RECOMMENDATIONS

The program of acid mine drainage control designated for theDeer Creek Watershed is based on source abatement. It is felt that the necessity to reducethe pollution potential of the source to completely erase the contaminating agent is the most efficient and economical means of controlling acid mine drainage.

The chemical treatment of acid mine drainage was not considered atthis time. The treatment process assures almost 100% neutralization of pollution; however, the operation and maintenance of a treatment facility is continuous and expensive. It is felt that the following source abatement measures are the most cost-effective means of permanently eliminating the sources of acid mine drainage from the Deer Creek Watershed. This approach places emphasis on eliminating the cause of the pollution rather than controlling the end result.

The following pollution abatement measures have been recommended for implementation in the Deer Creek Watershed. The methods have proven to be succesful for various projects designed to control or abate acid mine drainage. It is recommended that following the implementation of abatement measures, that theseareas be monitored and evaluated to. determine tile effectiveness of the completed work.

SURFACE MINE RECLAMATION

This work involves the regrading, backfillng, contouring, and the soil treatment and planting of abandoned surface or "strip" mined land. Overall, this measure is considered to be the most important abatement method recommended for the Deer Creek Watershed.

The reclamation work could include only the regrading and contouring ofminimally disturbed surface mined land. Where highwalls are exposed, however,and large spoil piles exist, this would require the complete backfilling of the siteto its original contour or a terrace type grading pattern.

Backfilling to original contour essentially restores the affected land to the state prior to when it was mined. Terrace backfilling is the method bywhich the spoil material is graded into benches thus promoting the rapid expedition of runoff. Both techniques utilize slopes that are designed to controlthe damaging affects of soil erosion and subsequent sedimentation.

The spoil material in the Deer Creek Watershed, for the most part, is very permeable and potentially acid producing. Therefore, special surface compaction may be specified for certain areas to prevent the percolation of runoff into the subsurface.

Immediately following backfilling procedures, the land will receive soil treatment and planting. Representative samples are taken of the material on the final-graded surface and are subjected to a complete soil analysis. The testing. determines the optimum. amount of soil treatment necessary to achieve the desired vegetation.

The soil, treatment, and planting phase of surface mine reclamation is crucial to maintaining the integrity of the reclaimed surface mine. The vegetation prohibits soil erosion and its subsequent sedimentation. A large quantity of surface water entering the reclaimed land is absorbed by the root system. This prohibits the water from permeating potentially acid producing spoil and polluting groundwater supplies. It also provides an aesthetically appealing appearance to the completed restoration work.

SURFACE WATER MANAGEMENT

This method directs the rapid removal of surface water runoff on or around reclaimed surface mined areas. This is done to prevent recharge to potentially acid producing material of restored strip mined areas. This reclam-ation measure is an integral part of surface mine reclamation recommended for various areas of the Deer Creek Watershed. Surface water management includes diversion ditches, lined channels or flumes and the reconstruction and/or re location of existing stream channels: Diversion ditches installed up-slope of the affected area are used to divert surface water around and away from the reclaimed mine site. Ditches located on the reclamation area are used to collect surface water and rapidly direct it into interceptor channels. These ditches are frequently used on terrace and are usually lined with impervious material to prevent percolation into the spoil. All ditches are grass lined and are constructed to slopes ranging from 1% to 2%. Interceptor channels accept and direct the diversion ditch flow over the reclaimed land for disposal into existing watercourses. They are lined with impervious material. Since the channels are usually installed on steeper grades, they are usually protected with a riprap lining or temporary jute matting for vegetation. The high exit velocities are dissipated by flared riprap discharge aprons at the end of the channels.

In areas where a stream enters strip mined land, the stream channel may be lined or relocated as necessary to prevent the water from flowing on or through acid producing material.

IMPERVIOUS COVER

Impervious covering over reclaimed strip mined land prevents surface water infiltration into acid producing spoil. Materials utilized include gels that form an impervious soil layer and natural impervious material (clay) compacted to a certain soil density. The latter method is dependent upon the relative proximity of natural impervious material to the abatement area.

An experimental project is presently being conducted on a large strip mine in the Toby Creek (SL 191) Watershed to determine, the most effective means of achieving impervious cover.

DEEP MINE SEALING

This method prevents the lateral discharge of acid mine drainage from openings of abandoned deep mines. The basic objective is to completely flood the deep mine workings, thereby prohibiting the contact of oxygen with sulphuric material and thus preventing the formation of acid mine drainage. All known deep mine entries within the watershed are caved and inaccessible. Therefore, it is recommended that those portals designated for closure be sealed by the remote method of deep mine sealing.

The procedure consists of drilling a series of bore holes into the mine entry and placing aggregate through the holes to form front and rear bulkheads. The cavity separating the two is filled with concrete in the same manner. A series of holes is then drilled perpendicular to the mine seal. The strata is pressure grouted to a predetermined height sufficient to flood the mind. An observation hole is then drilled into the mine to monitor water levels in the mine. All mine openings of a deep mine complex must be sealed in this manner is the inundation is to be successful.

Frequently, deep mines are intercepted by strip mine activities performed on its outcrop. This reduces the structural integrity of the outcrop barrier to contain a mine pool in the deep mine workings. Therefore, impervious barriers are required in this instance.

The successful sealing of a deep mine requires considerable knowledge of its structural geology, extent of mined-out areas, character of adjacent strata, and location of portals. Often times exploratory drilling is required to ascertain this information.

IMPERVIOUS BARRIERS

The purpose of these abatement methods is to contain the water table imposed by the flooding of a mine complex or to prohibit the seepage along the outcrop of strip mines. These measures include curtain grouting, clay packing, slurrytrench, and clay blanketing.

The construction of a grout curtain involves drilling a line of holes in undisturbed material to a depth below the coal measure. The grout can be a combination or a mixture of materials such as cement, fly ash, and bentonite, etc. The grout is pumped under pressure into the substrata, filling voids and fractures in the rock strata. This grout curtain forms a perched water table to a predetermined, height which in turn, inundates the coal measure. The most practical use of curtain grouting is in conjunction with the deep mine sealing procedure.

Clay packing is recommended many times in conjunction with strip mine reclamation. Its purpose is to form an impervious barrier to prevent seepage along the stripped-outcrop of a surface mine. The material utilized is frequently the clay found under the stripped out coal seam. Clay is compacted along the toe and up over reclaimed spoil for a short distance.

The construction of a slurry trench involves the excavation of a trench into which a clay bentonite slurry is pumped. The excavation extends to a short depth below the coal measure. As the digging continues, the excavated material is mixed with the slurry and is backfilled into the trench. The end result is an impervious barrier constructed to a height sufficient to inundate the coal measure or mine workings. The trench is generally installed along a strip mine intercepting the outcrop of a deep mine complex. The trench must be excavated in unconsolidated material. The general procedure is to backfill the strip mine to provide a bench for the excavation, of the slurry trench. Upon its completion, the backfilling of the strip mine proceeds to the final grade line.

The construction of a clay blanket is installed along a strip mine intercepting the outcrop of a deep mine complex. A clay blanket requires the excavation of a trench to a depth below the coal measure. Clay is placed in the trench and compacted in layers to an elevation necessary to inundate the coal measure. The remainder of the trench is filled and compacted with layers of fine grained spoil material. The top of the clay blanket is backfilled to a final grade line. Sufficient natural impervious material must be available near the job site for the use of this method to be economical. This method is not recommended where larg quantities of water may be expected to enter the excavation.

COAL REFUSE DISPOSAL AND MANAGE

The measures recommended in this section relate to the disposition of coal refuse from active and non-active mining operations. Coal refuse from abandoned deep mines is not considered to be a major source of pollution to the Deer Creek Watershed. The limited extent of deep mining in the area was such to preclude the formation of large gob piles. It is, however, recommended that refuse piles located within the proposed abatement areas be properly disposed of. When abandoned strip mines are in close proximity to the refuse sites, the waste material is excavated and transported to the strip-mine for burial.

When refuse sites are isolated from potential burial sites, the material is spread and graded at the site. The material is then disced with limestone screenings where it receives a final earth covering with soil treatment and planting.

Coal refuse is presently being generated from coal processing facilities located within the watershed. They are discussed further in the proposed abatement portion of this report. It is felt that any pollution discharged into the watershed from these sites and the responsibility for corrective actions rests solely with the owners of such facilities.

Methods to prevent pollution from these sources would include diversion ditches constructed upslope of tipples and storage areas. This would serve to channel water away from the sites and would not need treatment. In addition, ditches should be constructed down slope of the facilities to capture all runoff at the site. This flow would be directed into a series of settling and treatment ponds before being released in the watershed.

GAS AND OIL WELL PLUGGING

The abatement of acid mine drainage from abandoned oil and gas wells consists of a) locating the source (old casing) by excavation, b) reaming the well to a predetermined depth or acquifer source, c) grouting the hole to a certain depth and, d) plugging the remainder of the hole with concrete. Large quantities of acid mine drainage are discharged to the Deer Creek Watershed from these sources.

In 1975, various abandoned oil and gas wells discharging acid mine drainage were sealed under Department of Environmental Resources Contract No. AWSP 16:2 in the Upper Paint Creek Watershed. A total of 12 wells were plugged, many of which were previously monitored by this study from 1973 to 1974. After the sealing work had been completed, Gwin, Dobson & Foreman, Inc. performed an evaluation of the abatement measures. The program was felt to be 75 percent effective with an estimated average of 1,000 to 1,200 pounds per day of acidity removed from the watershed. (The wells located in a project area are discussed in more detail.) This would indicate that sealing of flowing oil or gas wells is a viable means of abating acid mine drainage from these sources. This abatement measure is a key component of the abatement plan proposed for the watershed.

EXPLORATORY DRILLING

This phase is not considered a physical abatement of acid mine drainage. The information gather during exploratory drilling operations, however, is essential for the engineering design of abatement facilities. It is included as an integral part of the overall abatement plan recommended for certain project areas.

Exploratory drilling is utilized for a) determining structural geology of a particular mining site relative to attitude of beds, outcrop determination fault displacement, etc., b) determining the stratigraphic relationships of a mining site (rock types, thickness of coal bed, presence of under clay), c) pressure testing strata adjacent to deep mine workings, d) determining permeability of, strip mine overburden or spoil, and e) ascertaining relationships between groundwater sources and mining sites relative to location and quality of acquifers and recharge of isolated springs and wells.

GEOLOGY

GENERAL

The geological information utilized builds upon the limited information contained in previously published geological reports. Many of these reports are over 75 years old during which time considerable mining activity has taken place. The mining operations may or may not confirm previous investigations. The geology of the watershed is complex and highly variable; however, the extensive field work required for identifying sources of acid mine drainage has provided some additional data on the geology of the watershed. It is felt that the geology as described in this report is adequate for the purposes of defining the subsurface conditions relative to the acid mine drainage problem. The Deer Creek Watershed is underlain by up to 12,000 feet of sedimentary rocks dating back 540 million years to early Cambrian times. The region at that time was occupied by a vast inland sea. During this period, of. time, the present rocks were laid down as sediments. The typed of sediment, varied with changing conditions so that a succession of shale, limestone, sandstone, coal and clay beds gradually accumulated and subsided. At sea level, extensive swamps developed in which large quantities of vegetable matter accumulated and gradually subsided. These deposits were covered with more sediments. This cycle continued for many eras and has resulted in the rocks presently exposed in the watershed.

Some 200 million years ago, a tremendous uplift of the earth's crust occurred from Alabama to New York. The forces were directed from the southeast and lifted the accumulated sediments above sea level. The sediments were severely folded in eastern Pennsylvania, but gentle folding occurred in the western part of the state. This area has since been above sea level and subject to the erosional processes of weathering and stream action.

Immediately following the uplift, erosional forces reduced the area surrounding the watershed to a region of broad hills and valleys. This surface is known as a peneplane. The remnants of such a condition exist to this day in that the hilltops in the area are nearly at the same level or elevation.

Due to a gradual uplift of the region, the streams have undergone a minor rejuvenation. This has increased the gradient of the stream and subsequently increased their ability to erode the underlying strata. The results of this rejuvenation were the steepening of the stream valleys with an associated lengthening of the streams to their present state.

The topography of the Deer Creek Watershed is characterized by steep, rugged valleys and broad, flat hilltops. The lower valley of Deer Creek near the mouth is steep sided and narrow while the upper reaches are broader and wider. The steepness near the lower end is apparently due to the outcropping of the rocks from the Mississipian period and the Pottsville Formation of the Pennsylvanian Period. These rocks are predominantly massive sandstone and are more resistant to weathering and erosion processes. The broad, hilltop cap rocks of the watershed consist of shale, sandstone, coal, and clay of the Allegheny Formation.

The gradient of Deer Creek averages 27 feet per mile with a slightly steepening gradient approaching the stream mouth. This relatively steep gradient and resulting high velocity of the stream prevents the accumulation of the iron precipitates (yellow boy, etc.) in the stream bed.

The drainage system of Deer Creek is dendritic in nature. This affect resembles the branching of a deciduous tree. This is due to the underlying bedrock (sandstones of Pottsville Formation) which is uniform in its resistance to erosion and has no control over the direction of valley development or drainage.

REGIONAL STRATIGRAPHY

The, exposed rocks of the Deer Creek Watershed are sedimentary in nature and belong to the Mississippian and Pennsylvania series of the Carboniferous system. The deeper stream valleys contain recent alluvium deposited during the Quarternary Period. The exposed rocks are underlain by a great thickness of sedimentary rocks. Information of these rocks has been gathered solely from a study of bore hole records of oil and gas wells. The rocks penetrated by these wells are believed to be portions of the Portage, Chemung and Catskill Formation of the Devonian system and a part of the Mississippian series of the Carboniferous system. A discussion of the exposed strata of the Deer Creek Watershed follows.

PENNSYLVANIAN SYSTEM

The Pennsylvanian system contains the principal coal bearing formations of the State. The rocks range in age from 270 to 325 million years old. They make up virtually the entire surface exposure of the Deer Creek Watershed. Deposited in near-shore marine or continental environments in the north central part of the Appalachian basin, these rocks consist of interbedded shale, sandstone, siltstone, limestone, clay and coal beds. (See generalized stratigraphic column, page 19.) The system has been subdivided into four groups, named from the oldest: Monongahela, Conemaugh, Allegheny, and Pottsville. The Monongahela, Conemaugh groups and the upper portion of the Allegheny group have been eroded or represent a hiatus in the Deer Creek Watershed. A discussion of the remaining portion of the Allegheny and Pottsville groups follows.

ALLEGHENY GROUP

The Allegheny group includes all rock between the top of the Upper Freeport coal seam to the base of the clay beneath the Brookville coal. It is composed of sandstones and shales, interbedded with minor amounts (volumetrically) of coal, clay, and Limestone. The Allegheny group has divided into three formations Freeport, Kittanning and Clarion. The Freeport formation and the upper portion of the Kittanning formation are not present in the watershed. The portion of the Allegheny group present in the watershed attains a maximum thickness of Kittanning Formation

The Kittanning formation extends from the top of the Upper Kittanning coal seam to the base of the clay under the Lower Kittanning coal. In the Deer Creek Watershed, only the shale above the Middle Kittanning coal is present and that being in isolated hilltops south of the Clarion Junction. The Lower Kittanning coal ranges from 3 to 4 feet in thickness and is considered to be, in terms of quality, the most valuable seam of coal in the watershed. Great quantities of coal, however, have been removed by erosion and the remaining reserves have essentially been mined out. The seam reached its greatest development south of Clarion Junction and north of Haynie where it was strip mined. Varying qualities of plastic and flint clay underlie the coal seam with thicknesses ranging from 3 to 8 feet.

Clarion Formation

The Clarion formation extends from the base of the Kittanning Formation to the base of the Brookville underclay. This formation contains nearly all of the mineable coals in the watershed. It consists of interbedded sandstone, siltstone, shale, clay, coal, and limestone. The principal mineral resources of the formation, in descending order, include: Vanport limestone, Upper Clarion coal, Lower Clarion coal, and the Brookville coal.

The interval between the Lower Kittanning clay and the Vanport limestone generally consists of coarse grained sandstone occasionally interbedded with shale or siltstone. The Vanport limestone, a persistent bed in western Pennsylvania, has been rarely observed in the Deer Creek Watershed. It is believed to have only spotty occurrence and has attained a thickness at most of eight feet. Immediately above the limestone is a layer of iron ore several inches in thickness. Iron furnaces west of Marianne and in Huefner utilized the iron ore and limestone from this member. In a large area of the watershed where the Vanport limestone is absent, the interval between the Lower Kittanning and Clarion coals is occupied by a massive coarse grained sandstone and dark shale.

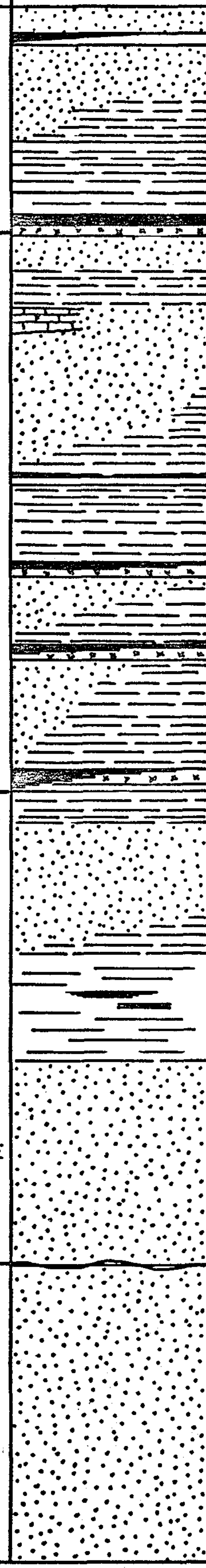
The absence of the Vanport limestone has major implications relative to the acid mine drainage conditions in the watershed. Groundwater quality in the acquifers normally associated with the Vanport limestone is of a highly alkaline nature. Intermixing of these waters (when present) with acid mine drainage neutralizes the acidity of the water and, in essence, acts as a buffering agent. Since the Deer Creek Watershed contains *very* little limestone, natural renovation of acid mine drainage is virtually non-existant. Without this renovation, it is not known whether the streams within the watershed can ever become totally non-acidic.

The Clarion coals have both been extensively mined in the watershed. Neither of the coals are entirely persistent, with one or the other frequently missing. Thus, seam identification has been difficult. Both Clarion coals are sulphurous, carry one or more binders and contain high ash contents. The Upper Clarion coal varies in thickness from 6 to 36 inches. This is separated by the Lower Clarion coal by approximately 20 feet of shale. The Lower Clarion ranges from 18 to 42 inches in thickness. Both seams are underlain by plastic clay, 3 to 10 feet in thickness. The coals have been extensively deep mined on the western water shed perimeter between Lucinda and Arthurs and in the central portion east of Millerstown. Strip mines have removed the coals on the broad hilltops anywhere high enough to hold the coal and where little overburden was encountered. A considerable quantity of the mineable Clarion coals has been exhausted in the watershed.

The interval between the Lower Clarion coal and the Brookville coal is separated by up to 70 feet of shale with occasional interbeds of sandstone. The Brookville coal seam averages 4z feet in thickness and is locally 7 feet thick. It has a high sulphur and ash content and contains thick partings of shale and

GENERALIZED STRATIGRAPHIC COLUMN OF EXPOSED ROCKS
DEER CREEK WATERSHED
SL 193

SYSTEM GROUP	FORMATION	MEMBER	SECTION	CHARACTER OF MEMBER
PENNSYLVANIAN	KITTANNING	MIDDLE KITTANNING COAL		
		LOWER KITTANNING COAL		PERSISTENT, AVG. THICKNESS 2-4 FT. UNDERLAIN BY FLINT CLAY (3-8 FT.)
	ALLEGHENY	VANPORT LIMESTONE		MOSTLY ABSENT IN WATERSHED OVERLAIN BY IRON ORE BED 0-1 FT. THICK OFTEN REPLACED BY MASSIVE SANDROCK OR SHALE
		CLARION RIDER COAL (SCRUBGRASS COAL?)		THIN, PERSISTENT, AVG. THICKNESS 0-1 FT.
		UPPER CLARION COAL		FAIRLY PERSISTENT, VARIABLE THICK. .5-3 FT.
		LOWER CLARION COAL		FAIRLY PERSISTENT, VARIABLE THICK. 1.5-4 FT. UNDERLAIN BY CLAY (3-10 FT)
		BROOKVILLE COAL		FAIRLY PERSISTENT, VARIABLE THICK. 2-5 FT. UNDERLAIN BY CLAY-3 FT THICK PARTINGS
	POTTSVILLE	HOMEWOOD SANDSTONE		MASSIVE, PERSISTENT, FINE GRAINED
		MERCER SHALE		INTERBEDDED BY OCCASSIONAL APPEARANCE OF MERCER COAL
		CONNOQUENESSING SANDSTONE		OFTEN MASSIVE, FINE GRAINED
				UNCONFORMITY AT BASE, MAUCH CHUNK FORMATION REMOVED BY EROSION
MISSISSIPPIAN	POCONO	BURGOON SANDSTONE		MASSIVE, CROSS BEDDED



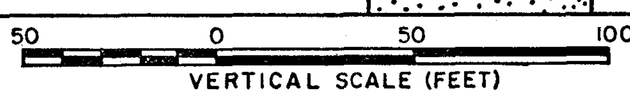


FIG. 2

pyrite. It is underlain by up to 10 feet of variable quality clay. Relatively little mining has been done on the Brookville coal due, in part, to the poor quality of the coal and the high level of activity on the Clarion coals; however, there are probably large, unproven reserves of Brookville coal remaining in the watershed and, therefore, some potential exists for future development.

POTTSVILLE GROUP

The Pottsville group extends from the bottom of the Brookville underclay to the. base of the Connoquenessing sandstone. It consists of thick bedded resistant sandstones with thin, lenses of shale and coal. It attains a maximum thickness of 130 feet in the watershed. The rocks of the Pottsville group form the hillsides and valleys of the watershed area. It consists of the following formations in descending order: Homewood, Mercer and Connoquenessing. The upper limit of the group is occasionally separated from the Brookville coal by a variable thickness of shale. The lower limit lies unconformably on the Burgoon sandstone of the Mississippian period since the Mauch Chunk formation has been eroded from this area. The line of separation is not clear due to the fact that the sandstones of the Pottsville and Burgoon Sandstones are very similar in nature.

HOMEWOOD FORMATION

The Homewood formation varies in thickness from 30 to 40 feet. It extends from the bottom of the Brookville underclay to the top of the Mercer shale. It consists of a gray massive coarse-grained sandstone.

MERCER FORMATION

The Mercer shale formation varies in thickness from 6 to 40 feet. The formation consists primarily of black and brown shales interbedded with thin beds of coal and clay. The Mercer coal bed sporadically outcrops in the watershed stream valleys but little, if any, coal has been mined.

CONNOQUENESSING FORMATION

The Connoquenessing formation ranges from 30 to 50 feet in thickness. It extends from the base of the Mercer shale to the Mississippian-Pennsylvanian contact. It consists of a coarse-grained, massive sandstone with occasional interbeds of shale.

MISSISSIPPIAN SYSTEM

The only exposure of the Mississippian system consists of the Burgoon sandstone of the Pocono group. It outcrops along the steep hillsides near the mouth of Deer Creek and is the oldest rock exposure in the watershed. The contact with the Pottsville Group could not be ascertained in the field due to the heavy talus on the valley walls.

The Burgoon sandstone attains an average thickness of 310 feet in the watershed. It is of non-marine origin and is usually thin bedded and unclean. It also contains frequent interbeds of thin shale lenses.

STRUCTURAL GEOLOGY

The Deer Creek Watershed is located on the northern limits of the Appalachian coal basin. The basin or synclorium is a large northeast-southwest trending down fold of strata. It is a near flat lying strata which is only occasionally broken by small faults and low, broad folds.

Limited information regarding structure has been obtained in and around the area of the Deer Creek Watershed. The geology of Clarion County was investigated by the Second Geological Survey of Pennsylvania (H.M. Chance) in 1880. In 1911, the United States Geological Survey (Shaw and Munn) published the geology of the Foxburg and Clarion quadrangles, including a small portion of the Deer Creek Watershed. Chance, in the 1880 study, reported straight, parallel folds at a strike of N 35^{0} through the Deer Creek Watershed; the Millersville anticline and syncline. In 1911, however, Shaw and Munn could find no such evidence of these folds, though the study proceeded only far north as Shippenville.

In lieu of complete geological data, structure contours have been formulated for the Deer-Creek Watershed. Since the area has been heavily surface mined, the topography of such activities are found on the U.S.G.S. 7½ minute quadrangle series. Coal elevations have been ascertained from these sites and correlated with available drill hole and deep mine data. Structure contours have been compiled on the Lower Clarion coal seam. The bed is considered to be the most persistent and heavily mined of any in the watershed. Therefore, the seam, where mined out, would be capable of generating more data relative to structure determinations. The resultant structure contours are in invervals of 20 feet.
It is felt that the contours are accurate to 10 feet. It must be emphasized that the structure obtained is of a regional nature only. Localized conditions at a certain mine site will vary with the formation presented. For the purpose of this report, however, it is felt that the structure presented reveals the regional trends and patterns.

As a result of the determination, it can be seen that the structure north of Shippenville can best be described as a monocline rising gently, less than one-half degree, to the north. As the structure is followed to the south, beginnings of an irregular fold begins to appear. Evidence of a long, shallow trough is found in the area, extending from Shippenville to Williamsburg, below Clarion. This feature together, with the overall southerly dip and constant elevation of the hilltops, serves to preserve the Lower and Middle Kittanning formation in the southern reaches of the watershed. In the northern reaches of the watershed, slight, folding and a general flattening of structure is evident. A slight dip to the northeast is noted near Tylersburg. Overall, the Lower Clarion coal seam raises an estimated 240 feet from the mouth to the headwaters of Deer Creek. As a result of this rise, the isolated patches of coal near Tylersburg and Frills Corners represent some of the northernmost reaches of mineable bituminous coal in the. Appalachian Basin.

The direction of groundwater flow seems to be largely controlled by the local anomalies in structure throughout the watershed. Because of this, there appears to be no general directional pattern to the flow of acid mine drainage. The interrelationships between abandoned surface mines and groundwater contamination is discussed under the Exploratory Drilling Program, page 25.

GEOLOGIC FACTORS AFFECTING ACID MINE DRAINAGE ACID PRODUCTION

The nature and quantity of acid mine drainage produced as an aftermath of coal mining is determined by various hydrologic and geologic factors. Some of these factors are:

1. Thickness and composition of the coal seams and associated strata.
2. Depositional environments of the strata.
3. Size and chemical constituents of the pyrite in the coal and associated strata.
4. Folding, fracturing, joints, faults, and strike and dip of the strata.
5. Location and extent of mined out area.
6. Roof thickness and character.
7. Topography.
8. Position of water tables.
9. Permeability and porosity of strata.
10. Availability of carbonates for natural renovation.

The basic theory of acid mine drainage formation is simple and well known. Coal mining exposes the sulphur-bearing minerals, pyrite and marcasite, to air and water. These minerals are oxidized chemically and biochemically, producing sulfuric acid, ferrous and ferric sulfate, and other acid salts such as the sulfates of iron, aluminum, and manganese. The mine drainage may also contain the neutral sulfates of calcium and magnesium when calcareous rocks are present.

Recent research conducted by Williams (1960), Williams and Ferm (1960), Williams and Keith (1963), Caruccio (1968, 1970, 1972), and Caruccio and Ferm (1974), has begun to develop patterns in acid mine drainage formation in Western Pennsylvania. Through the use of fossils, Williams first determined the stratigraphic paleoenvironments of deposition and their lateral variations for each of the major coal seams in the Allegheny Group. He found that in the basal portion of the Allegheny Group, the rocks contain fossils indicative of a marine-brackish water paleoenvironment. In the upper portion of the Group, fossils are present which indicate a continental freshwater paleoenvironment. In general, as one passes upward through the stratigraphic succession, the rocks grade slowly from marine to continental, indicating a slow marine regression over a long period of time. This work was further refined by Williams and Fern (1960), who demonstrated that the basal brackish rocks in the Allegheny Group also vary laterally, becoming progressively more marine to the west.

The significance of this, to the understanding of acid mine drainage, was revealed in a study by Williams and Keith (1963). This study investigated the possible correlation between sulphur (primarily as pyrite) in coals and the paleoenvironment of deposition of the coals. It was found that the amount of sulphur in the Lower Kittanning coal seam increased westward, directly correlating with the westward transition from continental to marine paleoenvironment. This was inferred to hold true for the other coal seams of the Allegheny Group.

For the past eight years, Caruccio has been investigating the nature of the pyrite which causes the acid mine drainage problem. In a series of field and laboratory studies conducted in western Pennsylvania, he determined that the most significant parameters affecting acid formation are:

1. Mode of occurrence of the pyrite.
2. Distribution of certain trace elements in the pyrite.
3. Permeability of the host rock, as a contributing factor to the oxidation rate.
4. Availability of calcium carbonate for natural renovation.
5. Groundwater pH before mining, as a control on the iron bacteria which catalyze the acid producing chemical reaction.

The studies showed that there are four types of pyrite occurrences in coal strata:

1. Euhedral crystals less than 10 microns in diameter.
2. Coarse-grained masses replacing original plant matter, greater than 25 microns in diameter.
3. Coarse-grained plate y masses occupying joints in the strata, greater than 25 microns in diameter.
4. Fine grained framboidal pyrite, generally occurring as spherical clusters of 0.25 micron particles.

The fine-grained framboidal and euhedral pyrite appear to have been formed contemporaneously with the host strata, since the pyrite grains are aligned parallel with bedding and form an integral part of the structure. These types of pyrite are products of the paleoenvironments of deposition for the strata. The other types of pyrite are secondary forms, resulting from deposition in joints and replacement of plant material.

Caruccio has further determined that only the framboidal primary pyrite is signficantly reactive. Samples containing similar amounts of total pyrite, but only a small percentage of framboidal, produce significantly less acid than samples with a high percentage of framboidal pyrite.

The reasons for the reactivity of framboidal pyrite appear to be at least partially controlled by the existence of trace elements. Size alone is not the answer, since coarse-grained pyrite was mechanically ground to a size equivalent to framboidal pyrite and tested, without a significant increase in acid production. Spectroanalysis of samples by Caruccio has shown significantly more titanium in stable pyrite than in reactive pyrite, and presence of silver in reactive samples only. More research is being conducted to determine if silver increases oxidation tendency, or if titanium increases stability.

Recent work by Caruccio and Ferm (1974), and work in progress, has determined the framboidal pyrite to be associated with strata from back barrier and lower delta plain deposits. Criteria are being developed to recognize paleoenvironments in the field, in hopes that progress can be made toward mapping these environments in the Appalachian coal fields.

There are several implications of these studies for the Deer Creek Watershed. The surface rocks of the watershed are from the basal portion of the Allegheny Group, representing restricted near-shore marine and marine paleoenvironments. As such, the Clarion coals and associated strata contain the greatest amounts of framboidal pyrite, and are therefore the worst acid producers.

The situation within the watershed is worsened by the scarcity of Vanport limestone, which is a major contributor to natural renovation throughout much of western Pennsylvania. The lack of limestone, high degree of reactive pyrite, and poor reclamation practices of past mining, have combined to produce the serious acid mine drainage problem in the Deer Creek Watershed. Moreover, the low pH values in many areas probably encourage the growth of various iron bacteria, which act as a catalyst in the acid production process.

EXPLORATORY DRILLING PROGRAM

Introduction

During the early stages of the study, one of the most persistent problems in relating geology to the acid mine drainage problem was tracing the movement of the pollution. Normally, seepages from surface mined land would occur at the toe of spoil and migrate in accordance with the geologic structure. At other times, rainfall would fall onto surface mined land, (particularly hilltop mines)

and disappear into the subsurface. In conjunction with this problem, springs and wells located far downslope of these mining areas, were discharging consid-

-erable quantities of acid mine drainage. The quality of the water closely resembled the drainage that normally would be discharged as seepage or runoff from strip mines.

It was suspected that precipitation was falling on the hilltop surface mines and infiltrating the highly permeable and acidic Clarion spoil material. This was thought to be a logical assumption in that the surfaces of the mines lacked vegetation, were flat lying, and contained rocky and pyritic overburden. The flow was then assumed to infiltrate to an aquifer and then conveyed to the suface, exiting in the form of springs and wells. To verify this assumption, an exploratory drilling project, SL 191-0-101.5, was established for various areas in the Deer Creek and adjoining Toby Creek (SL 193) Watershed. Core holes were drilled between the abandoned mine sites and the pollution points. The cores were examined in the field and in the office. Holes were drilled to depths so as to verify the presence or absence of a single contaminating transmission zone.

The drill logs and related drawings of the project are presented in the Appendix and should be referred to in conjunction with the following discussion.

Deer Creek Area No. 1

The project area was located approximately 2.5 miles northwest of Shippenville in Elk Township. The purpose of the project was to determine the source of pollution to the wells and springs along Deer Creek and the Penn Central (now Conrail) railroad tracks. It was suspected that the possible recharge area was a hilltop strip-mine in the Clarion coal seam approximately 160 feet above the discharges. Holes' were drilled below the strip mine to depths ranging from 60 to 180 feet.

An examination of the core borings revealed a limited amount of iron precipitate had formed on the rocks near the surface of each hole (except No. 15). The flow conveying the precipitate would appear to follow a near surface path and originates from the strip mine above the discharges. No evidence of a single contaminated acquifer zone could be found in the core borings. It is felt that the. springs are being recharged by the strip mine, but acid production is limited. In addition, the gas wells monitored by DC-221 and 222 are not affected by the mine as an examination of hole number 15 revealed. Recommendations for this area are included in Project Area numbers 4 and 7 of the proposed abatement plan.

Deer Creek Area No. 2

The project area was located just south of the village of Tylersburg. The purpose of the project was to determine the source of pollution to the gas wells and springs along a tributary to Licking Creek. It was suspected that the possible recharge area was a hilltop strip mine in the Clarion coal seam approximately 100 feet above the discharges. Holes were drilled below the mine to depths ranging from 30 to 80 feet.

An examination of the core borings revealed a limited amount of iron precipitate had formed on the surface of the rocks near the surface of each hole. The flow conveying precipitate would appear to follow a near surface path and originates from the strip mine above the discharges. No evidence of a single contaminated acquifer zone could be ascertained from the cores. It is felt that the springs are being recharged to a degree by the strip mine, however, the flows observed at the gas wells are probably beyond the influence of the mine. The well monitored by DC-46 and 47 was sealed under AWSP contract 16:2. Specific recommendations for this area are included in Project No. 21-2 of the proposed abatement plan.

General Conclusions

As a result of the drilling program, it appears probable that abandoned surface mines topographically situated on hilltops are capable of discharging variable amounts of acid mine drainage to shallow groundwater systems. It is felt that rainfall is percolating through an acidic, permeable spoil until it is contained by an impervious surface (usually the bottom of a strip mine pit). The flow is then conveyed laterally in accordance with local geologic structure, to a point where it intercepts the soil mantle. The flow then follows a near surface flow path until it appears to exit down slope at the surface usually at a spring. The quantity of pollution appears to depend on the surface area of the site, the degree of vegetation present, the amount of acid producing material in the spoil, the permeability of the surface material, the type and amount of backfilling afforded to the site and the presence of drainage facilities. The presence of a single contaminated acquifer zone was not found to exist as a result of this program.

The pollution attributed to gas wells is seen as a more complex problem. At certain extreme instances, the pollution to these wells may have its source from abandoned surface mines. It seems more likely, however, that the problems are generated far below the ground surface and beyond the influence of the local surface mined areas. An in depth study of the gas well pollution problem requires the use of more sophisticated hydro-geological techniques.

General Recommendations

The general findings of the exploratory drilling program should not be applied in a specific manner to all seepages and springs seemingly far removed from mined areas. The geology of the watershed relative to groundwater hydrology is far too complex to put into simplified terms. Some general recommendations, however, can be made that should improve the acid mine drainage conditions in these areas.

Relying on the assumption that the surface mining of coal within the watershed has effectively disrupted the groundwater system to some degree, it would seem logical that reclamation of these sites **is in** order. It is felt that re grading the sites end installing drainage facilities to promote the rapid expedition of runoff is essential. Special compaction of the surface to prevent the wholesale percolation of water into the spoil may be necessary in some cases. The experimental program et e strip mine in the watershed is testing several methods to achieve this end. Also considered necessary is complete revegetation of the reclaimed site. The root system of the vegetation will help to absorb the water that would normally be infiltrating through the acidic spoil.

Gas well plugging is considered e viable means of abating deleterious flows. This technique was successfully implemented under AWSP contract 16:2 in the Upper Paint Creek Watershed (Deer Creek Watershed).

If these measures are implemented, there is no guarantee that the acid mine drainage discharged from isolated springs and wells will be completely abated. **It is** felt that many of the sources have been discharging naturally for a period of many years. The abatement of these sources would be considered next to impossible. An evaluation of adjacent watersheds in the area indicate similar conditions of groundwater contamination. The problem may be one of a regionalized nature and not one due solely to local conditions. It is felt, however, that the quantity of water being discharged from these sources will be reduced if the abatement measures are implemented over a basin-wide area.

MINING HISTORY

Clarion County has been mined for a variety of mineral resources since 1830. The iron industry was the first activity to take advantage of various iron ore deposits in the county. One bed occurs immediately above the Vanport limestone (known then as the "Ferriferous" limestone). The ore at that time was obtained primarily by stripping. The mined ore was then smelted in charcoal furnaces, ruins of which are in evidence throughout Clarion County. Ruins of old furnaces can be observed on U.S. Route 322 east of Shippenville and at Huefner. At one time, there were 27 furnaces operating in the county producing a total of 40,000 tons of iron per year. The iron industry in this area, however, experienced steady decline after 1860 due to the exhaustion of the more economical deposits and the discovery of the higher grade Lake Superior ores.

Immediately after the Civil War, oil was discovered in Clarion County in commercial quantities. The production of oil reached a peak in 1874 with 3,900,000 barrels. By 1883, an estimated 5,000 oil wells had been drilled. Most of the crude oil production in the Deer Creek Watershed area resulted from the Venango, Third and Fourth Sands of the Conewango Formation, Devonian Period. The petroleum industry, however, steadily declined in Clarion County when, in 1941, production dropped below 100,000 barrels for the first time. In 1941, it was also estimated that 75 million barrels were physically recoverable from 180 million barrels of total crude oil still in the ground in Clarion County.

The development of the natural gas industry in Clarion County coincided with that of the petroleum industry. The production of gas in Clarion County reached 15 billion cubic feet in 1927 but has since declined. Most of the natural gas production in the Deer Creek Watershed area resulted from the Speechley Sand of the Canadaway Formation, Devonian Period and the previously mentioned Venango Sands.

Coal is the most valuable and abundant mineral resource in Clarion County. It has been responsible for the employment of thousands of men and has been the primary industry of the county for the past 100 years. The following estimates of the coal reserves of Clarion County represent the most recent estimates: original reserves - 2,043 million tons, mined out and lost - 190 million tons, recoverable by strip mining (0-120 feet cover) - 237 million tons, recoverable deep mining - 80 million tons. Mined in conjunction with coal were fire clays from primarily the Lower Clarion and Lower Kittarnning coal members. They have primarily been used for fire brick and a variety of other wares.

The major seams located in the Deer Creek Watershed are, in order of importance: Lower Clarion, Upper Clarion, Lower Kittanning, and Brookville. The coal, in general, is classified as high volatile and has been used primarily as a steam coal. It has the following typical analysis:

Volatile Matter	35-39%
Fixed Carbon	45-53%
Sulphur	3-6%
Ash	8-13%
Moisture	2-4%
Heating Value	13,000-14,000 BTU

Large quantities of Upper and Lower Clarion coal have been removed by the stripping method. The Lower Kittanning coal, where present, has been totally exhausted. Due to the topography of the area, the principal method of stripping has been hilltop removal.

Most of the economically recoverable coal in the watershed has been exhausted. The development of the Brookville coal will only occur when its reserves are proven and when more effective means of reducing sulphur content are found. With a few exceptions, active mining in the watershed has all but ceased at this time.

Deep mining was performed in the watershed up to 1930. Due to the thickness and extent of the seams, no large mines were developed in the watershed. Most deep mining was in the form of small country banks used mainly for local purposes.

Most of the mine drainage pollution comes from abandoned strip and deep mines where mining was conducted before the regulation of the industry and further aggravated by mining practices at the time. The major cause of deep mine pollution is the fact that until recently the mine openings were driven to the rise allowing for gravity draining of water from the mine. Inadequate mine design related to roof support lead to caving of the mine workings with resulting fracturing of adjacent strata. This has allowed surface and groundwater to percolate into the mine workings. Mine openings in the form of man-ways, ventilation and supply adits were not sealed following mine abandonment.

In regards to strip mining, most pits were not backfilled or planted allowing surface water to infiltrate through acidic spoil, settle into impoundments and contaminate groundwater supplies. Strip mine activities often removed the outcrop barrier allowing groundwater to flow unimpeded to the surface over theold strip pit. Mine and tipple refuse consisting of high sulphur material was not properly disposed of.

As a result of these practices, regulation of the mining industry came into existence with the Pennsylvania Clean Streams Act of 1937 (PL 1987 with amendments), the 1963 Bituminous Coal Open Pit Mining Conservation Act 133, the Land
the Surface Mining Conservation and Reclamation Act of 1971, and the FederalSurface Mining Control and Reclamation Act of 1977. Effective implementation and enforcement of these laws should eliminate or control any adverse conditionsresulting from active mining operations. Meanwhile, mine drainage from abandoned deep and strip mines will continue to degrade the water quality in the area placing severe restrictions on the land and water environment.

STREAM QUALITY EVALUATION

GENERAL DESCRIPTION

Deer Creek drains an area of approximately 69 square miles northwest of the Borough of Clarion. The stream rises in the north central portion of Clarion County and flows 18 miles in a southwesterly direction to the point of confluence with the Clarion River. The watershed attains a maximum width of 8 miles. The mouth of Deer Creek is located approximately 3 miles downstream of Piney Dam on the Clarion River.

There are no continuous recording gauging stations in the watershed; hence, long term discharge records are not available for characterizing stream flow. By assuming a runoff factor applicable to this area, however, a general idea of average discharge can be estimated. By applying a factor of 1.5 cubic feet per second per square mile, it is estimated that Deer Creek discharges an average of 103.5 cubic feet per second (66.9 million gallons per day) to the Clarion River.

The United States Geological Survey conducted a partial study of Toby Creek from July to December of 1973. Water quality and flow were monitored by a gaging station (03030100) on Deer Creek at the bridge over PA Route 854 near the mouth of Toby Creek.

The major tributary to Deer Creek is Paint Creek. It joins the main stream at Wilson's Mill below Shippenville. Paint Creek is formed below Huefner at the confluence of Mahles Run and Licking Creek. The major tributaries to Paint Creek include the following:

Tributary	Watershed Area (Sq. Mi.)
Little Paint Creek	6.3
Mahles Run (Below Huefner)	4.0
Step Run	3.2
Foy Run	2.0
Maples Run (above Shippenville)	1.8
Cooper Run	1.6
Grolemund Run	1.6
Rattlesnake Run	1.3
Frills Run	1.2

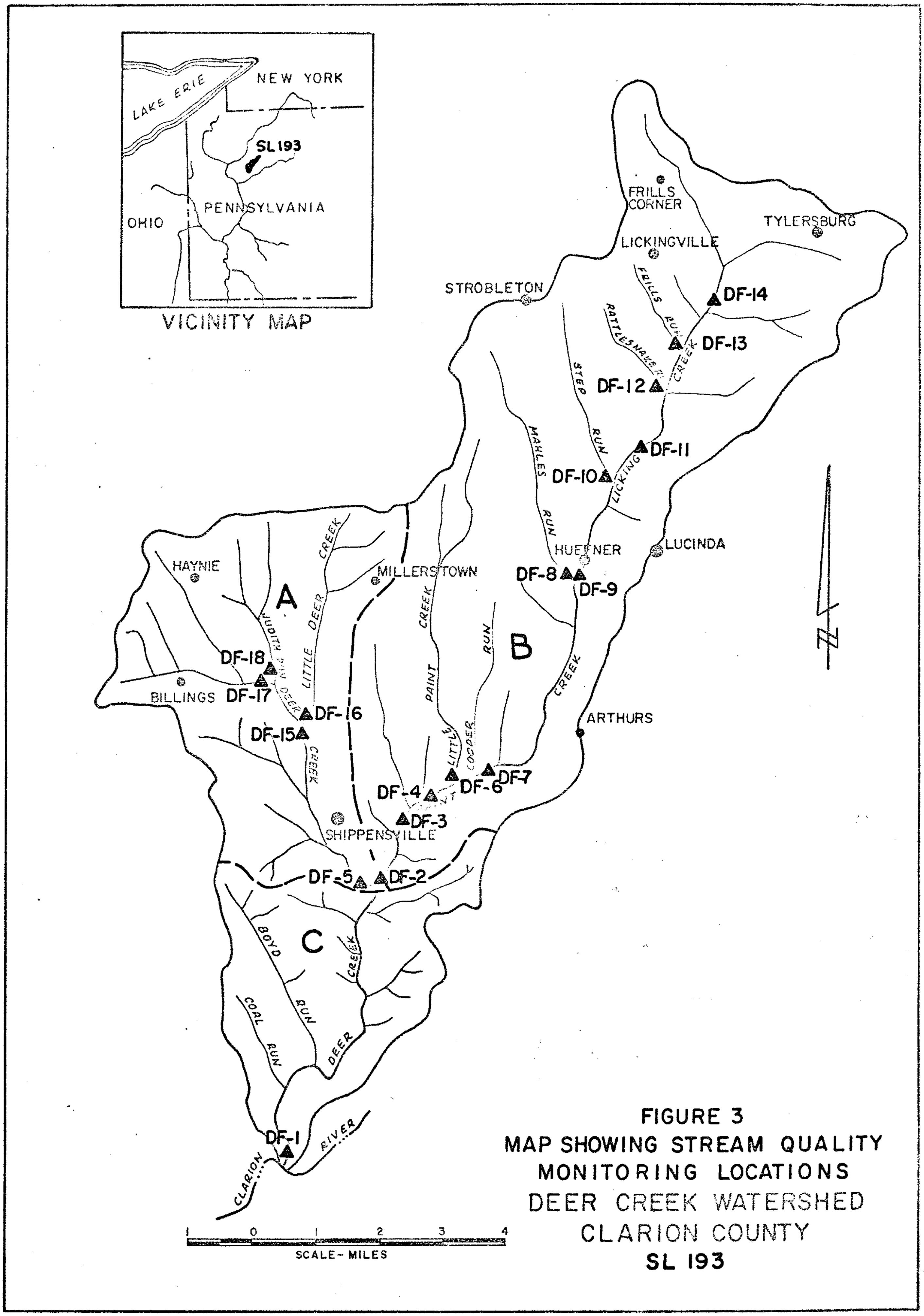


FIGURE 3
MAP SHOWING STREAM QUALITY MONITORING LOCATIONS
DEER CREEK WATERSHED
CLARION COUNTY
SL 193

The major tributaries to Deer Creek exclusive of Paint Creek are:

Tributary	Watershed Area (Sq. Miles)
Little Deer Creek	3.8
Judith Run	3.2
Boyd Run	3.0
Coal Run	1.4

These tributaries, as well as the main stream of Deer and various unnamed tributaries, were the subject of an investigation to determine in stream chemical quality relative to acid mine drainage pollution parameters in the watershed.

It was recognized, at the outset, that the time required for complete data collection at monitoring stations would impose a practical limit on the number of stream sampling points which could be used. For this reason, a cursory survey was undertaken to screen potential sites and select the stations most pertinent to the evaluation.

DATA COLLECTION

A preliminary survey, during which 230 grap samples were analyzed, was conducted in July of 1973 in order to evaluate stream quality and establish the optimum number and location of sampling points. Based on this information, stations were designated for periodic determinations of stream flow and water quality. The specific locations for these stream monitoring points are shown on the base map and Figure 3.

During the survey, additional sampling stations were assigned as needed to clarify data regarding pollutant loadings for specific stream reaches. In addition to determining stream flow, samples were collected and analyzed in the laboratory for pH, acidity, alkalinity, iron and sulfates. In-stream loadings for each constituent were computed from this data. Tables of the basic data for each water quality station are presented in Appendix B.

An effort was made to conduct sampling during periods with relatively consist ant stream conditions, i.e. under flow conditions roughly equivalent on a proportional basis throughout the watershed. This is important if the resultant data is to measure the in-stream effect of mine drainage sources for a particular stage of stream flow. In practice, however, it is often difficult to achieve this objective because the unexpected occurrence of rainfall, or varia tions in storm intensity during a sampling period, affect the watershed unevenly. Such variations in rainfall pattern preclude the possibility of correlating in stream chemical data. Appendix D has graphs showing daily rainfall accumulation during the study (July 1973 to September 1974), as measured at the Clarion weather station (Piney Dam). The periods for monitoring water quality stations are also shown to indicate the pertinence of rainfall to data interpretation.

Averages of the data obtained were used to express the general water quality effect of mine drainage problems in terms of acidity loadings. It should be noted that these values may be somewhat lower than actual mean loadings because data collection favored base flow, and between low and medium steam flows. Nevertheless, it is felt that the data generated provides a reasonable indication of the magnitude and distribution of the acid mine drainage problem in the project area.

DISCUSSION OF RESULTS

The following discussion of the in stream affect of acid mine drainage on Deer Creek was analyzed downstream from its headwaters to the mouth of the Clarion River. Figure 4, which represents a schematic diagram of the Deer Creek stream quality monitoring stations, should be used in conjunction with the narrative portion.

To facilitate the discussion of the water quality in the stream, the watershed has been separated into major areas.

Area A - Deer Creek from headwaters to confluence with Paint Creek.

Area B - Paint Creek sub-watershed

Area C - Deer Creek after confluence with Paint Creek

AREA A

This area encompasses that part of the watershed drained by Deer Creek from the headwaters to the confluence with Paint Creek. This section represents approximately 25 to 30 percent of the total watershed drainage area.

Monitoring station DF-17 recorded the water quality of the headwaters of this portion of Deer Creek. An average of 2300 lbs/day of acid and pH of 3.7 was recorded here. Since strip mines represent the extreme headwaters, this portion of Deer Creek is degraded by mine drainage its entire length. The sources of pollution are the strip mines northwest of Haynie and acid discharges from springs and wells located just above DF-17.

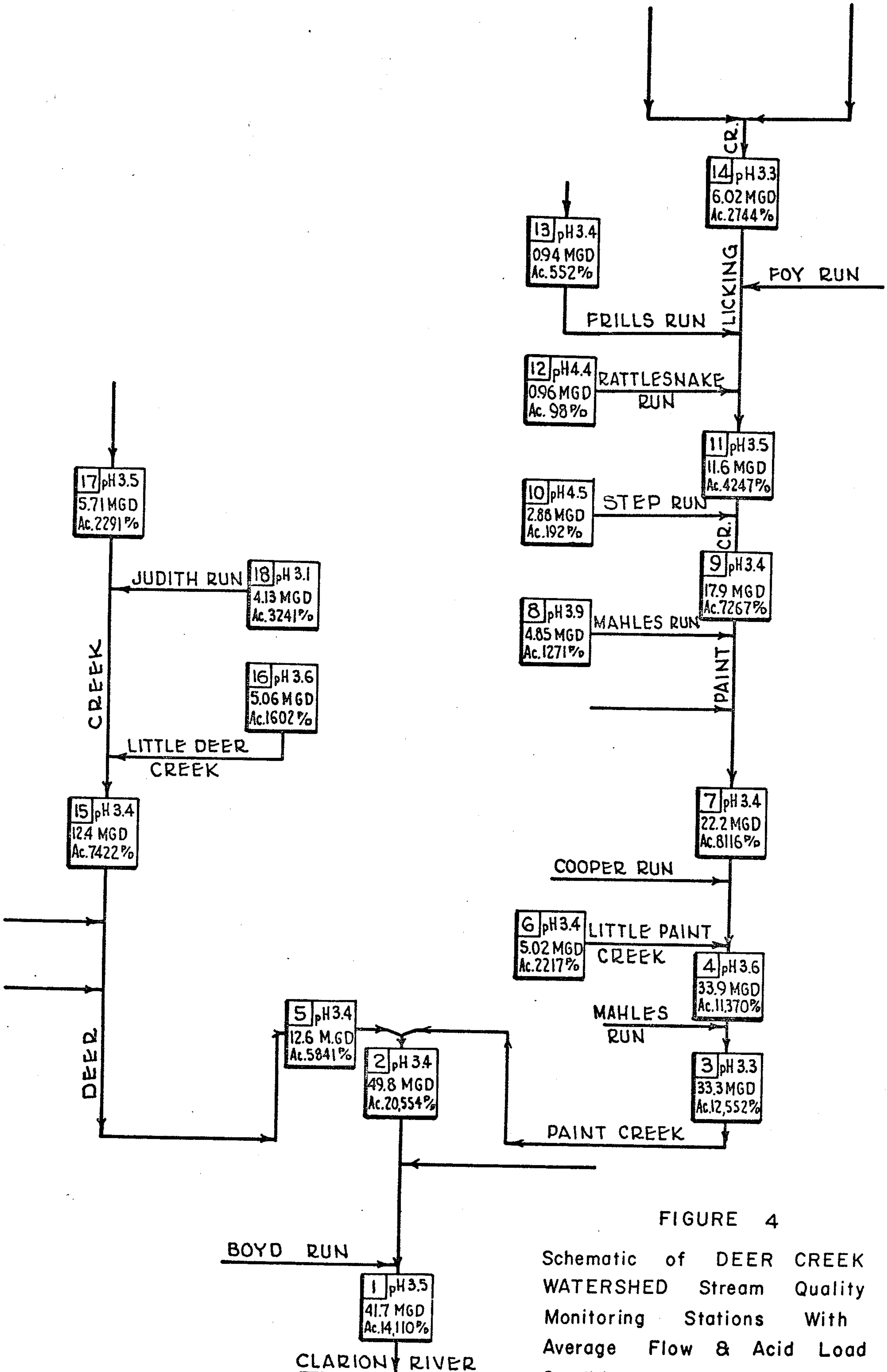


FIGURE 4

Schematic of DEER CREEK WATERSHED Stream Quality Monitoring Stations With Average Flow & Acid Load Conditions.

Judith Run was monitored by DF-18. An average acid load of 3250 lbs/day and pH of 3.1 was recorded. Judith Run is also in an acidic condition along its entire length. The major pollution source is the large strip mine at the headwaters north of Haynie. Little Deer Creek contributed an average of 1600 lbs/day of acid with an average pH of 3.6 as monitored by DF-16. Strip mines at the headwaters account for the acid condition of Little Deer Creek along its entire length.

Monitoring station DF-15 records the net affect of the tributaries to this point. Since the station was located below Judith Run, the loadings of the other stations (DF-16,17,18) add almost arithmetically. An average acid loading of 7400 lbs/day and pH of 3.4 was recorded here.

The water quality of Deer Creek to its confluence with Paint Creek was recorded at DF-5. Some dilution was afforded to the acidity in this reach as little mining activity occurred between DF-5 and DF-15. The pH, however, remained the same at 3.4 as did the sulphate loading of approximately 10 tons/day. In summary, Area A is degraded by acid mine drainage along its entire reach resulting primarily from strip mining along tributary headwaters.

AREA B

The area consists of the entire Paint Creek sub-watershed and represents approximately 65-70 percent of the total watershed area.

Monitoring station DF-14 represented the water quality of the headwaters of Licking Creek. An average pH of 3.3 and acidity loading of 2750 lbs/day was recorded. Sources of pollution are strip mines at the headwaters and springs and wells discharging mine drainage along the main stream.

Frills Run was monitored by DC-13. Water quality at this station indicated an average pH of 3.4 and acidity loading of 550 lbs/day. This stream has probably improved since the sealing of several gas wells under AWSP contract 16.2

Rattlesnake Run, monitored by DC-12, contributed a negligible acid load to Licking Creek.

Licking Creek was monitored one mile downstream of Rattlesnake by DF11.

An average pH of 3.5, acidity loading of 4250 lbs/day and over 8 tons of sulphate were recorded here. Pollution sources are attributed to the aforementioned tributaries and the acidic tributaries of Foy Run and Grolemund Run.

Monitoring station DF-10 monitored Step Run. This stream had the highest average pH of any major tributary in the watershed. Traces of alkalinity were noted in this stream. This must account for the negligible acid load noted at the mouth of Step Run, though there are many acidic springs located along its reach.

Licking Creek downstream of Huefner was monitored by DF9. Average acidity loadings of 7270 lbs/day and over 10 tons per day of sulphates were recorded here. This represents an increase in acidity of almost 3,000 lbs/day fromDF-11. This can be attributed primarily to the discharges of springs and wellsalong Licking Creek above Huefner and strip mine activity between Snydersburgand Lucinda.

Mahles Run, which joins with Licking Creek to form Paint Creek, was monitored by DF-8. It is degraded by acid mine drainage from flowing springs and wells atthe headwaters strip mines in the central region. An average pH of 3.9 and acidity loading of 1270 lbs/day was recorded here.

Paint Creek upstream of Cooper Run was monitored by DF7. An increase of acidity of only 850 lbs/day was recorded, however, sulphates increased by over4 tons/day. This resulted from the tributaries of Mahles Run and Lauer Run andstrip and deep mine discharges along the watershed boundary between Lucinda andArthurs.

Monitoring station DF-6 recorded the water quality of the acidic tributary of Little Deer Creek. Sources of pollution are almost solely attributed to deep mine discharges east of Millerstown and flowing gas wells. An average pH of 3.4 and acidity loadings of 2200 lbs/day were produced by the sub-watershed.

Paint Creek downstream of Little Paint Creek was monitored by DF-4. Increases of over 3200 lbs/day of acid and 25,400 lbs/day of sulphates occurred in thisreach. This can be attributed solely to the introduction of acidic flows fromCooper Run and Little Paint Creek.

Negligible increases in acidity and sulphate loadings were noted between DF-4 and DF-3 on Paint Creek. Little mining activity occurred in this reach. Results at DF3 above the confluence with Deer Creek at Wilsons Mills revealthat Paint Creek is a consistent and substantial acid tributary to Deer Creek. The average water quality indicates a pH of 3.3, acid loading of 12,600 lbs/dayand sulphate loadings approaching 28 tons/day.

AREA C This area comprises the watershed area downstream of the confluence of Paint Creek and Deer Creek. At station DF-2 below the juncture, the following average values were obtained pH - 3.4, Acidity 20,500 lbs/day, Iron - 1344 lbs/day and Sulphates - 86,500 lbs/day. Approximately 70 percent of the loadings were attributed to the Paint Creek watershed. Between DF-2 and DF-1 at the mouth, no major acid tributaries enter Deer Creek. In fact, measureable sources of alkalinity were recorded at Boyd Run, Coal Run, and several other unnamed tributaries. However, this has a negligible affect on the overall water quality of the stream. Mining activity in this reach is restricted to the watershed boundary south of Clarion Junction and isolated hilltops south of Shippenville. Also occurring in this reach was a loss of flow between the confluence and the mouth. On November 27, 1974, intermediate measurements were taken between DF-1 and DF-2 to ascertain the location of the flow loss.

Location	Flow(gpm)
DF-1	64,577
First stream bend above DF-1	66,974
Interstate 80 Bridge	60,804
DF-2	57,224

The loss of flow would appear to occur in the stream reach between the first stream bend above DF-1 and the mouth. An inspection of the area geology map of the Clarion-Foxburg Folio reveals the deposition of alluvium in this same area. These deposits are unconsolidated in nature, composed chiefly of gravel, sand, and silt. It would appear that a portion of the flow of Deer Creek is infiltrating the alluvium and being conducted laterally through the streambed to the Clarion River. Other possibilities may include the diversion of flow to regional groundwater systems by way of jointing and/or fracturing of the Mississippian rocks. Whatever may be the case, this factor has a major implication on the monitoring of acid mine drainage of the Deer Creek Watershed. It would appear that the acid loading to the Clarion River measured at the mouth of Deer Creek is materially reduced due to the loss of flow. It must

be assumed, however, that the subsurface flow containing significant quantities of acid mine drainage also has its ultimate disposal in the Clarion River. The problem, therefore, becomes one of monitoring the mine drainage where the total in-stream water quality is relative to the stage of consistent streamflow.

The most rational location of measuring the contribution of acid mine drainage from the Deer Creek Watershed to the Clarion River would be in the vicinity of the first bend upstream of the mouth of Deer Creek.

CONCLUSIONS

The net effect of the entire Deer Creek drainage system that discharges to the Clarion River is the contribution of acid-laden stream-flow derived from coal mine related drainage, For the purposes of this study, the assumption has been made that the contribution of acid mine drainage to the Clarion River from Deer Creek would be more realistically reflected below the junction of Deer Creek and Paint Creek. Averages of data collected during the survey indicated that concentrations of pollutants measured at DF-2 related to 50 mgd would define loadings from the watershed of over 10 tons per day of acid and four times that amount of sulphates, For the range of conditions sampled, the pH was determined to vary from 3.1 to 3.5.

For the sake of comparison, the data were also analyzed from the standpoint of water quality at the mouth of Deer Creek characteristic of mean stream flow. It is estimated that at a mean flow rate of 104 mgd., Deer Creek would discharge about 13 tons/day of acid and approximately 77 tons per day of sulphates.

It is evident from both of these loadings, no matter which is closer to the actual values, that severe deterioration of stream quality occurs within the watershed, and that Deer Creek is causing a significant deleterious effect on water quality in the Clarion River.

The major findings of the stream quality evaluation are summarized in the following statements:

1. The water quality of Deer Creek is severely degraded by acid mine drainage along its entire length. The pH of the Creek generally ranges from 3.0 to 4.0.
2. The majority of the major tributaries within the watershed are acidic. The tributaries in order of degradation are: Judith Run, Little Paint Creek, Little Deer Creek, Mahles Run (below Huefner) and Frills Run. Overall, the Paint Creek Watershed contributes approximately 70% of the acid mine drainage.
3. The severity of the acid condition increases in a downstream trend, with loadings at peak proportions at the juncture of Paint and Deer Creeks.

4. The magnitude of pollution loadings increases from base flow to high flow conditions, though not in corresponding proportion. Although slugging conditions occur at high flow periods, some degree of dilution is afforded to the acidity during these conditions.

S. The watershed contains very few sources of measureable alkalinity. Grab samples taken in the preliminary survey indicate insignificant sources at Coal Run, Boyd Run and other smaller tributaries near the mouth. Therefore, little or no neutralization or buffering capacity is afforded to the acidity of Deer Creek. This fact also places meaningful doubt on whether Deer Creek can ever be economically returned to a non-acidic condition; however, a significant decrease in the total acid loading to Deer Creek and the Clarion River can be achieved by the implementation of various abatement procedures.

6. A loss of flow in Deer Creek occurs between the mouth and the juncture of Deer Creek and Paint Creek. This may be due, in part, to the infiltration of flow into alluvium in this reach. It is recommended that future monitoring of Deer Creek relative to the overall contribution of mine drainage to the Clarion River be made in the vicinity of the first bend above the mouth of some other intermediate point before the affect of stream flow loss becomes evident.

7. The major sources of acid mine drainage in the Deer Creek Watershed are, in order of magnitude: strip mines, oil or gas wells, deep mines, springs and tipple runoff.