IV. HYDROLOGY

A. GENERAL

In this Section of the report the water budget for the study area is analyzed, including precipitation, evaporation-transpiration, infiltration, runoff, ground water movement and stream flow. Information developed in this Section was used in the development of later Sections of the report. This particularly applied to the determination of the average acid production assignable to various strip pit areas.

Most writers have not attempted to estimate these values, perhaps due to the many variables involved. However, based on average annual precipitation and reasonable assumptions as to evapotranspiration etc it is believed that average estimated values can be obtained.

First, it was necessary to determine the estimated amount of water attributable to overland flow entrapped by strip mines. It is known that when this same entrapped water emerges from the respective mine pool overflow (with which it communicates), that it will have a certain water quality. This water quality was then used in determining the respective acid/iron production assignable to the particular strip pit area.

It seems immaterial that some of the acid/iron production may have been produced in the abandoned deep mines, as well as the particular strip mine. It can be demonstrated that the acid load for the study area would have been proportionately less if the runoff had continued uninterrupted to the streams and not been entrapped by the strip pits communicating with various mine pools.

B. PRECIPITATION

The average annual precipitation for this zone of the Swatara Creek Basin, as reported by the U. S. Geological Survey, is about 47 inches. The average for the entire Swatara Creek basin for the same period of record was 45.5 inches.

Precipitation, recorded at a rain gauge maintained during the field studies on the project site, amounted to 44 inches during the period October 1, 1969, through September 30, 1970, the first full twelve months of record. This obviously is somewhat below the Swatara Creek Basin average and the recorded average annual precipitation of 47 inches for our zone within the basin.

Following is a tabulation of recorded precipitation from our rain gauge located at the Indian Head Colliery east of Tremont. This Taylor, 11 inch direct reading gauge, was located at Elevation 920t and was read daily on weekdays, beginning September 8, 1969:

MEASURED RAINFALL WITHIN STUDY AREA

1969	Month	Precipitation	Remarks
	Sept.	0.96"	Partial Month
	Oct.	2.37"	
	Nov.	5.02"	
	Dec.	6.72"	
1970	Jan.	0.50"	
	Feb.	3.73"	
	March	3.16"	
	April	4.75"	
	May	3.46"	
	June	4.15"	
	July	5.28"	
	Aug.	1.99"	
	Sept.	2.85"	
	Oct.	6.57"	
	Nov.	4.66"	

C. EVAPORATION - TRANSPIRATION

The annual consumptive use for this region of Swatara Creek has been set by the U. S. Department of the Interior at 24.6 inches. Using the 47 inches of rainfall recorded in the Geological Paper, a consumptive rate of 52.3 percent is established.

To determine the validity of the consumptive rate a composite rate of evapotranspiration over the study area was calculated. The watershed was divided into four categories:

1. Rainfall directly falling on strip mines, refuse banks and other areas of little or no vegetation.

2. Rainfall on undisturbed land or land with cultivated growth.

3. Rainfall on populated areas.

4. Rainfall directly into streams, lakes, and reservoirs.

The following assumptions were made:

1. All rainfall within a category was uniformly characteristic in nature.

2. Precipitation into the strip mines was considered to have little or no effect on transpiration.

The American Society of Civil Engineers' Method was used to determine evaporation:

(1) U.S. Department of Commerce, Weather Bureau

(2) Swatara Creek Basin, 42 Year Composite Record, U.S.G.S.
(3) A.S.C.E. Manual No.28, Hydrology Handbook, p.132

EVAPORATION OF STRIPPED AND DISTURBED AREAS

Month	Mean (1) Temp. (°F)	Rainfall(2) (Inches)	Monthly Evaporation (3) (Inches)
Jan	31	3.2	1.0
Feb	32	2.7	0.9
Mar	45	3.9	1.4
Apr	53	3.8	1.6
May	67	4.6	2.3
June	70	4.2	2.3
July	76	5.0	2.9
Aug	75	4.0	2.2
Sept	70	3.7	2.0
Oct	57	3.7	1.6
Nov	52	4.1	1.5
Dec	41	3.5	0.9

Annual Evaporation . . . . 20.6 Inches

Precipitation on undisturbed land involves evapotranspiration ("U"). The "Lowry & Johnson" method was used for calculations:

$$U = 0.00015\,H + 0.9$$

(Where U is the Evapotranspiration in inches and H is the annual degree-days above 32°F.)

EVAPOTRANSPIRATION OF UNDISTURBED LANDS

Month	No. Days	Mean Temp. (°F.)	Temp.(-32°F)	Degree-days (H)
Jan	31	31	0	0
Feb	28	32	0	0
Mar	31	45	13	403
Apr	30	53	21	630
May	31	67	35	1085
June	30	70	38	1140
July	31	76	44	1364
Aug	31	75	43	1333
Sept	30	70	38	1140
Oct	31	57	25	775
Nov	30	52	20	600
Dec	31	41	9	279

Annual Degree Days 8749

$$U = 0.00015\,H + 0.9 = .00015\,(8749) + 0.9 = 2.21 \text{ feet}$$

Average Evapotranspiration (Undisturbed land) U = 26.5 inches

Precipitation falling on towns involved a breakdown of those areas with a direct runoff (70 percent of the area) and those areas having sufficient vegetation (30 percent) to provide a source of ground water infiltration. Runoff evaporation was determined based on the U. S. Weather Bureau Class A Pan. Groundwater evapotranspiration was based on Lowry & Johnson methods as previously described. The Standard Pan evaporation is 34 inches at 400 feet elevation in the Swatara Creek Basin. By transposing Pan measurements the following deductions can be made.

EVAPORATION AND EVAPOTRANSPIRATION OF POPULATED AREAS

	Elev.	Runoff Evaporation	Ground Water Evapotranspiration
Tremont	800	32 inches	26.5 inches
Donaldson	875	31 inches	26.5 inches
Good Spring	1320	2 inches	26.5 inches
Average (Populated Areas)		31 inches	26.5 inches

Precipitation falling directly into streams, lakes and reservoirs was established by using data from a Standard Class A Pan interpolated for an average elevation of 1100 feet:

Evaporation = 30 inches

To arrive at a composite rate of evapotranspiration for the study area each category of precipitation was compared to the area covered:

D. INFILTRATION

COMPOSITE EVAPOTRANSPIRATION

Strip Mine Areas - Evaporation	(3009 Acres) (20.6")	61,985.4
Undisturbed Areas - Evapotranspiration	(5969 Acres) (26.5")	158,178.5
Populated Areas - Evaporation	(517 Acres) (31.0")(.7)	11,218.9
Evapotranspiration	(517 Acres) (26.5")(.3)	4,110.2
Streams, Lakes, etc. - Evaporation	(23 Acres) (30.0")	690.0
		236,183.0
Total Acres	9,518	

Composite Evapotranspiration or — 25.4 Inches, 57.8 percent Rate

This 57.8 percent compares favorably to the 52.3 percent established by the Department of the Interior.

Due to the very extensive longitudinal strippings along the contour it has been estimated that 83 percent of all surface water enters the ground as infiltration, most of which reaches the several mine pools beneath the watershed. No attempt was made to isolate a single mine pool and to determine its ground water recharge rate of infiltration. Others have indicated in subsidence areas the start of increased pumping in active mines is from one to three days after the start of significant rainfall after which the rate decreases. However, during the field studies a long duration high volume storm, coupled with snow melt over the entire watershed, influenced the stream network for a period of seventeen days.

S. H. Ash et al, in a research paper "Water Pools In Pennsylvania Anthracite Mines", U. S. Bureau of Mines, Technical Paper 727, concerning infiltration stated:

The volume of water entering into mine workings during and after any period of precipitation varies greatly in adjoining basins, and even in adjoining collieries in the same field, because of differences in the condition of the strata as affected by the progress of the extraction of the anthracite, particularly that from the uppermost beds. The ratio between run-off and infiltration varies for each period of precipitation in any given area because of variables in the rate of precipitation, duration of storm, rate of evaporation that depends upon the temperature and humidity, transpiration dependent on the season and the amount of vegetable life, status of the water table,

"Strippings especially contribute to this infiltration of water because of the removal of overburden and because of the longitudinal extent of strippings along the outcrop of the anthracite beds. Many fissures and cave-ins are not visible on the surface because they are hidden under refuse banks or are partly filled with dirt; nevertheless these openings contribute much to water seepage."

E. RUNOFF

Factors considered in determining the amount of runoff for the watershed are the type and percentage of vegetation, the general slope of terrain, the type of soil and the climatological data.

The watershed is generally one of steep slopes (up to 35 percent) with a thick covering of deciduous trees in unmined or undisturbed areas. There is no farming in the watershed. The strip mines, refuse banks, and colliery areas in general constitute 32 percent of the total area and either have no vegetation or have widely scattered thorn thickets which can be discounted as a factor in determining the runoff. The towns and villages are located generally on the valley floor and account for 5 percent of the watershed.

Undisturbed samples obtained from two representative locations in the study area were tested in accordance with American Association of State Highway Officials (A.A.S.H.O.) Specifications. These classification tests indicated that the materials were of the A-2-4 and A-6 types and they were visually classified as a clayey silt and a silty clay, respectively.

These soils exhibit a moderate to high degree of permeability, depending primarily upon their density. They are, quite naturally, more permeable in the disturbed state as would be found in loosely compacted strip mine spoil banks. Spoil and refuse material release water and hence AMD for long periods after rainfall has ceased.

The typical annual precipitation cycle follows a pattern in which rains during November and December saturate the soil and begin to freeze in place as winter begins. During December, January, and February the ground is covered with up to two feet of snow and is frozen to a depth of 45± inches.

In the spring snow melt is typically somewhat rapid while the soil thaws at a much slower rate. During this time the soil is usually saturated and any rapid increase in precipitation will create a high rate of runoff. There is a high probability for spring flooding at the mouth of the watershed. Once the soil has completely thawed its permeability is sufficiently high to accommodate any storm of normal duration and intensity without a prolonged saturation period. During the summer months and early autumn the streams approach their base flow and the major sources of sustained runoff are ground water, mine pool overflows, and entrapped mine water recession from spoil and refuse banks.

The mouth of the watershed is 0.4 mile south of Tremont. A sampling and measurement station, Sampling Station GS-61, at this point indicates runoff of 7,900 g.p.m. based on an integrated annual volume. The average annual base flow for the watershed has been determined to be 3,000 gpm. Considering the three major streams and excluding some of their minor tributaries, 30 percent of the runoff enters Good Spring Creek, 18 percent enters Middle Creek and another 18 percent enters Gebhard Run.

The base flow to the streams can be attributed principally to the overflow of mine water pools within the area of which the Middle Creek Pool and Good Spring No.3 Pool serve as the two major ground water sources. The Colket Pool and Indian Head Pool both discharge into the study area, and although quite potent as sources of pollution, the quantity of discharge from each is one-fourth the discharge of the Middle Creek Pool (the major overflow discharge). The Good Spring No.1 Pool discharges out of the study area; however, during periods of heavy rainfall the mine water pool does intermittently overflow into the Good Spring Creek watershed through an air hole (Sampling Station GS-96) in the Tracy Vein adjacent to Route 125 and Barrier Pillar XXIV.

F. GROUND WATER AND ITS MOVEMENT

The availability of ground water is dependent upon numerous factors among which are the composition, thickness, geologic structure of the underlying rocks, and variable fracturing of strata due to the extraction of anthracite. The study area can be viewed as a large synclinal trough, or "basin'", with its axis somewhat tilted toward the east. The lower beds of rock and coal outcrop generally parallel to the mountain crests to the north and south. On the west in the vicinity of Lykens the axis of the "basin" surfaces, forming what would appear to be one end of an elongated dish. The bottom of the basin appears at progressively lower elevations to the east. The average regional plunge of structural features in the area is 6° in a N 72^{0} E direction.

Infiltrating surface water travels downward toward the synclinal axis then eastward through the plunging basin. This uniformity of structure and drainage pattern is interrupted in the Middle Creek area by faulting perpendicular to the general strike of the geologic structure. This has resulted in the formation of a subwatershed wherein the surface topography and drainage is generally perpendicular to the regional structure.

This sub-surface drainage condition has been drastically altered by coal mining throughout the area. Major aquifers have been breached by openings between the underground mines and by connections direct to the surface which have created hundreds of points of discharge from the underground system. Barrier pillars consisting of un-mined coal are effective in confining the mine water pools provided the pillars have not been breached by subsequent mining or altered by structural failure.

In certain instances it is known that water travels for miles through this maze of sub-surface mines prior to emptying into a mine water pool and/or discharging to the surface.

G. STREAM FLOW

Streams encountered from east to west in the watershed consist of Gebhard Run, Middle Creek, Coal Run, Bailey Run, Martins Run and Good Spring Creek. Good Spring Creek has two small tributaries, Poplar Creek and Hollenbach Run. The total watershed discharges through the lower reaches of Good Spring Creek into Swatara Creek south of Tremont.

Based upon the average of flows recorded at selected locations on streams during the study period the following tabulation indicates stream flows for the study area:

Stream	Average Flow (g.p.m.)
Gebhard Run	1,233
Middle Creek	2,112
Coal Run	2,843
Bailey Run	140
Martins Run	719
Good Spring Creek	16,024 (*)

(*) Measured below Tremont - includes all streams above that point. Based on average measured flow.

The highest flows measured during the study period occurred in April, 1970, following 2.52 inches of rainfall in a 17 hour period. This, combined with moderating temperatures, caused a heavy, rapid snow-melt. It is estimated that the winter accumulation of snow at the time was between 15 and 21 inches. The flow in Good Spring Creek was too high during peak flow (1.5 feet above top of banks) to use stream gauging equipment. However, the velocity was measured four days later when the stage had dropped to bank full. This velocity was adjusted slightly to compensate for peak flow conditions and, utilizing a reconstructed cross-section of the stream channel, a peak flow of 124,900 g.p.m. at Sampling Station GS-61 was estimated for this storm. This was 7.8 times the average flow.

While probably not the storm of record, when considered with the winter snow melt it certainly would class this storm as a low frequency storm. A high flow of 15,742 g.p.m. was recorded for Middle Creek at Sampling Station MC-12 during the storm noted above. However during the period from late August through September, with two exceptions, the Middle Creek channel was dry when inspected. During this same period the "Otto" strippings overflow (Sampling Station MC-1) representing the headwaters of Middle Creek, along with most sources of water in this sub-watershed, were either dry or their volume of discharge was greatly reduced. The exceptions to this, of course, were the two active and one abandoned deep mines which continued to discharge mine water by gravity flow or intermittent pumping. Middle Creek traverses the area over the Middle Creek Mine Water Pool., and further downstream, the Indian Head Mine Water Pool. (See Plate No.9). In these two reaches the streambed is formed in spoil material from previous strippings. It is very probable that much of this loss of stream flow can be attributed to infiltration through this spoil material to the Middle Creek and Indian Head Mine Pools, respectively. A study of the data indicates that in many areas a marked increase in stream flow had little or no effect on acid and iron concentrations. This phenomenon no doubt is influenced by the high percentage of water discharging from the very extensive underground system including mine pools, where infiltrated water has considerable opportunity for acid production prior to discharging from the mine pool overflow points.

In the long history of anthracite deep mining the practice of "grass roots" mining was employed in the first lift of mine development. Later in strip mining this area the deep mines were intercepted in many instances or lie very close to the bottom of the strips, thus providing a direct flow route for water to the deep mines. Both the strip mining and the deep mining have disturbed the hydrological ground flow system. The mines are periodically being flushed by this unnatural flow system and producing considerable quantities of sulfuric acid and iron.

Runoff from spoil and refuse areas is also acidic since it consists of the "flush-out" of acid salts produced between periods of rainfall. Generally speaking, where acid and iron concentrations result from leaching of spoil banks and refuse piles, prolonged high flows do tend to yield a less acidic water having lower concentrations. However despite this dilution, with increased volumes of water more acid and iron will be flushed out, producing more total pounds of acid and iron. Conversely, prolonged periods of low flow usually result in water having higher concentrations of acid and iron, but less total. pounds of acid and iron.

H. PRESENT CONDITION OF STREAMS IN WATERSHED

With the exception of Poplar Creek and one short stretch of Gebhard Run, which will be discussed later, all of the streams within the watershed studied contain acidic water resulting from coal mining operations.

The streams draining the sub-watersheds are tabulated in order of occurrence from east to west:

	Sub-Watershed (Stream)	Drainage Area (Sq. Mi.)	Percent of Total Study Area	Miles of Affected Stream
1.	Gebhard Run	2.6	17	4.3
2.	Middle Creek	2.7	18	4.4
3.	Coal Run	1.1	8	1.9
4.	Bailey Run	0.4	3	0.7
5.	Martins Run	0.6	4	0.6
6.	Good Spring Creek	7.5	50	7.1
	Totals	14.9	100%	19.0

1. Gebhard Run

This stream originates from headwaters on the north side of Route 25, about 1.5 miles north of the Village of Newtown. Flows measured at our Sampling Station G-21, consisting of a 2 foot weir located in the stream at the north edge of Route 25, ranged from 0 to 2359 g.p.m., averaging 215 g.p.m. during the water year.

The existing conditions on this stream, prior to this engineering study, will be described first. All of the water in the northern portion of Gebhard Run discharged into the abandoned Mammoth Vein strip pits in the "Fisher Basin" area, about 1000 feet south of our Sampling Station G-21. The water thus discharged entered the Middle Creek Mine Water Pool through the Mammoth Vein deep mine complex and eventually discharged to the surface at the "Tracy Overflow" (Sampling Station C-34).

South of the "Fisher Basin" water from active and abandoned mines, springs, etc., had been diverted from its normal course in Gebhard Run and entered the abandoned Indian Head Colliery (Tracy Vein) deep mine workings. From this point, the water travelled through the underground system of abandoned mines and eventually discharged through the "Marshfield Slope" (Sampling Station C-37) and thence from abandoned strip mines to Coal Run. This underground water in the abandoned mine workings in this area represents the Indian Head Mine Water Pool.

A project to prevent the flow of Gebhard Run from entering the underground workings at the Indian Head Colliery was completed in August, 1967.

This was accomplished by excavating a new stream channel at one point and by reconditioning a portion of the original channel directly adjacent to a large refuse bank (44.3 acres and 1,540,000 cu. yds. - locally known as the "Rock Pile") to the east of the Colliery.

In June, 1970, a project to prevent the discharge of Gebhard Run from entering abandoned strip pits in the "Fisher Basin" was completed. This project consisted of the construction of an earth ditch, the reconditioning of a portion of the stream channel, and the installation of a 72 inch half-round concrete flume to transport the stream's water over and through the strip pits.

Both of these remedial projects were designed by, and completed under the supervision of the Pottsville Office of the Department of Environmental Resources.

A resume of the results of stream flow measurements and tests of water quality samples obtained at our Sampling Station G-26 throughout the study period is tabulated below. An 8 foot weir was installed at this Sampling Station and is considered to be the major sampling station in this sub-watershed. Another Sampling Station, G-27, is located downstream at the confluence with Middle Creek; however, with the exception of acidic surface runoff from the slopes of the Indian Head Slush Dam, (144 acres and 5,658,000 cu. yds.), no other source of acidic water is known to enter the stream between these stations.

The following data was recorded for the Gebhard Run sub-watershed during the study period:

Length of stream	- 4.3 miles
Total Drainage Area	- 2.6 square miles
Percent of Total Study Area	- 17 percent
Percent Total Drainage Area disturbed by mining	- 26 percent
Percent Total Drainage Area disturbed by strip pits	- 12 percent

	FLOW - g.p.m.			ACID - Lbs/24 hours			IRON - Lbs/24 hours		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
(*)	11,657	96	1,233	1,869	66	514	1,539	0	66

(*) Sampling Station G-26 (Weir)

During the water year, acid concentrations of 0 to 280 mg/l and iron concentrations of from a trace to 11 mg/l were recorded.

Stream flow in this sub-watershed can vary significantly as evidenced by the range in recorded flows presented above. During the study period the stream flow here fluctuated at a more rapid rate than that of the other sub-watersheds. This is due at least in part to a relatively steep gradient and comparatively lower percentage of area disturbed by strip mining which facilitates more surface run-off.

In an attempt to further isolate the major source of pollution, at certain times simultaneous samples were taken in order to compare the quality of water at the point where the stream crosses Township Road 571 with that at our downstream Sampling Station G-26.

A swampy area is located directly below Township Road 571 and a large refuse bank ("Rock Pile") is located at the Indian Head Colliery, approximately midway between the Township Road and Sampling Station G-26.

The quality of water sampled at the Township Road, and in the swampy area was considerably better than that obtained at Sampling Station G-26. Laboratory test results of simultaneous samples taken at (1) the Township Road and (2) Sampling Station G-26 are as follows:

	pH		Alkalinity		Acidity		Iron		Sulfates		
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	Remarks
	6.1	3.6	8	0	0	248	2.3	0.9	310	1300	
	5.8	3.5	0	0	10	280	3.1	4.36	200	1300	
	6.1	3.9	4	0	0	14	7.	5.	280	385	
(*)	5.9	-	6	-	-	-	3.25	-	56	-	
	6.3	3.5	29	0	0	280	0.7	1.9	1200	3200	
	5.8	4.3	4	0	0	52	1.34	2.	170	245	
	6.2	4.4	24	0	0	72	1.8	1.7	310	340	
	5.5	4.4	0	0	4	24	30.	1.4	380	185	Heavy Rain
	6.1	4.4	4	0	0	40	0.35	0.2	200	220	
	6.4	4.6	2	0	0	16	1.2	1.2	78	72	

(*) Swampy Area - sampled at same time as preceding samples.

It can be seen from this tabulation that water at the Township Road (l) was almost always alkaline and that its pH was always considerably higher than that at Sampling Station G-26 (2).

Water from the swampy area was very similar in nature to that sampled at the Township Road. On one occasion it was noted that minnows were in the water, well distributed throughout the area of the swamp.

The stream flows by a large refuse bank ("Rock Pile") on the east side of the Indian Head Colliery. The stream is in direct contact with this bank and surface run-off carries. considerable quantities of coal silt and acid salts from the bank to the stream. Surface water also seeps through the bank and runoff flows over ground a short distance to the stream. Contact with this refuse bank results in a polluted stream from this point to its confluence with Middle Creek.

As mentioned previously, the water in Gebhard Run is alkaline upstream from this refuse bank ("Rock Pile") and acidic below it. It is concluded that the acid present at Sampling Station G-26 is being produced by the refuse bank.

The refuse bank ("Rock Pile") is typical of such piles in this area in composition, surface gradient, etc., occupying a land surface area of 44.3 acres, and comprising 1,5+0,000 cu.yds.

Surface slopes on this bank are generally in the range of 2 : 1 to 5 : l, with the steeper side away from the colliery which is indicative of the manner in which the bank was constructed. These steeper slopes are on the side adjacent to Gebhard Run, which results in an accelerated rate of bank surface erosion in that area due to 'the absence of vegetative cover.

Coal silt eroding from this bank extends to the edge of Gebhard Run and is washed into this stream with even small amounts of surface runoff in that area.

On occasion, coal silt was noted in the stream bed for a considerable distance downstream from the refuse bank. As noted earlier suspended solids in the form of coal silt can also produce a continuing additional acid contribution to the stream.

In October, 1970 during a special study, the water quality/ quantity at Sampling Station G-26 was monitored frequently throughout one 32 hour period of heavy rainfall, to determine the increase in acid load and rate of acid production by the Indian Head Refuse Bank ("Rock Pile"). Prior to this storm a flow of 134 g.p.m. was recorded and during the heaviest rainfall (April, 1970) the flow was in excess of 12,000 g.p.m. Acid production is shown graphically on Plate No.9.

As mentioned previously in this report, tests by others indicate that 70± percent of precipitation falling on a refuse bank is discharged in the form of surface run-off. Good, Ricca and Shumate (The Ohio State University)* also suggest that the ratio of the amount of acid appearing in the runoff to the total amount flushed out of the mantle is equal to the ratio of runoff to precipitation. The average figure for this distribution is 0.7. They further state that:

"In a typical refuse pile the zone of reaction extends only a few inches into the pile. Between rains the pyrite oxidation reaction proceeds at a more or less uniform rate with the acid products accumulating in the outer mantle. When a storm occurs it is estimated that 70 percent of the acid salts appear in the runoff, and the remainder is carried into the interior of the pile, eventually reappearing as seepage around the pile."

* Paper presented before the Third Symposium on Coal Mine Drainage Research, May 19-20, 1970, Pittsburgh, Pennsylvania, entitled "The Relation of Refuse Pile Hydrology to Acid Production".

The investigations by others further reveal that swampy and wet conditions generally occur around the base of large refuse banks. This is the seepage referred to above and constitutes the base flow. This seepage has been observed at the refuse banks in this study area.

Using the accumulated data the rate of acid production in runoff from this refuse bank was computed as follows:

$$\frac{T}{P \times I \times A}$$

Where:

T = Total acid produced by storm, pounds (See Plate No.9)

P = Ratio of run-off to precipitation

I = Interval, in days, since previous rainfall (period of acid production)

A = Land area of refuse bank, acres (draining to Gebhard Run)

Therefore, the estimated average acid formation rate during periods of non-precipitation for this refuse pile is:

$$\frac{2967}{0.7 \times 9 \times 21} = 22.4 \text{ Lbs./acre/day}$$

and,

22.4 Lbs./acre/day x 21 acres = 470 lbs./day.

As noted in the previous tabulation of test results, the average acid load recorded at Sampling Station G-26 was 514 lbs./24 hours. This limited check sampling indicates that the acid load produced by the refuse bank runoff represents over 90 percent of the average acid load measured at Sampling Station G-26. The remainder could be attributed to acid load in the base flow from seepage appearing around the bank perimeter.

Based upon the following modifications we believe that the average daily rate of acid production from this refuse bank can be applied to other such banks in this watershed. For such estimating purposes it is assumed:

(l) That minimal oxidation occurs during periods of precipitation and that therefore little or no acid is produced at this time.

(2) That significant precipitation occurs an average of 65 days/year; therefore:

$$\frac{\text{No. of days without precipitation (yr)}}{\text{No. of days (yr)}} \times \begin{array}{c}\text{Acid production lbs/acre/day} = \\ \text{(Indian Head Colliery Refuse Pile)}\end{array}$$

$$\frac{300}{365} \times 22.4 = 18.4, \quad \underline{\text{SAY}} \ 18 \text{ lbs/acre/day}$$

On the basis of the previously mentioned tests and assumptions we believe that the above is a conservative figure and it is reasonable to assume that other refuse piles in the watershed which are similar in composition to the one at the Indian Head Colliery produce acid at the rate of 18/lbs/acre/day.

As mentioned previously, surface run-off from the nearby slopes of the Indian Head Slush Dam enters Gebhard Run downstream from Sampling Station G-26. An analysis of the results of tests performed on several water samples from Sampling Stations G-26 and G-27, taken on the same day or within one day of each other, indicates a considerable increase in the acid load in the waters of Gebhard Run between these sampling stations. Gebhard Run lies in close proximity to the southern edge of the Indian Head Slush Dam and surface run-off from the Slush Dam is the only known source of polluted water entering the stream in that area.

While no detailed study was made at the Slush Dam as was done at the "Rock Pile", the increase in acid load between the two sampling stations is attributed to run-off from the silt dam and coal refuse previously deposited in and adjacent to the stream channel.

Water quality/quantity was monitored on Gebhard Run at eleven sampling stations, listed as follows:

	Number of Stations	Description
	4	Directly on stream by weirs and/or flow meter
	3	Springs
	1	Shallow well
	1	Active deep mine
	1	Abandoned deep mine
	1	Abandoned strip pit
Total	11	

Water tested from one of the springs and the shallow well was alkaline.

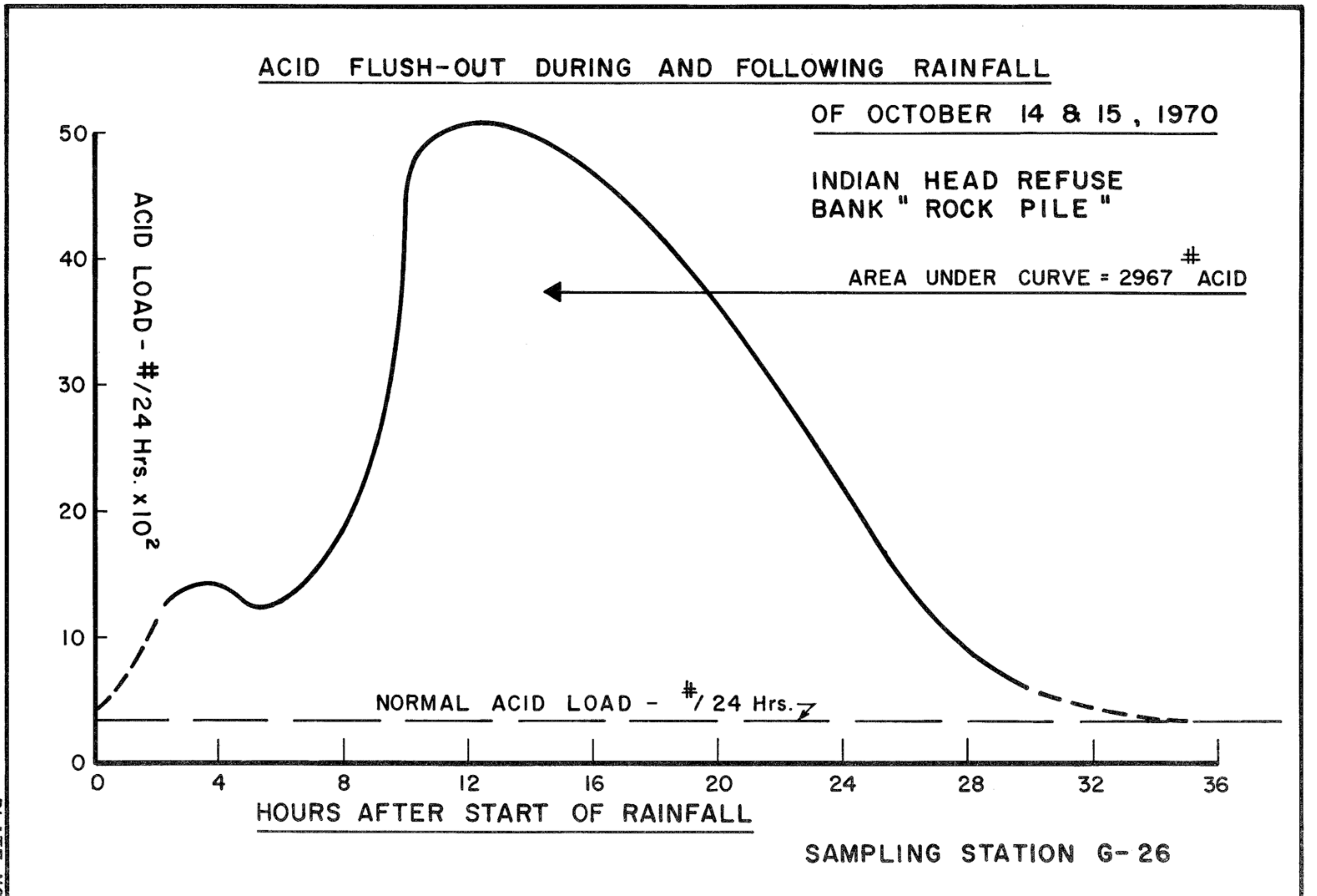
ACID FLUSH-OUT DURING AND FOLLOWING RAINFALL
OF OCTOBER 14 & 15, 1970
INDIAN HEAD REFUSE
BANK " ROCK PILE "
AREA UNDER CURVE = 2967 # ACID
ACID LOAD - #/24 Hrs. x10²
NORMAL ACID LOAD - #/24 Hrs.
0
10
20
30
40
50
0
4
8
12
16
20
24
28
32
36
HOURS AFTER START OF RAINFALL
SAMPLING STATION G-26

PLATE NO

2. Middle Creek

This stream originates in various abandoned strip pits, including the "Otto Strippings", approximately 0.8 mile north of the intersection of Interstate 81 and Pennsylvania Route 25. This is the most northerly and the highest point within the study area.

From its headwaters Middle Creek flows south under Interstate 81 and Pennsylvania Route 25 into the "Fisher Basin" area. There the stream crosses the Mammoth Vein strippings through a relocated stream channel which was constructed as part of the strip mining operations.

The mining engineer for that operation has said that the stream channel was constructed without special material by moving spoil materials back into the strip pit by bulldozer, and that no particular attempt was made to create an impervious channel through the Mammoth Vein Strippings. It is almost a certainty that water is lost to the Middle Creek Mine Pool via the streambed in this area. The geographical significance of this can be seen from the special plan "Underground Mine Water Pools Study Area and Vicinity" located in the back cover folder.

At present, the stream channel is very rough, being lined with rock of varying dimensions which has remained in place as the finer materials were washed out by the stream flow. Due to the condition of the stream channel in that area, it was impossible to install a weir or to make flow meter measurements.

From the "Fisher Basin" Middle Creek flows south, under Township Road 571, then in a southwesterly direction past the Indian Head Slush Dam where it is joined by Coal Run.

Continuing toward the southwest this stream is joined by the flow from Gebhard Run prior to its confluence with Good Spring Creek in Tremont.

Previously, the original channel of Middle Creek entered the north end of the area of silt deposits and flowed southerly across this area to a more direct connection with Gebhard Run. This area is now completely confined by the Indian Head Slush Dam which lies astride the original Middle Creek channel (west of the Indian Head Breaker). When Middle Creek flowed southerly into this area, for the most part, the water stagnated there, and eventually flowed into abandoned deep mine workings through an old air shaft. Flowing through the underground complex (Indian Head Mine Water Pool) the water reappeared at the surface through the main overflow point, an abandoned strip mine connected to the Marshfield Slope (Sampling Station C-37), and thence discharged into Coal Run.

In December 1966, the flow of Middle Creek was relocated to correct this condition by constructing a dozer compacted clay lined ditch through an abandoned strip pit. A new earth ditch was constructed between this point and existing Coal Run. Middle Creek now flows southwesterly parallel and directly adjacent to the north edge of the Indian Head Slush Dam, through the abandoned strip pit, thence to Coal Run. It is believed that water is lost to the Indian Head Mine Pool via the streambed in this area, although the relocated stream did achieve the objective of keeping the stream out of the main Indian Head Colliery area. (The west end of this relocated channel, beyond the Indian Head Slush Dam, was severely eroded by a severe flash flood in the Spring of 1970, and requires rehabilitation.)

This remedial project was designed by and completed under the supervision of the Pottsville Office of the Department of Environmental Resources.

Our Sampling Station MC-12, consisting of a 10 foot weir in the relocated section of Middle Creek (north of the Indian Head Slush Dam), was the major station used to determine water quality/ quantity prior to its confluence with Coal Run. Two additional sampling stations utilizing flow meters were located downstream in Middle Creek at the confluence of Coal and Gebhard Runs; however, with the exception of normal surface run-off, no other water was found to enter the stream between these stations.

The following data was recorded for the Middle Creek subwatershed during the study period:

Length of stream	4.4 miles
Total Drainage Area	2.7 square miles
Percent Total Study Area	18 percent Percent Total
Drainage Area disturbed by mining	19 percent Percent Total
Drainage Area disturbed by strip pits	9 percent

	FLOW - g.p.m.			ACID - Lbs/24 hours			IRON - Lbs/24 hours		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
(*)	15,742	0	2112	1,630	0	188	1,512	0	60

(*) Sampling Station MC-12 (weir).

During the water year acid concentrations of 0 to 14 mg/l and iron concentrations of from a trace to 8 mg/l were recorded.

It should be noted that except for periods during which mines were pumping water or following periods of rainfall, there was no flow in Middle Creek during the month of September, 1970.

This condition had not occurred previously during the study and, based on discussions with local residents, apparently was somewhat unusual.

Infiltrating surface and ground water is impounded in very extensive abandoned deep mine workings underlying much of this area of which the Middle Creek Mine Water Pool is the major mine pool. This mine water pool discharges from the abandoned workings through a trench created for that purpose, known as the "Tracy Overflow", (Sampling Station C-34), which is discussed at length elsewhere in this report.

While there was activity in the underground workings of the Middle Creek Colliery, the water level in the mine pool was maintained by pumping to the surface through the Middle Creek Shaft. The ground surface elevation at this shaft is 980±, while the bottom of the shaft lies at Elevation 195±, indicating a shaft depth of 785± feet. The elevation of the Middle Creek Mine Water Pool is measured by the elevation of water in this shaft (approximately 100± feet below the ground surface elevation at the shaft), since in the U. S. Bureau of Mines reports pumping was still in progress.

At the time of active mining the elevation of the mine pool was maintained at Elevation 798± by pumping from the shaft as mentioned previously. When the Middle Creek Colliery operations were abandoned, the mine water pool elevation raised and a new discharge was created through the "Tracy Overflow" at Elevation 885±. This corresponds approximately to the elevation of water in the Middle Creek shaft as noted above. In 1945, the Middle Creek Mine Water Pool contained an estimated 700 million gallons (U.S.B.M. estimate).

3. <u>Coal Run</u>

This stream originates from natural springs and surface runoff high on the southern slopes of Broad Mountain, approximately 2 miles due north of the Borough of Tremont.

At the beginning of this engineering study, these headwaters flowed south for a short distance and entered the abandoned Mammoth Vein strippings. This water then entered the abandoned deep mine workings through cropfalls and other openings in the strip pits and, after travelling a lengthy circuitous route, discharged to the surface as acid water at the "Tracy Overflow" (Sampling Station C-34).

The flow of Coal Run near its headwaters was diverted to correct this condition. This remedial project consisted of the installation of a 72 inch diameter half-round concrete flume, new ditches, strip pit backfilling, and the reconditioning of the stream bed. It was completed in April, 1970. The flow- is now carried through the flume across and through the strip mine area.

This remedial project was designed by and completed under the supervision of the Pottsville Office of the Department of Environmental Resources.

South of Township Road 571 this flow is joined by the highly acid discharge at Sampling Station C-34, the "Tracy Overflow", previously described. This is the overflow from the large Middle Creek Mine Water Pool.

Continuing downstream, the main flow is joined by water as measured at our Sampling Stations C-37 and C-38, representing the overflow from the Indian Head Mine Water Pool. Coal Run then joins the flow of Middle Creek at a point west of the Indian Head Slush Dam.

The following data was recorded for the Coal Run sub-watershed during the study period:

Length of stream	1.9 miles
Total Drainage Area	1.1 square miles
Percent Total Study Area	8 percent Percent Total
Drainage Area disturbed by mining	41 percent Percent Total
Drainage Area disturbed by strip pits	20 percent

During the water year acid concentrations of 44 to 180 mg/l and iron concentrations of from a trace to 17 mg/l were recorded.

In terms of acid and iron loads per day contributed to the Upper Swatara Creek Watershed, the water in Coal Run is by far the worst in the study area.

	FLOW - g.p.m.			ACID - Lbs/24 hours			IRON - Lbs/24 hours		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
(*)	8,164	888	2843	14,701	1279	4189	717	18	255

(*) Sampling Station C-39.

The water from Coal Run contributes approximately 50 percent of the average acid load per day produced within the study area.

As mentioned previously, the "Tracy Overflow" is the point of discharge for the Middle Creek Mine Water Pool, This overflow discharges through a trench resembling a strip pit, which was deliberately excavated to create a connection to the underground workings, thus drawing water off at a lower elevation and allowing removal of coal without excessive pumping. The mining company was then able to recover considerably more coal by maintaining the pool at the lower elevation. Mine water was discharged at this point during the water year of sampling at the average rate of 2471 g.p.m. and produced acid in the average amount of 4294 lbs/day.

This mine water pool is fed by innumerable sources of surface and ground water from points more than two miles distant from the point of discharge. It extends to the east, past Swatara Creek, and terminates on the west near Martins Run above Donaldson, a total length of 3.8 miles.

It is suspected that surface water is infiltrating to the Middle Creek Mine Water Pool outside the study area, through the streambed at the point where Swatara Creek flows through the Mammoth Vein strippings.

Mine water in this pool flows from east and west toward the "Tracy Overflow" discharge, therefore, even though some of the infiltrating water enters the pool outside the study area, it eventually all discharges into Coal Run and hence this watershed.

The Indian Head Mine Water Pool is relatively small by comparison with other pools in this area. Compared to its relative size it contributes quite significant quantities of acid mine water to the flow of Coal Run. However, it is still dwarfed in size compared to the Middle Creek Mine Pool which has on the average 12.5 times more acid contained in its overflow. The pool is long and narrow, lying in an east-west direction between the Village of Newtown and Coal Run, and is split into three fingerlike sections in the area of Coal Run. It has been stated by others that work was started to drive a tunnel between the two mine complexes (Middle Creek and Indian Heal).However, work was stopped while the tunnel was approximately 30 feet from holing through and this connection was never made.

The two points of overflow (Sampling Stations C-37 - Marshfield Slope and C-38 - Marshfield No.2 Outfall) from this mine water pool are located in abandoned strip mine pits and were monitored for quality/ quantity prior to discharging into Coal Run.

4. Bailey Run

This stream, like Coal Run, has its origin high on the southern slopes of Broad Mountain, approximately one mile north of Donaldson.

At the time of commencing this study, the headwaters of this stream flowed south for a short distance where they entered abandoned strip pits, eventually discharging to the surface as badly polluted water at the "Tracy Overflow" in the Coal Run sub-watershed,

The flow of this stream was diverted and prevented from entering these strip pits by completion of a remedial project in July, 1970. The project consisted of the installation of a 42 inch half round concrete flume, the construction of new ditches and the reconditioning of the existing stream channel. The flow is now carried through the flume and natural drainage course.

This remedial project was designed by and completed under the supervision of the Pottsville Office of the Department of Environmental Resources.

Water discharging from this sub-watershed enters Good Spring Creek at the south edge of Donaldson.

The following data was recorded for the Bailey Run sub-watershed during the study period:

Length of stream	0.7 mile
Total Drainage Area	0.4 square mile
Percent Total Study Area	3 percent
Percent Total Drainage Area disturbed by mining	44 percent
Percent Total Drainage Area disturbed by strip pits	26 percent

	FLOW - g.p.m.			ACID - Lbs/24 hours			IRON - Lbs/24 hours		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
(*)	500	30	140	120	0	32	9	Trace	2

(*) Sampling Station B-47.

Sampling Station B-47 was located in Bailey Run near its confluence with Good Spring Creek. During the water year acid concentrations in the range of 0 to 80 mg/l and iron concentrations of from a trace to 3 mg/l were recorded.

Sources producing a discharge include two active (pumping) deep mines, one abandoned deep mine with gravity discharge, and two abandoned strip pits with variable flows.

The discharge from Bailey Run can be considered to be comparatively good when compared to streams such as Coal Run and Gebhard Run.

The laboratory test results obtained over the period of the water year indicate that most of the sources of water are alternately alkaline - acid, although the total effluent from the sub-watershed is acidic.

5. Martins Run

The headwaters of Martins Run originate on the south slope of Broad Mountain due north of Donaldson and approximately one-half mile west of Bailey Run. As the water descends the mountain, it is joined by the water being discharged from the Mercury Coal Company's "Mercury Tunnel", an active mine. (Sampling Station MR-52).

Approximately l,000 feet south of this point, these waters enter a relatively small, abandoned strip pit through which they enter the Colket Mine complex. From this point the water flows eastward through the underground mines for a distance of 1-l/2 miles where it discharges to the surface through the "Tracy Overflow" in the Coal Run sub-watershed. Refer to the special plan "Underground Mine Water Pools Study Area and Vicinity" in the back cover folder.

A remedial project has been recommended later in the report which will divert water from the strip pits and into the natural stream channel south of the Colket Tunnel.

The abandoned Colket Water Level Tunnel is located l,000 feet t south of the above mentioned abandoned strip pit. This tunnel has been breached by the Mammoth Vein strippings, which has also resulted in a change in sub-surface drainage. On the east side of the tunnel, drainage originating north of the Mammoth Vein flows toward the east discharging at the "Tracy Overflow".

Water flowing from other workings, including those as far west as the Bowman - Coleman Water Level Tunnel, enters the Colket Mine Water Pool and eventually discharges through the Colket Water Level Tunnel, (Sampling Station MR-53). This discharge, supplemented by water pumped to the surface from the Colket Company's No.1 and No.2 Tracy Slopes, forms Martins Run which flows south under Pennsylvania Route 125 and joins Good Spring Creek in the village of Donaldson.

The following data was recorded in the Martins Run sub-watershed during the study period:

Length of stream	0.6 mile
Total Drainage Area	0.6 square mile
Percent Total Study Area	4 percent
Percent Total Drainage Area disturbed by mining	23 percent
Percent Total Drainage Area disturbed by strip pits	10 percent

	FLOW - g.p.m.			ACID - Lbs/24 hours			IRON - Lbs/24 hours		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
*	1,537	110	407	480	8	108	231	2	23
**	1,835	241	491	1983	(-243)	382	253	13	90
***	2,089	468	719	1304	31	354	529	5	134

* Sampling Station MR-52 - "Mercury Tunnel".
** Sampling Station MR-53 - "Colket Tunnel".
*** Sampling Station MR-55 - Combined water from Colket Tunnel and that pumped to surface from Colket Coal Company No.1 and No.2 Tracy Slopes.

As mentioned previously, the flow at Sampling Station MR-52 now enters the underground mine complex through an abandoned strip pit, while the flow at Sampling Station MR-55 represents the total flow entering Good Spring Creek at Donaldson.

The Colket Mine Water Pool, containing an estimated 513,000,000 gallons of water, underlies an area north of Donaldson. This area, lying in a general east-west band, consists of the inundated deep mine workings between a point slightly east of Martins Run to Barrier Pillar XIX, some 8,000 feet to the west near the Bowman - Coleman Water Level Tunnel.

Mine water in this pool flows from both east and west, discharging to the surface through the Colket Tunnel.

During the water year, acid concentrations of 4 to 74 mg/l and iron concentrations of from a trace to 67 mg/l were recorded for water in Martins Run entering Good Spring Creek.

6. Good Spring Creek

Good Spring Creek originated in two abandoned strip pits, (Sampling Stations GS-100 and GS-101), approximately 1/2 mile south of the Village of Good Spring. Recently the strips were pumped down and the area between them stripped forming a single stripping. These strip pits very likely will eventually again fill and discharge at a point near Sampling Station GS-100. This water flows northeastward to Good Spring, thence easterly through Donaldson where it is joined by Martins Run and Bailey Run. Continuing southeastward, Good Spring Creek is joined by Middle Creek in Tremont, finally discharging into Swatara Creek approximately l/2 mile south of Tremont and some 7 miles from its source.

The valley through which this stream passes is well defined topographically, especially between Good Spring and Donaldson. In that area the stream channel closely approximates the axis of the Donaldson Syncline whose flanks rise north and south.

A total of 78 sources of potentially acid water were sampled in this sub-watershed during the course of the study. In certain cases the source of water proved to be alkaline and sampling was discontinued; however, in the majority of cases, the water was acidic and a program of continued sampling was established.

The major sources of acid mine drainage in the Good Spring Creek sub-watershed consist of discharges from what is known as the "Good Spring Tracy Airhole" (Sampling Station GS-95) and an abandoned Orchard Vein stripping (Sampling Station GS-119-A), along with AMD from the Donaldson, Westwood and PenAg refuse banks. All these sources of pollution are discussed in detail later.

The following data was recorded for the Good Spring Creek sub-watershed during the study period:

Length of stream	7.1 miles
Total Drainage Area	7.5 square miles
Percent Total Study Area	50 percent
Percent Total Drainage Area disturbed by mining	37 percent
Percent Total Drainage Area disturbed by strip pits	18 percent

(<u>NOTE</u>: Summary above includes Poplar Creek and Hollenbach Run sub-watersheds which are discussed later in this section).

FLOW - g.p.m.			ACID - Lbs/24 hours			IRON - Lbs/24 hours		
Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
* 13,536	1,052	5,303	3,647	303	1,894	2,437	32	298
**124,900	2,787	16,024	50,979	553	8,962	10,870	48	953

* Sampling Station GS-68 - on Good Spring Creek above its confluence with Middle Creek.

** Sampling Station GS-61 - represents total water discharging from project area.

During the water year, acid concentrations of 4 to 120 mg/l and iron concentrations of from a trace to 8.5 mg/l were recorded at Sampling Station GS-61.

As mentioned previously, the preceding data includes the Poplar Creek sub-watershed. This sub-watershed, although representing some 16 percent of the total study area, is the least disturbed and does not produce an acid discharge through Poplar Creek. Poplar Creek is located some 500 feet to 1000 feet south of and generally parallel with U. S. Route 209, southwest of Tremont.

A series of three small reservoirs, designated the Upper, Middle and Lower, are located in this sub-watershed and were sampled as necessary to determine the quality of water passing through them.

All water tested from the Poplar Creek Reservoirs contained from 8 to 40 mg/l alkalinity with pH values in the range of 5.5 to 6.7, averaging greater than 6. Once the quality of the water had been established, sampling was discontinued.

Relatively small areas of strippings are located near the upper reaches and along portions of the ridges to the north and south of this sub-watershed; however, the quantity of acidic water which could possibly be produced in this area is considered to be negligible, based on sampling data.

Hollenbach Run is also a minor tributary to Good Spring Creek. It is located some 1500 to 2,000 feet north of and generally parallel with U.S. Route 209, west of Tremont. The major sampling station was Sampling Station GS-106. The water quality and possible sources of this acid are discussed fully in Section VI-B "Recommended Abatement Measures".

The "Good Spring Tracy Airhole", identified as Sampling Station GS-95, is the largest single source of acid mine drainage in the Good

Spring Creek sub-watershed and represents the overflow from the Good Spring No.3 Mine Water Pool. This overflow has many sources of water, including those as far removed as the regraded strip pits in the Lykens Valley Nos.2, 4 and 5 Veins outcropping near the crest on the south slope of Broad Mountain. This regrading is negated for the lack of a minimal amount of maintenance required at several cropfalls where drainage is lost. Water infiltrating through these strip pits enters a large deep mine complex (abandoned in 1966) of the PenAg Coal Company. This mine is connected by a north-south underground tunnel to the vast workings of the Philadelphia and Reading Coal and Iron Company (early 1900's) which forms the Good Spring No.3 Mine Water Pool. This pool contains an estimated 471,000,000 gallons of water and lies between Barrier Pillars XIX and XXIV. These pillars separate it from the Colket Pool to the east and the Good Spring No.l Pool to the west. The water then travels a circuitous route through the pool, discharging to the surface some 1500 feet west of Interstate 81 and just north of Route 125 through a Tracy Vein Airhole. This airhole lies on a south dip of 57°, (Sampling Station GS-95). The acidic water thus discharged flows under Route 125 to join Good Spring Creek.

A high flow of 5,567 g.p.m. and an average flow of l,758 g.p.m. were recorded at Sampling Station GS-95 during the water year. This flow contributed an average of 794 lbs/24 hours of acid to Good Spring Creek.

There is also a small active mine in this area in the Buck Mountain Vein (Broad Mountain), the Senawaitis Brothers Coal Company.

The volume of flow from this station is highly variable on occasion. During one 4 hour period, the recorded flow varied between 101 to 1914 g.p.m. for no apparent reason, and fluctuations of this magnitude were recorded on subsequent occasions. It can only be presumed that some temporary blockage of the underground drainage system creates this condition, whereby the flow is restricted to the point where hydrostatic pressure "blows out" the obstacle and the rate of flow increases then stabilizes.

Interstate 81 traverses the end of an abandoned Orchard Vein strip pit on the north dip approximately 2,000 feet south of Route 125. This abandoned pit along with several other strip pits is discharging considerable acidic water and has been monitored at our Sampling Station GS-119-A. The water being discharged from this pit is supplemented by acidic water flowing through the western face of the 1-81 roadway cut immediately south of the abandoned strip pit.

This water discharging from the roadway cut face is apparently ground water flowing along the axis of the eastwardly plunging Tremont

Syncline. The folds of this syncline are clearly apparent when viewed from 1-81. In all likelihood the normal ground water is supplemented by general seepage and runoff from the east slopes of the large Westwood Colliery Refuse Bank (31 acres and 3,670,000 cu. yds.) and from adjacent water filled strip pits lying slightly to the west of Interstate 81.

The Westwood Slush Dams lie slightly north of and west of the Westwood Refuse Bank. Acidic runoff from the north and east slopes of the Westwood Slush Dam also contributes AND to the abandoned Orchard Vein stripping and others previously mentioned.

Travelling through the dark shales and coals in the syncline the water discharges through the exposed highway cut and flows northward through the roadway drainage swale ditch for some 700 feet where it joins the drainage from the Orchard Vein strip pit (previously discussed). This water then travels eastward, underneath the Interstate 81 roadway, and thence through the weir at Sampling Station GS-119A.

Runoff from the south and west slopes of the Westwood Refuse Bank and Westwood Slush Dams enters the Lower Rausch Creek watershed, under study by others.

The abandoned Westwood Deep Mine Complex had its main discharge at the south end of the north-south oriented "Main Tunnel". This discharge was the main headwaters of Lower Rausch Creek. However, present stripping operations in the area have included pumping down the water level in the mine so that this discharge at the portal does not occur. The north end of this tunnel is connected by an airway to the Orchard Vein and could have been a secondary discharge. Mining engineers have indicated that there was reportedly quite a flow from the Orchard Vein Stripping at the time the vein was stripped.However, now that the area has been pumped down for new stripping the flow from the old Orchard Vein Stripping is still sustained, indicating that the deep mine overflow was not the major source of AND. The Westwood Refuse Bank and Westwood Slush Dam runoff, along with the acid formed in the fractured synclinal structure could explain the high degree of acid measured at Sampling Station GS-119A. The flow is also a rather sustained flow which further supports this supposition.

An attempt has recently been made (Summer - 1971) to plant the slopes of the Westwood Refuse Bank lying adjacent to 1-81. This was a joint project of the Department of Environmental Resources and The Pennsylvania State University. The results of this experiment do not appear promising, but if it or another method of surface stabilization can be made feasible, it may considerably reduce the periodic flush-out of acidic water from the mantle (estimated 70 percent of total acid as runoff and 30 percent from interior of pile).

Besides its negative environmental effects (adjacent to 1-81) and AMD production, the Westwood Refuse Bank also creates a considerable air pollution problem due to its exposed location on the top of a ridge.

A maximum flow of 1,195 g.p.m. and an average flow of 415 g.p.m. was recorded at this sampling station during the water year. This flow produced an average of 319 lbs/24 hours of acid entering Good Spring Creek.

Good Spring Creek also attains additional acidity as it passes directly adjacent to a number of smaller silt banks (total of 21.9 acres and 946,000 cu, yds.) lying along its northern bank and, somewhat further upstream from the large Donaldson Slush Dam (47.9 acres and l,804,000 cu. yds.) along its southern bank.

I. WATER QUALITY CRITERIA

Pennsylvania's "Clean Streams Law" has recognized, by declaration, that clean, unpolluted streams are absolutely essential if the State is to attract new industries and tourists and if future generations of Pennsylvanians are to be provided with adequate outdoor recreational facilities.

The objective of this Law is not only to prevent further pollution of the waters of the Commonwealth but to restore every polluted stream in Pennsylvania to a clean, unpolluted condition.

In the Anthracite Region, due to severe folding, numerous coal veins often outcrop within a relatively small area.

With reference to water quality it is recognized that the streams in the "Coal Region" traversing these outcrops have always been "polluted" to a degree by the introduction of acid, iron, sulfates, etc to the streams as the result of natural weathering processes acting upon the exposed coal outcrops. In addition, much of the area is composed of plunging (tilting) anticlines/synclines which facilitate the movement of ground water along the coal veins and thus provide a condition conducive to acid formation.

The "Cleam Streams Law" recognizes that an inherent degree of pollution has existed and provides that a "Board" shall determine when a discharge constitutes pollution.

With regard to water quality limitations on mine drainage discharges from active mines, Article 900, Section 6, "Rules and Regulations" of the former Sanitary Water Board states:

A. (amended October 19, 1966) There shall be no discharge of mine drainage which is acid.

B. There shall be no discharges of mine drainage containing a concentration of iron in excess of seven milligrams per liter.

C. The pH of discharges of mine drainage shall be maintained between 6.0 and 9.0."

With respect to the streams themselves the Sanitary Water Board acting under authority as granted them by the Clean Streams Law, has established general and specific water quality criteria for the waters of the Commonwealth, which are included in "Rules and Regulations, Article 301 - Water Quality Criteria", as amended. This Article establishes the following water quality criteria for the Swatara Creek Basin from the "Source to but not including Swatara Gap Reservoir and including all tributaries named and un-named" -

pH - Not less than 6.0; not to exceed 8.5
Total Iron - Not to exceed 15 mg/l
Alkalinity - Not less than 20 mg/l
Sulfate - Not to exceed 250 mg/l or natural levels, whichever is greater

In addition to the preceding and other items, this criteria also establishes that these waters shall be satisfactory for "Cold Water Fishes - Maintenance and propagation of the family Salmonidae and fish food organisms".

In August, 1969, the former Department of Forests and Waters announced the proposed acquisition of approximately 3,900 acres of land in Lebanon and Schuylkill Counties, along Swatara Creek, for the development of a State Park and a water supply reservoir. The proposed park would contain a multipurpose lake of approximately 100 acres for recreation and water supply. The dam would be located near Greenpoint at the north end of Swatara Gap.

This announcement pointed out that "The actual construction of the dam might be delayed as long as ten years in order to carry out water pollution control projects in the watershed to ensure satisfactory water quality. As a result the major park development will be delayed until the reservoir is constructed".

The Water Quality Criteria for streams within this study area is essentially the same as that for the proposed reservoir. Therefore, to satisfy the present Criteria, it is essential that water discharged from the Upper Swatara Creek Watershed be of such quality as to preclude the possibility of polluting the downstream impoundment area. In addition when treatment may be required consideration should be given to complete treatment rather than neutralization only, in view of the possibility that some of the precipitates may be deposited within the impoundment area, requiring abnormally high maintenance.

J. WATER PUMPED FROM MINES

The anthracite industry is confronted with a crucial problem of excessive water in the mine workings. In the study area this water comes from two sources. Many of the abandoned workings and reserves are inundated by water impounded in underground pools and most areas receive water by infiltration from streams and surface runoff into strip pits, crop falls, etc.

Throughout the history of anthracite mining the problem of water in the workings has become progressively more difficult and costly to handle. Deeper underground workings and stripping of the croplines which exposed the lower workings were both conducive to the creation of the present day condition.

Generally, mine water in this area is discharged to the surface as follows: (a) Pumping, (b) Water level drainage tunnels, (c) Combination of pumping and drainage tunnels, (d) Overflows from mine pools through strip pits and other openings connected to the underground workings.

Nine active and one inactive deep mine contributed water by pumping to the surface during the study period. Water from these mines was acidic with the exception of the Starr and Williamson Mine which consistently produced an alkaline water.

The following tabulation lists all of the mines which were pumped at one time or another throughout the study period:

Sampling Station	Mine Name	Pumping Hours/Day	Pumping Days/Week	Pump Capacity (G.P.M.)	Remarks
MC-3	Miller	9	2	450	Pumped
MC-8	Hatter	10	7	450	Pumped
MC-11	Renninger	1/2	-	-	Pumped + Gravity
G-22	Federovich	2	7	300	Pumped
B-43	Wolfgang Bros.	1	7	200	Pumped
B-44	Herring Bros.	2	6	350	Pumped
MR-52	Mercury	6	6	200	Pumped + Gravity
MR-54	Colket	2	7	300	Pumped
GS-91	Starr & Williamson	2-1/2	7	250	Pumped
GS-99	Senawaitis Bros.	1	7	300	Pumped

NOTES:

l. Mines at Sampling Stations MC-11 and MR-52 discharge water to surface through water level tunnels. All the others are slope mines.

2.Mine at Sampling Station MC-11 (Renninger) - mining was discontinued here in June, 1970; however the tunnel continues to discharge acidic water by gravity.

It is doubtful whether a direct correlation between precipitation and the volume of water discharged from a mine can be made. With regard to this relationship the U.S. Bureau of Mines has stated: "The volume of water pumped to the surface from the anthracite mines depends on so many factors that it is impossible to ascertain definite relationship between precipitation and volume of water pumped." However, in Section VI - Abatement Measures a further discussion on the active mines is given, including minimum, maximum and average acid loads contained in the mine water discharges.