LOSSES TO THE DEEP MINES IN AREA E. IN THIS AREA, THE STREAM IS RECHARGED BY GROUNDWATER AND MINE POOL SEEPAGE.

WATERSHED DRAINAGE AREAS

Tributary Stream	Sub-Watershed D.A. (Sq. Mi.) A	B	C	D	E	Total
Coal Brook	-	.58	2.02	-	-	2.6
Laurel Run	9.53	.18	1.03	.75	.01	11.5
Mill Creek	8.23	-	1.76	2.46	.05	12.5
Gardner Creek	6.28	.11	3.61	-	-	10.0
Total Mill Creek	24.04	.87	8.42	3.21	.06	36.6

NOTES:

1. BASE MAP IS REPRODUCTION OF PARTS OF USGS 7½ MINUTE TOPOGRAPHIC QUADRANGLES (WILKES-BARRE EAST, PITTSTON, AVOCA AND PLEASANT VIEW SUMMIT).

2000 0 2000 4000
SCALE IN FEET

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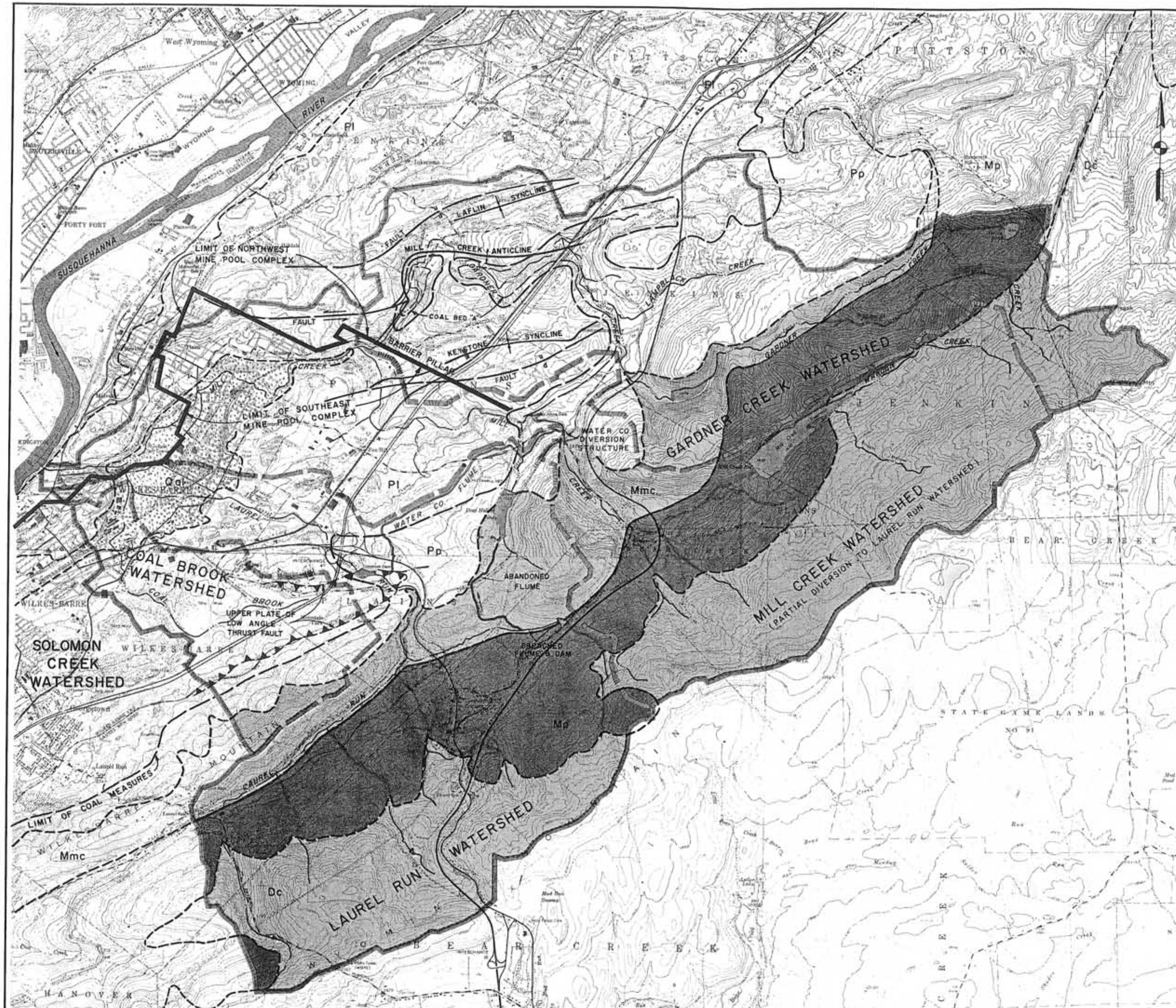
WATERSHED MAP
& WATER COMPANY DISTRIBUTION SYSTEM

DATE: DEC. 1976

FIGURE No. 1



ANTHRACITE COAL FIELDS OF PENNSYLVANIA

GENERALIZED STRATIGRAPHIC COLUMN

AGE	FORMATION	SYMBOL	DESCRIPTION
QUARTENARY HOLOCENE PLEISTOGENE	SEDIMENTS ALLUVIAL DEPOSITS GLACIAL DEPOSITS	Qal	RECENT RIVER SEDIMENTS UNDERLAIN BY GLACIAL LAKE SEDIMENTS TO 300' DEEP, BEDS OF CLAY, SILT, FINE TO COARSE SAND AND GRAVEL
PENNSYLVANIAN	LLEWELLYN (2,300')	Pl	LIGHT TO MEDIUM GRAY SANDSTONE AND CONGLOMERATE WITH SHALE, CLAYSTONE AND AT LEAST 26 BEDS OF ANTHRACITE COAL (1" TO 27' THICK) 10' RED ASH - BOTTOM OF COAL MEASURES
	POTTSVILLE (300')	Pp	LIGHT GRAY TO WHITE MEDIUM TO COARSE GRAIN SANDSTONE AND CONGLOMERATE.
MISSISSIPPIAN	MAUCH CHUNK (1000')	Mmc	RED SHALE INTERBEDDED WITH SOME GREEN, GRAY AND BROWN SHALE, SILTSTONE AND SANDSTONE.
	POCONO (600')	Mp	GRAY, MASSIVE SANDSTONE AND CONGLOMERATE WITH SOME SHALE AND SILTSTONE.
DEVONIAN	CATSKILL (2000')	Dc	RED, GRAY AND GREEN SHALE, SILTSTONE AND FINE TO MEDIUM SANDSTONE.

2000 0 2000 4000

SCALE IN FEET

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GEOLOGIC MAP

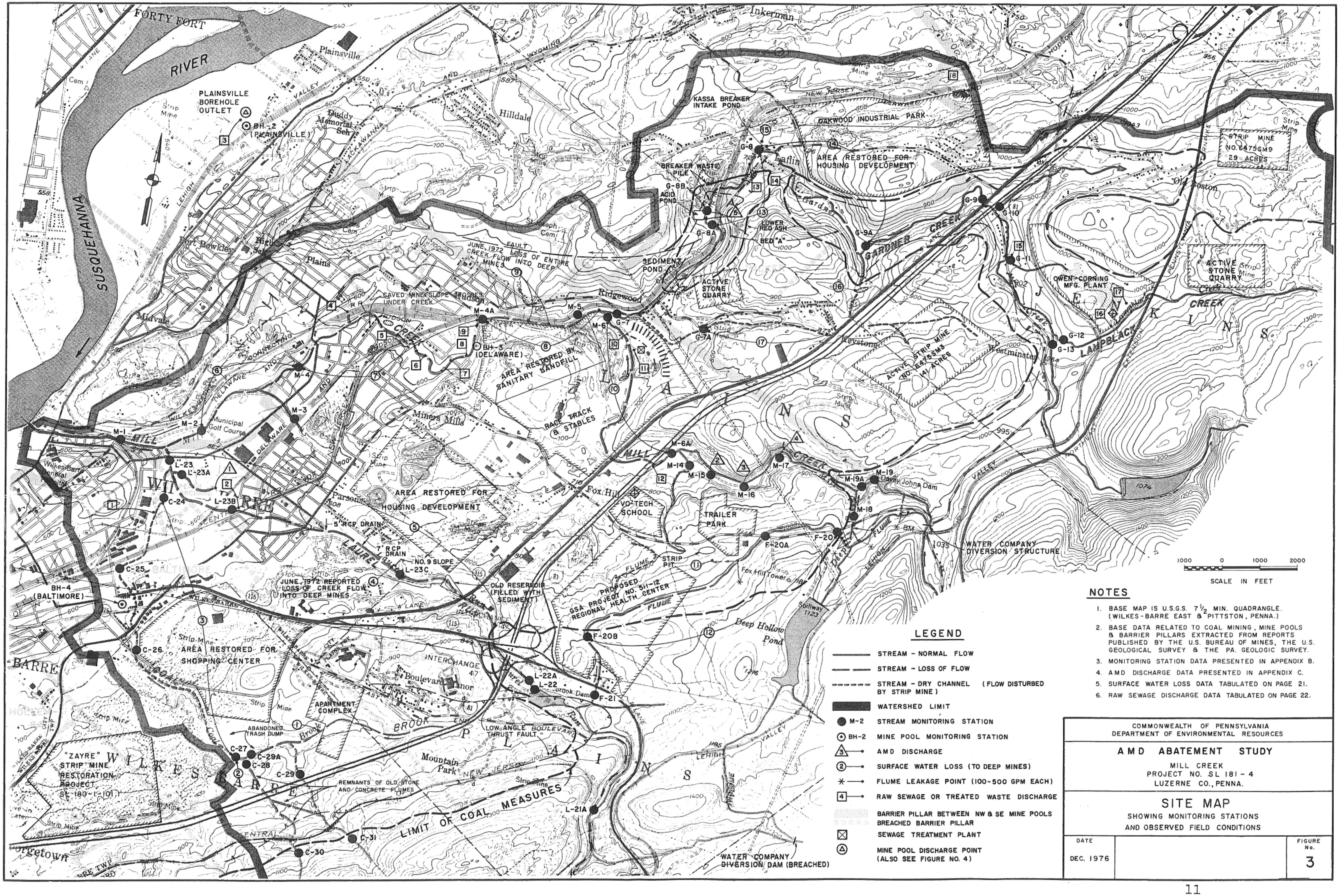
DATE: DEC. 1976

FIGURE No. 2

to isolate suspected stream loss areas. The locations of all forty-two stations are shown in the Site Map on page 11. At three stations, (M-2, L-22A and L-23), continuous water level recorders were installed to document continuous surface flow data of the two main branches of Mill Creek. In order to determine the relationship between precipitation, surface flows, surface losses and mine pool discharges, continuous water level recorders were also installed at four major mine pool discharge points. The approximate locations of the mine pools and major AMD discharge points are shown on the Mine Pool Map (Figure 4, page 13).

Flow measurements, water temperature and pH were recorded monthly in the field for each station. Flow measurements were made by use of an Ott 10.200 Current Meter, weirs and volumetric methods. Water samples were collected at each station and shipped for testing to B-H Laboratories, York, Pennsylvania; the Department of Environmental Resources Laboratory, Harrisburg, Pennsylvania; and Green International, Inc., Sedgewick, Pennsylvania (in order of progression). It should be noted that B-H Laboratories' test results for natural sulfate concentrations in the clean streams above the coal measures were found to be high. Check tests by GEO-Technical Services laboratory and subsequent verification by the DER laboratory, indicated that the sulfate test results prior to June 1975 were not reliable. Accordingly, correlation of sulfate test data was utilized only after the DER laboratory commenced processing samples in June 1975, followed by Green International, Inc.. The field information obtained to date, together with the laboratory test results were computerized to facilitate data processing and analysis. Additional sampling and flow measurements were conducted as required to define a particular problem or to verify specific flow and quality data. Comparison of the computer print-out data between successive monitoring stations enabled direct determination of "in stream" surface water losses and areas of stream contamination.

Supplementing the collection of data described above, are monthly data sheets of forty (40) mine pool monitoring stations located throughout the Wyoming Valley. Twelve of these stations were equipped with continuous water level recorded. Pertinent data was com-


SUSQUEHANNA
RIVER
FORTY FORT
Plainsville
PLAINSVILLE
BOREHOLE
OUTLET
BH-2
(PLAINSVILLE)
KASSA BREAKER
INTAKE POND
OAKWOOD INDUSTRIAL PARK
AREA RESTORED FOR
HOUSING DEVELOPMENT
BREAKER WASTE
PILE
ACID
POND
LOWER
RED ASH
BED
GARDNER CREEK
SEDIMENT
POND
ACTIVE
STONE
QUARRY
STRIP MINE
NO. 6475SM9
29 ACRES
JUNE, 1972 FAULT
CREEK FLOW INTO DEEP
MINES
CAVED MINE SLOPE
UNDER CREEK
BH-3
(DELAWARE)
AREA RESTORED BY
SANITARY LANDFILL
RACE TRACK
& STABLES
ACTIVE STRIP MINE
NO. 164SM3
141 ACRES
OWEN-CORNING
MFG. PLANT
LAMPBLACK CREEK
Municipal
Golf Course
Miners Mill
AREA RESTORED FOR
HOUSING DEVELOPMENT
5' RCP DRAIN
7' RCP
DRAIN
NO. 9 SLOPE
JUNE, 1972 REPORTED
LOSS OF CREEK FLOW
INTO DEEP MINES
OLD RESERVOIR
(FILLED WITH
SEDIMENT)
VO-TECH
SCHOOL
TRAILER
PARK
STRIP
PIT
PROPOSED
GSA PROJECT NO. 511-12
REGIONAL HEALTH CENTER
FLUME
Deep Hollow
Pond
Spillway
1123
WATER COMPANY
DIVERSION STRUCTURE
BH-4
(BALTIMORE)
AREA RESTORED FOR
SHOPPING CENTER
INTERCHANGE
47
Boulevard Manor
APARTMENT
COMPLEX
ABANDONED
TRASH DUMP
LOW ANGLE
THRUST FAULT
"ZAYRE"
STRIP MINE
RESTORATION
PROJECT
SL-180-1-101
REMNANTS OF OLD STONE
AND CONCRETE FLUMES
LIMIT OF COAL MEASURES
WATER COMPANY
DIVERSION DAM (BREACHED)
MILL CREEK
LAUREL RUN
WILKES-BARRE
PLAINS
JENKINS
M-1
M-2
M-3
M-4
M-4A
M-5
M-6
M-6A
M-14
M-15
M-16
M-17
M-18
M-19
M-19A
G-7
G-7A
G-8
G-8A
G-8B
G-9
G-9A
G-10
G-11
G-12
G-13
L-21A
L-22
L-22A
L-23
L-23A
L-23B
L-23C
C-24
C-25
C-26
C-27
C-28
C-29
C-29A
C-30
C-31
F-20
F-20A
F-20B
F-21
SCALE IN FEET
1000
0
1000
2000
LEGEND
STREAM - NORMAL FLOW
STREAM - LOSS OF FLOW
STREAM - DRY CHANNEL (FLOW DISTURBED BY STRIP MINE)
WATERSHED LIMIT
M-2 STREAM MONITORING STATION
BH-2 MINE POOL MONITORING STATION
AMD DISCHARGE
SURFACE WATER LOSS (TO DEEP MINES)
FLUME LEAKAGE POINT (100-500 GPM EACH)
RAW SEWAGE OR TREATED WASTE DISCHARGE
BARRIER PILLAR BETWEEN NW & SE MINE POOLS
BREACHED BARRIER PILLAR
SEWAGE TREATMENT PLANT
MINE POOL DISCHARGE POINT
(ALSO SEE FIGURE NO. 4)
NOTES
1. BASE MAP IS U.S.G.S. 7 1/2 MIN. QUADRANGLE.
(WILKES-BARRE EAST & PITTSTON, PENNA.)
2. BASE DATA RELATED TO COAL MINING, MINE POOLS
& BARRIER PILLARS EXTRACTED FROM REPORTS
PUBLISHED BY THE U.S. BUREAU OF MINES, THE U.S.
GEOLOGICAL SURVEY & THE PA. GEOLOGIC SURVEY.
3. MONITORING STATION DATA PRESENTED IN APPENDIX B.
4. AMD DISCHARGE DATA PRESENTED IN APPENDIX C.
5. SURFACE WATER LOSS DATA TABULATED ON PAGE 21.
6. RAW SEWAGE DISCHARGE DATA TABULATED ON PAGE 22.
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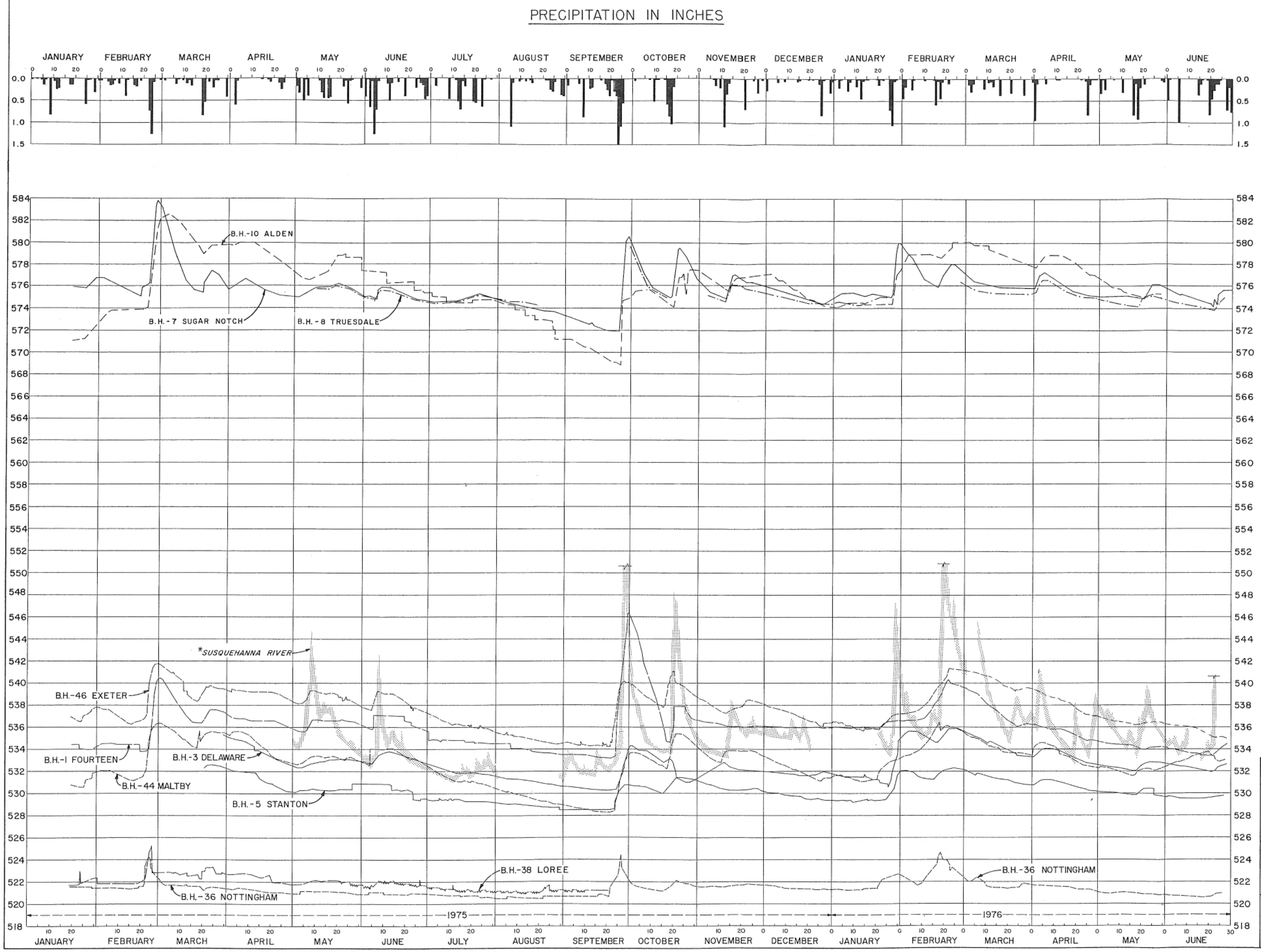
LUZERNE CO., PENNA.
SITE MAP
SHOWING MONITORING STATIONS
AND OBSERVED FIELD CONDITIONS
DATE
DEC. 1976
FIGURE No.
3



*STAGE OF SUSQUEHANNA RIVER AS RECORDED AT THE WILKES-BARRE U.S.G.S. GAGING STATION AND PROJECTED UPSTREAM TO SCOVILLE ISLAND

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MINE POOL LEVELS

DATE		FIGURE No.
OCT. 1976		5