INTRODUCTION

In an Engineering Agreement, SL-133-5, dated February 28, 1975, Gwin Engineers, Inc. was contracted by the Department of Environmental Resources of the Commonwealth of Pennsylvania to perform an acid mine drainage abatement study on the Mill Creek Watershed, Clarion and Jefferson Counties, Pennsylvania.

The purpose of this study was to determine the amount, nature, and origin of pollution by acid mine drainage in the watershed and to recommend procedures for the abatement of such pollution.

The study was initiated by conducting a preliminary reconnaissance of the watershed to determine the various sub watersheds within the drainage system and the relative acid contribution from each. A system of sampling and flow measurement stations was developed on major streams and tributaries and at all mine drainage sources. Flow measurements and samples were collected monthly at each station for a one year period. Extensive field investigation and data collection led to the formulation of an abatement plan for each acid mine drainage source area. These plans were evaluated for cost effectiveness, subsequently producing an assignment of reclamation priorities for the various reclamation project areas.

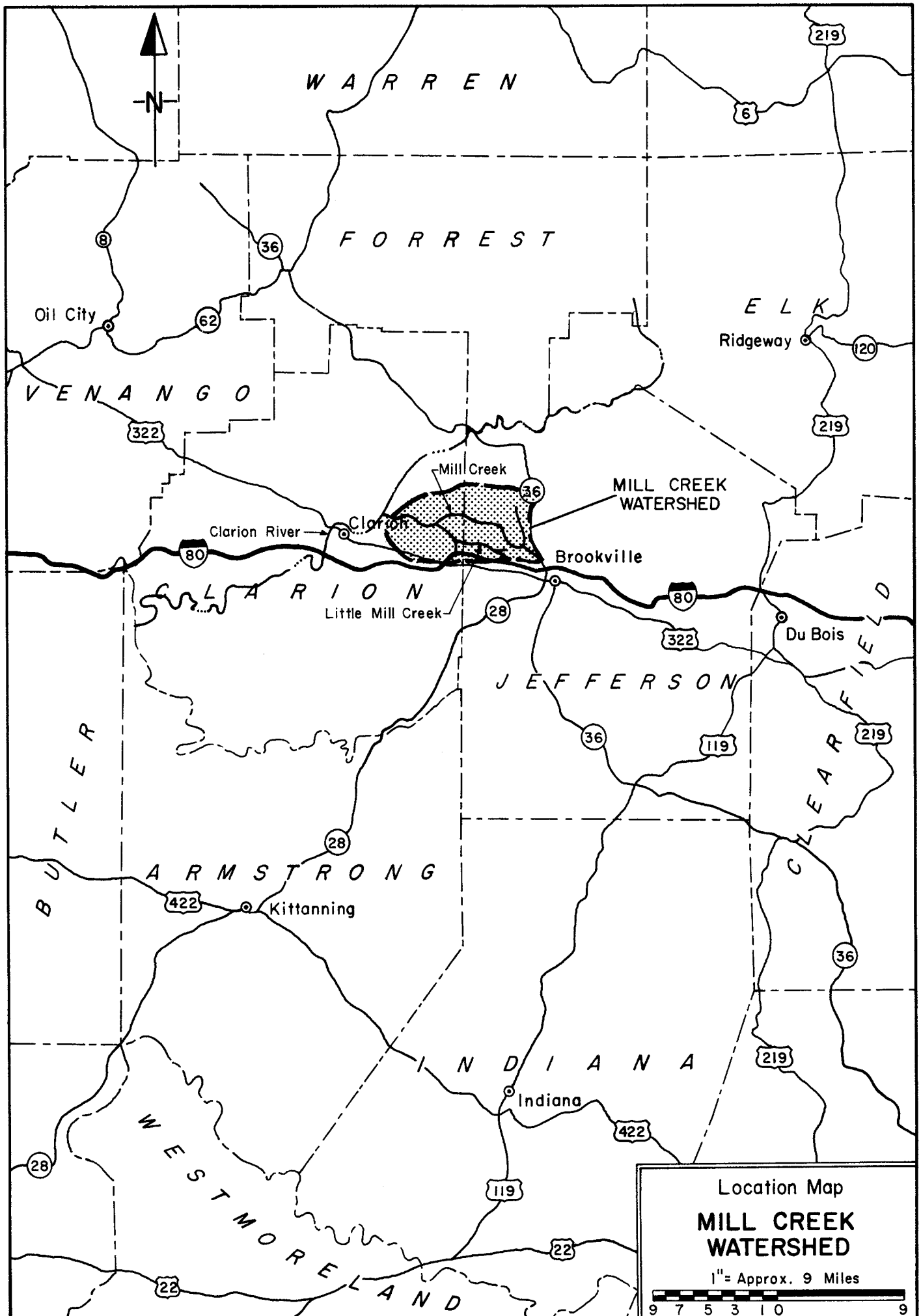
An important aspect of the study was to determine areas of high priority on which rapid design of reclamation measures should be considered. It is expected that immediate abatement of the acid mine drainage from these areas would constitute a substantial step toward the improvement of the water quality of the Mill Creek. Watershed.

I MILL CREEK WATERSHED GENERAL INFORMATION

LOCATION AND DESCRIPTION

The Mill Creek Watershed is located in northwestern Pennsylvania,, occupying portions of Clarion and Millcreek Townships in Clarion County and Eldred and Union Townships in Jefferson County. The watershed lies approximately 2 miles east of the Borough of Clarion and 2 miles northwest of the Borough of Brookville.

The Mill Creek Watershed covers an area of approximately 56 square miles. The watershed includes approximately 6162 acres of State Game Lands No. 74. There are no population. centers within the watershed although the towns of Fisher and Sigel border the watershed to the northwest and northeast respectively. The watershed is bordered on the south by the Boroughs of Strattanville and Corsica. Interstate Route 80 runs east-west just south of the watershed. The southern limit is roughly formed by U.S. Route 322.


N
WARREN
FORREST
ELK
VENANGO
CLARION
JEFFERSON
CLEARFIELD
BUTLER
ARMSTRONG
INDIANA
WESTMORELAND
Oil City
Ridgeway
Mill Creek
MILL CREEK WATERSHED
Clarion River
Clarion
Brookville
Little Mill Creek
Du Bois
Kittanning
Indiana
219
6
8
36
62
120
322
80
28
119
422
22
Location Map
MILL CREEK WATERSHED
1" = Approx. 9 Miles
9 7 5 3 1 0 9

GEOGRAPHY

Topography

The Mill Creek Watershed lies in the Appalachian Plateau Province. The Allegheny Front lies to the southeast. In general, the valleys are narrow and steep-sided having virtually no flood plains. The valleys are separated by moderately broad, flat uplands. The surface elevations in the watershed range from 1100 feet to 1900 feet above sea level. The average relief is about 400 feet with a maximum relief of 800 feet. Topography increases in elevation slightly to the north. Highlands average between 1400 feet and 1800 feet in elevation in the northern portion of the watershed and between 1500 feet and 1600 feet to the south.

The topographical features of the project area are shown on the Strattanville, Corsica, Brookville, Lucinda, Cooksburg, and Sigel 7½ minute U.S.G.S. Topographic Quadrangles.

Drainage

Mill Creek and its tributaries, which include Whites Run, Trap Run, Stroup Run, Woods Run, Douglass Run, Little Mill Creek, Pendleton Run, Updike Run, Rankin Run, Martin Run, Parks Run and several unnamed tributaries, drain approximately 56 square miles. The Mill Creek drainage system is essentially a trellised type although some of the subsystems appear to b e dendritic. Mill Creek itself flows a distance of about 21 miles with a vertical drop of 670 feet from a high of 1770 feet at its headwaters to an elevation of 1100 feet at its mouth about 3 miles north of Clarion where it flows into the Clarion River. The major tributaries of Mill Creek are Douglass Run and Little Mill Creek.

Douglass Run flows about 3 miles with a vertical drop of 350 feet from an elevation of 1580 feet to 1230 feet at its confluence with Mill Creek. Douglass Run enters Mill Creek 5.9 miles upstream from the Clarion River. Douglass Run has a drainage area of 6.1 square miles. The principal tributary to Douglass Run is Jones Run which drains 3.0 square miles.

Little Mill Creek flows a distance of approximately 8 miles with a vertical drop of 355 feet descending from a high elevation of 1590 feet to a low at its mouth of 1235 feet. Little Mill Creek drains 13.7 square miles. A number of unnamed tributaries make-up-the Little Mill Creek drainage basin.

It is important to note that at the time of the Second-Pennsylvania. Geologic Survey the stream now known as Martin Run was commonly referred to by some as Jimmy Run, and the stream now known as Updike Run was referred to as Nolf Run on PennDOT county maps.

GEOLOGY

Geologic History

The geologic history of the sedimentary rocks underlying the watershed dates back to early Cambrian time, nearly 550 million years ago, when most of the area now called Pennsylvania was covered by a vast inland sea. This sea received terrestrial sediments from a large land area located to the southeast. The variable nature of the strata is due to changing geologic conditions during this period of deposition. As the sea filled with these sediments the underlying geosyncline subsided causing the adjacent landmass to rise. As the landmass increased in elevation the rivers acquired steeper gradients and greater velocities, carrying coarser sediment, notably the sands and pebbles, which were deposited and eventually formed sandstones and conglomerates. As the landmass eroded,, the gradient, and therefore velocity, of the rivers diminished, and only finer sediments were carried and deposited, forming shales. During other periods or greater distances from the shoreline no detritus was deposited and limestones were deposited by precipitation of calcium carbonate from the sea water, with contemporaneous accumulation of calcareous testes of minute sea creatures. Build-up of sediment as well as widespread uplift around the beginning of Carboniferous time resulted in the raising of the underlying land to mean sea level. This marshy environment was very conducive to luxuriant plant growth and the subsequent formation of extensive peat bogs. From time to time different parts of the marshland were flooded and thin layers of sediment were deposited. These variable periods of vegetation, deposition, subsidence, deposition

and revegetation continued throughout-most of the-Carboniferous-time. Orogenic forces near the end of the Pennsylvanian age,. approximately 280 million years--ago,, pushed the accumulated lithified sediments westward, crushing and stretching those to the east. This early event of the Appalachian Orogeny raised the rocks above sea level. The rocks west of the Allegheny Front were only mildly folded as they escaped the immediate effects of this mountain building process.

Occurring with and immediately following this folding, erosion cut down the folds and gradually reduced the entire area to a. region of broad flat hills and wide valleys. Such a surface is called a peneplane. The final peneplane, from which the present topography was carved following uplift, dates back to Tertiary time. This down-cutting etched out the new topography by a varied sequence of geologic processes. In some instances a stream was greatly hindered in its down-cutting when a hard, massive, resistant sandstone was encountered. When this occurred, the softer rocks overlying this sandstone within the drainage area were slowly eroded to a nearly level plane on which the stream eventually acquired a meandering course. It is possible that such delayed down-cutting created the general uniformity of the hilltops of the watershed as well as the meanderings of the Clarion River to the north. Other areas exhibit relatively level and evenly elevated hilltops for another reason; the uniform mineralogical character and the homogeneous structure has permitted a uniform erosion process. Erosion lowered this surface uniformly so that at any time it represented the level character of the peneplane from which it was formed. In many cases erosion cut the surface of the peneplane down until hard sandstones were encountered, so that today a hilltop may represent a residual bed of sandstone. Configuration of such a hill depends upon the structure and attitude of the original sandstone bed.

The present courses of the major streams of the area developed on the peneplane, and the meandering nature of the Clarion River suggests that it formed on a flat surface. Subsequent gradual uplift of the land surface without folding or faulting rejuvenated the slow-moving streams and reinitiated

Down-cutting while maintaining the pre-uplift courses of the streams, Thus, these streams exhibit incised, deep valleys with sometimes sinuous courses through the evenly elevated hilltops which serve as the only reminder of the peneplane surface. It should be noted that prior to glaciation all of the westward drainage flowed northwest to a master stream in what is now the Lake Erie basin. When the glacial ice closed these outlets, the drainage was directed to the southwest around the ice front, resulting in the present Ohio and Allegheny Rivers. This post-glacial drainage flowed, then, to the southwest corner of the state, following the bottom of the lower folds around the periphery of the anticlines.

The overall pattern developed by a system of streams depends primarily on the nature of the underlying bedrock and the geologic and geographic history of the area. Two principal type of drainage systems. result from different sets of geologic circumstances. Dendritic patterns, which resemble the branching habit of a deciduous tree, develop when the underlying bedrock is uniform in its resistance to erosion and exercises no control over the direction of valley growth. This situation occurs when the bedrock is composed either of flat-lying sedimentary rocks or massive igneous or metamorphic rocks. The dendritic pattern is, in essence, a random orientation of the streams. Trellis drainage patterns are frequently caused by zones in the bedrock that differ in their resistance to erosion. The trellis pattern generally indicates that the region is underlain by alternate bands of resistant and nonresistant rocks. The trellised nature of the Mill Creek watershed is the result of such conditions. The alternating sequence of sandstones and shales of the Allegheny Group combined with regional structural sequence of northeast-southwest trending anticlines and synclines produce the generally northeast-southwest orientation of the tributaries within the Mill Creek drainage system. On a smaller scale the dendritic nature of some of the tributaries is unaffected by the broader nature of regional structure.

Structure

There are three pronounced structural features present in the Mill Creek Watershed, the Kellersburg Anticline, Corsica, Syncline, and Roseville Anticline. The axes of these-structures-are roughly parallel, trending between N 30 degrees E and N 50 degrees E. The. Kellersburg Anticline initially strikes N-S as it enters the watershed just east of the Village of Day, and then strikes N 30 degrees E. This anticline produces exposures of lower Pocono rocks where it is bisected by Mill Creek and Little Mill Creek. The western flank of the anticline dips-to.-the northwest at about one percent and the eastern limb dips to the southeast at between two and three percent. Although the exact extent and configuration of the anticline is uncertain north of the Mill Creek Watershed, it is possible that the structure persists to the northeast becoming the Smethport Anticline of Elk County. The Corsica Syncline is a broad shallow structural basin north of Corsica and to the east of the Kellersburg Anticline. The syncline strikes N 60 degrees E and produces dips of between one and two percent on its flanks. The Corsica Syncline appears to tie in with another structural depression near Richardsville to the northeast. Further to the east the Roseville Anticline, an elongated dome, enters the watershed about three-fourths of a mile east of Roseville. This anticline, striking N 40 degrees E, leaves the watershed to the east midway between Alaska and Howe. The southwest closure of the Roseville Anticline is quite definitely determined by elevations on the Vanport limestone, but boundaries are somewhat less certain to the northeast. The anticline, with average dips of around two percent on its flanks, is. probably an extension of the Hebron Anticline of Elk and McKean Counties.

In the area west of the Allegheny Front. the folding was quite gentle in contrast to the close folding and faulting to be found in the Appalachian Valley and eastward. In many portions of the watershed the strata lie nearly flat or are only slightly folded locally.

Stratigraphy

The bedrock in the Mill Creek Watershed is entirely of sedimentary origin. These rocks are primarily of the Allegheny and Pottsville Groups of Middle

and Lower Pennsylvanian age. The Shenango sandstone of the lower Pocono Group outcrops in the stream valleys of Mill Creek near its mouth as well as at the mouths of several of the western tributaries to Mill Creek. The Mauch Chunk Formation and Burgoon sandstone have been entirely removed by erosion or were never deposited in this area, creating disconformity between the Shenango member and the overlying Pottsville rocks. Coals and clays in the watershed usually occur in beds less than five feet thick. The sandstones and shales in the watershed are quite variable with some beds reaching a thickness of 50 feet or more. The sandstones and shales frequently grade into each other vertically and horizontally with no distinct delineation between beds. The sandstones are often massive and are very abundant. Limestone beds in the watershed are almost non-existent, and those beds encountered are usually thin and impure.

The Allegheny Group was formerly known as the Lower Productive Coal Measures because of the numerous mineable coal seams that it contains. This group contains a variable sequence of shale, sandstone, limestone, clay, and valuable beds of coal. Sandstones are much less prominent than in the overlying Conemaugh Group or underlying Pottsville Group. The Allegheny Group includes all the strata between the top of the Upper Freeport coal and the base of the Brookville underclay. In areal extent this group covers nearly the entire watershed. Erosion has removed the upper portion of the group throughout much of the watershed and has removed these rocks entirely in the deeper valleys of the major streams, exposing the underlying Pottsville and Pocono Groups. Although there is considerable variation between members of the Allegheny Group, it has a relatively uniform thickness of about 325 feet. Due to the variable vertical sequence of this group and the inconsistant lateral extent of beds in the watershed, it is impractical to rely on a generalized geologic column as such a column would probably be quite different at any two locations.

The Allegheny Group has been divided into three formations: the Freeport, extending from the top of the Upper Freeport coal to the top of the Upper Kittanning coal; the Kittanning, extending from the top of the Upper Kittanning

coal to the base of the clay underlying the Lower Kittanning coal; and the Clarion, extending from the base of the Kittanning underclay to the bottom of the Brookville coal underclay.

The uppermost strata of the Allegheny Group is the Upper. Freeport coal which is an extremely variable bed both in thickness and lateral extent. The Upper Freeport generally exists as a single bed ranging from a few inches to 6 feet in thickness and averages about 4 feet thick. The Upper Freeport coal is generally overlain by a massive sandstone which grades to a sandy shale at places. The Upper Freeport clay, the Bolivar fire clay, usually underlies the Upper Freeport coal. This clay ranges from l to 15 feet thick and averages about 4 feet. Underneath the clay is the Upper Freeport limestone which occurs in places and ranges from 0 feet to about 5 feet in thickness. The limestone is replaced by a calcareous shale in many places. Below the limestone lies 35 to 50 feet of shales and sandstone. The Butler sandstone, reaching 20 to 30 feet in thickness frequently occurs in this interval. The Lower Freeport coal underlies the Butler sandstone, and is generally quite thin in this area, averaging a foot or less in thickness. This coal generally lies about 47 feet below the Upper Freeport coal. The Lower Freeport coal is underlain by up to 6 feet of fire clay. The interval between the Lower Freeport fire clay and the Upper Kittanning horizon contains a series of interbedded shales and sandstones. The Freeport sandstone, which ranges from a few feet to nearly 80 feet in thickness, occurs in this interval. The Freeport sandstone is quite variable, ranging from a flaggy, fine grained sandstone to a coarse conglomerate.

About 110 feet below the Upper Freeport coal a minor coal seam, the Upper Kittanning, occurs. This seam is thin and non-persistent, rarely reaching a foot in thickness. In many places the coal is entirely replaced by a carbonaceous black shale. Another thin rider coal sometimes occurs about 30 feet above the Upper Kittanning horizon. The Upper Kittanning coal is underlain by approximately 50 feet of shales with interbedded sandstones. Some areas of the watershed may exhibit up to 30 feet of Worthington sandstone at this interval. The Middle Kittanning coal is also variable in thickness

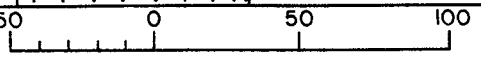
and persistency. There are few places in the watershed where the Middle Kittanning coal reaches workable thickness. Frequently this seam will split into two distinct beds separated by as much as 6 feet of shale. The Middle Kittanning coal is underlain by a plastic clay ranging from 2 to 12 feet in thickness and averaging about 5 feet thick. The strata below the Middle Kittanning coal and clay consists of up to 70 feet of shales and sandstones. The upper portion of this interval is largely sandstone or sandy shale and the lower portion is characteristically a fissile carbonaceous black shale. The Lower Kittanning coal is one of the more regular coals in the watershed. It ranges from 2 feet to $3^{1}2$ feet in thickness and is often called the "30 inch vein." The Lower Kittanning coal has been mined. throughout the watershed. A high grade plastic fire clay underlies the Lower Kittanning coal. This clay ranges in thickness from a few feet to nearly 20 feet, averaging 3 to 4 feet of good quality clay. The Kittanning sandstone lies below the clay and has a usual thickness of 30 to 50 feet. This member, in actuality, consists largely of greenish sandy shale and rarely becomes massive. The Vanport limestone lies from 30 - 50 feet below the Lower Kittanning coal. This limestone is sometimes referred to as the Ferriferous limestone because it is often capped by a thin bed of iron ore, often siliceous siderite, limonite, or hematite. The Vanport is a key bed through western Pennsylvania, being generally very persistent. It appears, however, that this limestone is present only in the southern portion of the watershed and is replaced by sandstone to the north. Where present, the Vanport is a highly fossiliferous bluish-gray limestone which generally runs over 90 percent calcium carbonate. The interval between the Vanport limestone and the Upper Clarion coal is 25 to 35 feet. The upper portion of the interval is black carbonaceous shale; the equivalent of the Scrubgrass coal horizon. The remainder of the interval is composed of greenish sandy shale. The Upper Clarion coal is quite persistent but averages only from 8 to 20 inches thick, generally. The interval to the Lower Clarion coal ranges from a few feet to about 20 feet and usually consists of plastic clay, clay shale, and black shale. The Lower Clarion coal has been a very important seam in this watershed. It is usually the thicker of the two Clarion seams ranging up to 32 feet thick. The Lower Clarion coal is often quite sulphurous. The Lower Clarion

coal is underlain by a bed of plastic clay ranging from 4 to 10 feet thick. Between the Clarion underclay and the Brookville coal is the horizon of the Clarion sandstone. This sandstone, which is generally fine grained, brown, and thin bedded, is frequently cross-bedded and often replaced by a sandy shale. This horizon is generally from 25 to 50 feet thick. The Brookville coal is the base of the Allegheny Group. Despite its name, the Brookville coal is generally quite poorly developed in the watershed usually being only 12 feet in thickness. This coal does reach 5 feet in thickness, however, along Mill Creek in Eldred Township, Jefferson County. The Brookville coal is often underlain by 1 to 4 feet of clay.

The Pottsville Group is generally from 150 to 200 feet thick in this area. The uppermost member is the generally massive Homewood sandstone. The Homewood sandstone is generally light brown and often streaked with iron oxide. The sandstone ranges from 20 to 80 feet thick, averaging about 40 feet. Underlaying the Homewood sandstone is the extremely variable Mercer shale and coal member. The sequence of shale, coal, and clay averages about 30 feet thick but at places reaches 70 feet in thickness. The Mercer coal generally appears as two seams, each only about 1 foot thick, The Mercer flint clay which is of major economic significance in Clearfield County is not so well developed in the watershed. The lower part of the Pottsville Group is occupied by the Connoquenessing sandstone which reaches a thickness of 90 feet in places. The base of the Pottsville is not distinquishable in this area as the underlying Mauch Chunk Formation and Burgoon sandstone
have been entirely removed by erosion or never deposited and the Connoquenessing sandstone rests unconformably on the Shenango sandstone of the Pocono Group. The Shenango sandstone is quite similar lithologically to the overlying Connequenessing sandstone. The Shenango sandstone outcrops in the deep valley of Mill Creek and possibly along the valleys of its major tributaries.

GENERALIZED COLUMNAR SECTION OF EXPOSED ROCKS

System	Group	Formation	Member	Section	Character of Member	General Character of Formation
PENNSYLVANIAN	CONEMAUGH		Lower Mahoning sandstone		Sandstone and sandy shales	Generally removed by erosion in the Watershed
	ALLEGHENY	Freeport	Upper Freeport coal		Persistant, average thickness 4'	A variable sequence of shale, sandstone, limestone, clay, and valuable beds of coal. Average thickness is about 300'– 350'.
			Butler sandstone			
			Lower Freeport coal		Thin, not persistent	
		Kittanning	Freeport sandstone			
			Upper Kittanning rider		Thin, variable	
			Upper Kittanning coal		Thin, variable	
			Middle Kittanning coals		Two seams, irregular	
			Lower Kittanning coal		Very persistent, average thickness 2½' to 3½'	
		Clarion	Vanport limestone			
			Scrubgrass coal		Thin, often absent	
			Upper Clarion coal		Persistent, average thickness 2'	
			Lower Clarion coal		Persistent, average thickness 3½'	
			Clarion sandstone		Fine grained, cross-bedded	
			Brookville coal		Variable, often split	
	POTTSVILLE		Homewood sandstone		Fine grained, often irony	Consists primarly of sandstones, often massive, with some unimportant coal beds and fire clay
			Mercer coals Mercer clay		Thin, variable. Generally two seams	
			Connoquenessing sandstone		Massive, fine grained	
			Disconformity			
MISSISSIPIAN	POCONO		Shenango sandstone			Only the lower portion of Mississippian age rocks appear in some of the deeper stream valleys. The Mauch Chunk Formation and Burgoon Sandstone have been removed by erosion or never deposited.



Coal Seams

Practically all of the coal mined in the project area is that of the Allegheny Group. The only exception is the Mercer coal seam of the Pottsville Group which is mined locally on a limited scale, primarily for house coal. In general, the coals increase in thickness from west to east and the number of seams increase in the same direction. Fixed carbon increases from west to east also. There may be as many as ten or more coal beds in the watershed; four of these are probably mined quite extensively and the others have been mined only on a small scale locally. The principal coal seams in the watershed are the Brookville, Lower Clarion, Upper Clarion, and Lower Kittanning. Workable beds range from slightly less than 2 feet in thickness to about 6 feet thick. The coal seams present in this area are generally all considerably less than 400 feet deep. Throughout most of the area some or all of the Allegheny Group coals have been removed by erosion. The coals of the watershed are underlain practically everywhere by clay. The principal coals of the Mill Creek Watershed are as follows:

Upper Freeport

Also known as E seam. The Upper Freeport coal is generally one of the most persistent beds of the Allegheny Group reaching thicknesses greater than 6 feet in parts of Clarion and Jefferson Counties. This seam, however, has been removed by erosion throughout most of the Mill Creek Watershed.

Lower Freeport

Also known as D seam. The Lower Freeport coal is quite regular throughout most of Clarion County averaging about 311 feet in thickness but being split by thick partings of shale or bone. In the Brookville area of Jefferson County only the Upper Freeport coal is of any significance while the Lower Freeport horizon exhibits only a very thin coal seam. The Lower Freeport coal has also been removed by erosion throughout most of the Mill Creek Watershed.

Upper Kittanning

Also known as C' or Pot Vein. The Upper Kittanning coal is of only

minor importance in this area. This coal ranges from a few inches to nearly 4 feet thick and may-occur as several seams. The Upper Kittanning coal is generally only about a foot thick. Most of the cannel coal in the state appears to occur at this horizon.

Middle Kittanning

Also known as C seam. The two Middle Kittanning coals generally about 15 feet apart are very irregular but may reach a thickness of nearly 3 feet locally. One of the seams is generally absent. The Middle Kittanning was reportedly mined at many places around Roseville and Corsica, but may have been confused with the Lower Kittanning coal, as the Middle Kittanning seldom exists in the thickness reportedly mined.

Lower Kittanning

Also known as B or 30 Inch Vein. The Lower Kittanning coal is present throughout most of the watershed and is probably the most persistent coal' of the Allegheny Group in the watershed. The coal is well developed throughout the southern half of the watershed and has been mined extensively in this area. The Lower Kittanning is commonly 30 inches thick but reaches 4 feet in thickness throughout much of this portion of the watershed. In the western end of-the watershed the coal generally exists as two benches separated by an inch or two of bone. This coal is underlain by fire clay between 3 and 20 feet thick, the upper 3 to 4 feet of which is high quality plastic clay.

Upper Clarion

The upper Clarion coal alone is generally not worthy of commercial exploitation, averaging only 20 inches in thickness, and is usually mined along with the underlying Lower Clarion coal 10 to 20 feet below. Elsewhere in Clarion County this coal reaches 4 feet thick in small areas.

Lower Clarion

Also known as A' or Sulfur Vein. The Lower. Clarion coal has been an important coal particularly in the western portion of the watershed. The

Lower Clarion coal ranges from 2 feet to 7 feet in thickness and is consistently 5 to 6 feet thick throughout much of Clarion Township, Clarion County. The Lower Clarion-coal frequently contains a large quantity of iron pyrite, and is split by lenses of pyritic shale and bone. Both of the Clarion seams are frequently underlain by fire clay.

Brookville

Also known as the A or Craigsville coal. The Brookville coal is very variable, ranging in thickness from a few inches to about 5 feet. Throughout much of this area, particularly in the western portion of the watershed, the Brookville bed is split by two bone partings 1 to 4 inches thick. The Brookville seam is often high in sulfur and quite dirty, thus decreasing its value.

Mercer

This is the uppermost coal of the Pottsville Formation. This coal is of little economic consequence in this area. It is frequently represented by several seams none generally exceeding 12 inches in thickness, although scattered locations exhibit Mercer coals of workable thickness. Two seams of Mercer coal totaling nearly 3 feet have been mined in stream valleys north of Roseville.

Clay

Underclays occur immediately under nearly every coal seam present in the watershed. Although these underclays are more refractory than most other clays and are quite often suitable for use in the manufacture of fire brick, to label them as fire clays is inaccurate. The term fire clay is restricted to flint clay and only the most highly refractory plastic underclays. The underclays differ chemically from other clays and shales, having smaller amounts of fluxing elements such as oxides of iron, lime, magnesia, soda, and potash. The absence of these elements gives the underclay a much higher melting temperature. The small percentage of fluxing elements present in the underclays has been attributed to their association to the plant life which formed the overlying coal seam. The fluxes have alledgedly been removed by the plant

roots for use by the plant. The Lower Kittaning and Lower Clarion underclays have been the most economically significant clays-in the watershed, being mined in many areas of Clarion and Jefferson Counties. They are potentially significant in the watershed itself although they have not, as yet, been developed. These clays have an average thickness of 6 to 8 feet and range as high as 20 feet thick in places.

Flint clay by comparison contains almost no fluxing elements, and therefore has a high refractory value. These clays are chiefly associated with and are very possibly a modification of the underclays. Flint clay is of two types: block clay and nodular clay. Block clay resembles limestone in appearance, having a sharp, flint-like fracture and breaking with smooth conchoidal surfaces. It is hard enough to ring under a hammer blow and does not weather to a plastic mud as do most clays. Nodular clay, on the other hand, has low rounded protuberances and breaks unevenly. There is no general qualitative difference between flint clay and nodular clay. Flint clay, if ground and molded by itself, will not bond into brick but must be mixed with a certain proportion of plastic clay. The Mercer flint clay is present in the watershed but has not played the significant economic role that it does in other parts of the Pennsylvania Bituminous Coal Field, such as in Clearfield County.

MINING HISTORY

The Mill Creek Watershed was first viewed by white men in 1788 when David and John Meade blazed a trail through this heavily forested area. It was this forest that led to settlement of the region about 1800. For years lumbering was the chief industry in the watershed, the first sawmill being built in the area in 1805 just south of Clarion. The lumber industry boomed during the mid-1800's with lumber being floated down the Clarion River to the Allegheny River and thence to Pittsburgh. The first coal mined in the area was in 1832 by Charles Anderson. Mr. Anderson lived in Brookville and opened a small drift in two feet of coal on the Joseph Clements farm northwest of Brookville. At the time of the Second Geological Survey of

Pennsylvania investigation of the area in 1880, there were many small active drift mines. By 1920 coal mining had become the principal industry of the area but it decreased in importance rapidly up to World War II. During this time the development of natural gas production occurred in the area. The importance of both coal and natural gas production increased with the Second World War and continues today. Agriculture began to increase in importance around the late 1930's with particular emphasis on the growing of potatoes and raising of dairy cattle.

The mineable coals of the watershed are all relatively shallow and hence coal mining has been restricted to strip mining and small scale drift mines. There has been no need for extensive deep mining and there are currently no active deep mining operations in the Mill Creek Watershed. Companies presently conducting strip mining operations in the watershed include Bracken Construction Company of Sligo, Pennsylvania, W. P. Stahlman Coal Company of Corsica, Pennsylvania, and Zacherl Coal Company of Lucinda, Pennsylvania.

Although strip mining has been a major industry in the watershed, particularly in the southern portion, considerable reserves remain in the ground. The estimated reserves for the four townships comprising the Mill Creek Watershed are as follows:*

Clarion Township (Clarion Co.)

	Acres**	Original Deposit (tons)	Recoverable (tons)	Mined to Date (tons)**
U. Kittanning	940	2,300,000	1,700,000	
M. Kittanning	1,590	5,200,000	2,600,000	130,000
L. Kittanning	6,930	28,300,000	18,000,000	1,200,000
Clarion	10,450	76,800,000	50,000,000	5,600,000
Brookville	18,240	44,700,000	28,700,000	

* Reese, John F. and Sisler, James D. "Bituminous Coal Fields of Pennsylvania - Coal Resources" Pennsylvania Geological Survey 4th Series, Bulletin M6

** Estimated

Millcreek Township (Clarion Co.)

	Acres**	Original Deposit (tons)	Recoverable (tons)	Mined to Date (tons)**
L. Kittanning	370	1,500,000	900,000	60,000
Clarion	2,380	17,500,000	11,400,000	460,000
Brookville	4,290	10,500,000	6,300,000	90,000

Eldred Township (Jefferson Co.)

	Acres**	Original Deposit (tons)	Recoverable (tons)	Mined to Date (tons)**
Brookville	13,570	77,660,000	50,100,000	--

Union Township (Jefferson Co.)

	Acres**	Original Deposit (tons)	Recoverable (tons)	Mined to Date (tons)**
U. Kittanning	3,550	8,700,000	6,000,000	--
M. Kittanning	4,440	14,500,000	11,000,000	560,000
L. Kittanning	5,700	23,300,000	16,000,000	2,000,000
Brookville	6,830	27,900,000	17,500,000	1,200,000

** Estimated