PENNSYLVANIA GEOLOGY

THE PENNSYLVANIA GEOLOGICAL SURVEY VOL. 18/6

COMMONWEALTH OF PENNSYLVANIA
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TOPOGRAPHIC AND GEOLOGIC SURVEY
Donald M. Hoskins, Director

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ON THE COVER: Aerial view of the rockslide on Interstate Route 81 southeast of Nanticoke, Luzerne County, as it appeared on March 21, 1986, one day after cut-slope failure. Note the long headwall scarp and the blocky nature of the slide mass. (Photograph courtesy of the Pennsylvania Department of Transportation.)

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A River Runs Through It

On occasion come stories that are meant to be shared. Few works of fiction include geology in a way that describes some of the beauty of our science. This is one. Although geology plays only a small part in these stories, those of you who are fishermen, foresters, geologists, or poets, and others who don't mind trees, will enjoy the three stories included in *A River Runs Through It and Other Stories*.

Norman Maclean included under this title two novellas and a short story, which were published by the University of Chicago Press in 1976. These are stories of out-of-doors experiences written so eloquently that geology is a natural part of the main themes of fly fishing, logging, and summer jobs with the U.S. Forest Service. While probing the mysteries of the human players in the stories, Maclean includes much of nature's arts. In his story on the U.S. Forest Service he writes, "You might never have heard the word geology and yet have known the instant you looked down Blodgett Canyon that you were looking at a gigantic, glacial classic. For thousands of years it must have been a monster of ice hissing in the cracks of mountains." Such is the flavor of his writing. These are the stories of a fisherman, philosopher, and poet who understands the geology of the rivers that run through rocks.

Anyone who wishes to learn or relive fly fishing in the great trout rivers of the Continental Divide and to learn of the geologic origins of the rivers, or to know logging in the quiet days before chain saws, or to discover how long is a Forest Service mile when climbing steep trails alone to a fire tower, will need to obtain a copy of this book. For the winter solstice season it is a marvelously good read!

Donald M. Hoskins
State Geologist

The Nanticoke Rockslide of March 20, 1986

by Duane D. Braun, Bloomsburg University, and J. Peter Wilshusen and Jon D. Inners, Pennsylvania Geological Survey

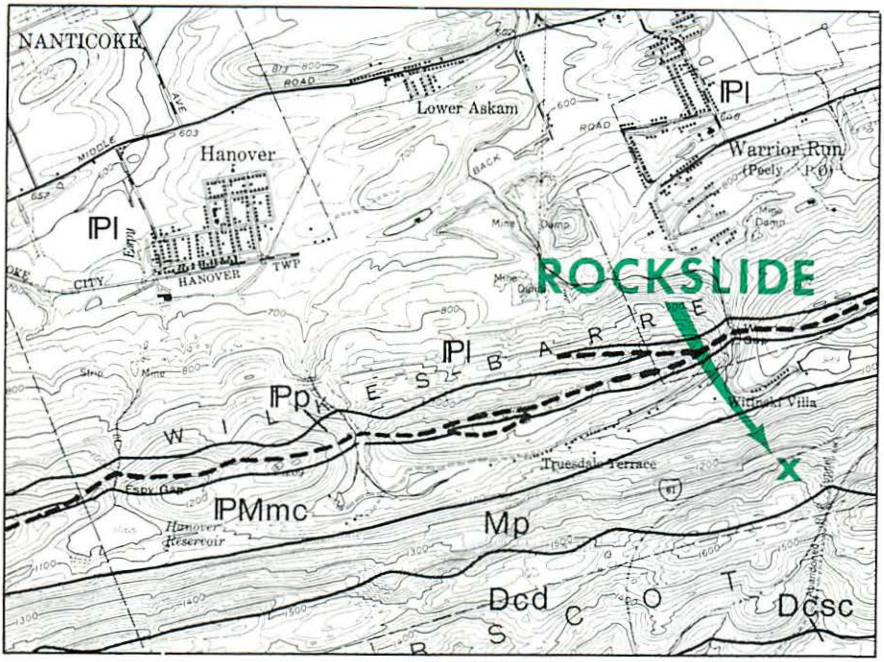
INTRODUCTION

At 12:15 a.m. on March 20, 1986, a massive rockslide blocked all three southbound lanes of Interstate Route 81 approximately 2 miles southeast of Nanticoke, Luzerne County, northeastern Pennsylvania (Figure 1). The failure occurred in a deep cut on the dip slope of Penobscot Mountain, one of several spectacular rock cuts excavated in the mid-1960's to allow passage of Interstate Route 81 through the southeastern rim of the Wyoming-Lackawanna basin. Because cuts on both northbound and southbound lanes expose rock layers that dip directly into the roadway, this section of Interstate Route 81 had long been suspected of being particularly susceptible to rockslides. For this reason, geotechnical engineers of the Pennsylvania Department of Transportation (PennDOT) had visually monitored its behavior on several occasions. The cuts appeared to be stable, however, and only a few falls of individual rocks took place in the 20 years between construction of the highway and the failure of March 1986.

Luckily, the cut slope in question failed catastrophically at a time of minimal traffic volume on the highway. Although one car—a Corvette—ran up over the rock pile an instant after the slide had stopped moving, no one was injured. By early in the afternoon of the same day, PennDOT maintenance crews had cleared enough of the debris to permit southward traffic flow in the outer two lanes. The third lane was opened several days later.

GEOLOGIC SETTING

The mountainous southeastern rim of the Wyoming-Lackawanna basin in the vicinity of Nanticoke is formed by clastic sedimentary rocks ranging from the Upper Devonian Duncannon Member of the Catskill Formation to the Lower Pennsylvanian Pottsville Formation (Figure 1). Penobscot Mountain, the higher of two northeast-southwest-trending ridges, is underlain by the Duncannon Member on its southeastern, or scarp, slope and the Lower Mississippian Pocono Formation on its northwestern, or dip, slope. The cut-slope failure of March 20, 1986, took place in the latter unit.



EXPLANATION

ℙl—Llewellyn Fm.
ℙp—Pottsville Fm.
ℙMmc—Mauch Chunk Fm.
Mp—Pocono Fm.

Dcd—Duncannon Mbr. of Catskill Fm.
Dcsc—Sherman Creek Mbr. of Catskill Fm.

Geologic contact
Includes approximately located and inferred contacts.

Fault
Approximately located.

SCALE
0 1/2 MILE

Figure 1. Geologic map of a portion of the Wilkes-Barre West quadrangle, showing the site of the rockslide on Interstate Route 81. Geology after Sevon, in Berg and Dodge (1981), and Bergin (1976).

The Pocono Formation at the site of the rockslide is medium- to thick-bedded (mostly 1- to 2-foot beds), trough-crossbedded, medium-gray, medium- to coarse-grained, micaceous quartzose sandstone, containing thin, discontinuous beds of medium-light-gray mudstone. These rocks represent the deposits of a great braided-river system that developed along the margin of the Appalachian highlands approximately 360 million years ago (Inners, l978).

Structurally, the site lies on the southeast limb of the Wyoming-Lackawanna synclinorium, a complex, canoe-shaped downfold that contains the numerous anthracite seams of the Northern Anthracite field. Bedding planes dip at moderate angles (30 to 50 degrees) to the northwest, and conspicuous strike and dip joints are mostly subvertical. Spacing of the joints varies from less than 0.5 foot to 10 feet, averaging 1 to 2 feet. The bedding planes and joints are geologic discontinuities which greatly facilitate the percolation of vadose water and the circulation of groundwater through the rock mass.

The area lies 10 to 15 miles northeast of the late Wisconsinan terminal moraine (Crowl and Sevon, 1980) and was last subject to the rigors of continental glaciation about 15,000 years ago. Preserved glacial deposits are very sparse on the mountain slopes, however, and none were observed locally.

THE ROCKSLIDE OF MARCH 20, 1986

At failure, the slide mass was approximately 185 feet wide, 40 feet long, and 20 to 40 feet high and had a total volume of approximately 7,000 cubic yards (see cover). The limiting discontinuities of the failure consisted of a curved, subvertical strike joint (head scarp), subvertical dip joints (side scarps), and several undulatory bedding planes (slide surface) (Figure 2). Shear failure took place mainly within weathered mudstone lenses that partially fill several adjacent northwest-plunging crossbed troughs. At the extreme northeast end, however, slippage occurred on a 1- to 2-inch band of friable sandstone that had been intensely leached and oxidized by the intermittent movement of perched groundwater. The average size of blocks in the slide—1 to 2 feet on a side—reflected the typical spacing of bedding planes and strike and dip joints; one huge block—more than 10 feet square—remained intact at the extreme northeast end (Figure 3).

The trigger for the rockslide may have been two periods of rainfall 5 days (3.1 inches within 24 hours) and 10 hours (0.4 inch within

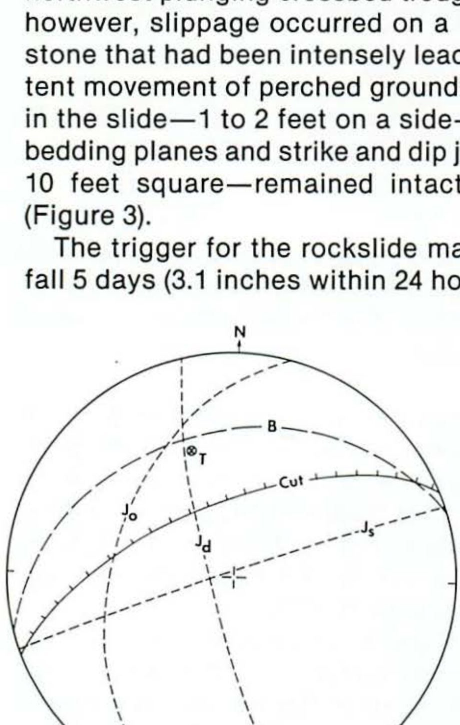


Figure 2. Stereogram (equal-area lower hemisphere projection) of discontinuity planes in the Pocono sandstone at the site of the rockslide on Interstate Route 81. Bedding: B, N73E/35°NW (failure surface). Joints: Js, N70E/89°NW (head scarp); Jd, N15W/82°SW (side scarps); Jo, N15E/46°NW. Axis of crossbed trough: T, N20W at 40°. The cut face shown (N66E at ½ to 1, or 63°) is the design cut slope prior to failure.

Figure 3. View of the northeast end of the rock-slide, showing the large intact block adjacent to the side scarp. Note the subvertical head scarp.

3 hours) before failure (Figure 4; Inners and others, 1987). Excess pore-water pressure in the mudstone lenses probably reduced shear strength below a critical level, leading to abrupt slippage. The 5-day

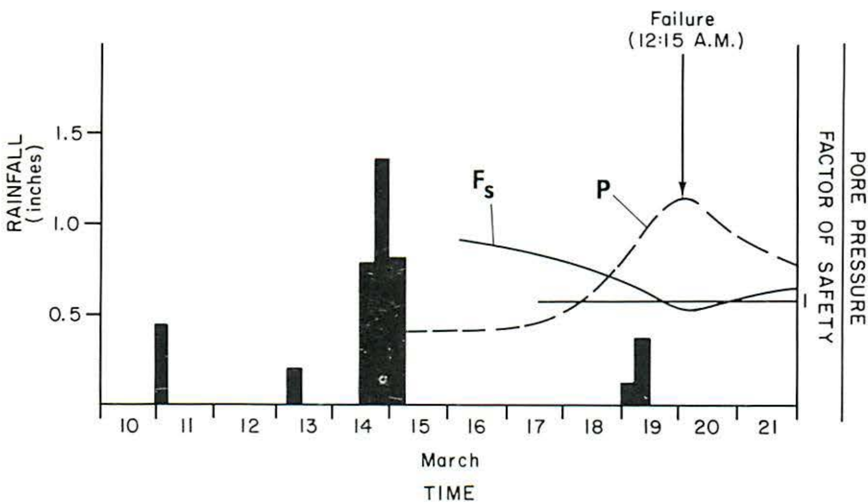


Figure 4. Composite of histogram of rainfall at Wilkes-Barre Scranton airport, Avoca, Pennsylvania, in mid-March 1986 (data from National Oceanic and Atmospheric Administration, 1986) and graphs of the ideal temporal relationship of pore pressure and factor of safety to period of rainfall (from Freeze and Cherry, 1979). Note the lag time between peak rainfall and slope failure at the presumed maximum pore pressure within a slope.

lag between the major rainfall event and failure is apparently related to the time it took for the precipitation to infiltrate from the surface and upslope of the incipient slide and generate maximum pore-water pressure within the potential slide surface and the headwall tension crack (Freeze and Cherry, 1979; see Figure 4). Wilson and Dietrich (1985) observed a similar delayed response (about 4 days) in the maximum pore-water pressures registered in piezometers in an incipient slide mass on a slope in the California Coast Ranges.

But why did the cut slope fail on this particular occasion more than 20 years after construction of the highway? Considering that the shear stress imposed by the weight of the incipient slide mass has been relatively constant since the cut was excavated and that high excess pore-water pressures have probably developed in the slope on many occasions, it seems likely that only a weakening of the bond across the slide surface over time can account for the failure. Both weathering and fatigue could cause critical reductions in strength of the mudstone and sandstone that would lead to slippage of the bedrock wedge off the slope.

Repair of the Nanticoke rockslide caused an extensive traffic detour, took several days of unplanned-for work time, and cost approximately $53,000.

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EARTH SCIENCE TEACHERS' CORNER

by The Schoolhouse Mouse

If We Don't Teach Them, Who Will? A New Teaching Resource for the Earth Sciences

One pitfall geologists and miners have historically succumbed to is our reluctance to explain what we do, why we do it, and how it makes life a little easier and safer for the rest of the population. We have had a difficult time with the social and political aspects of extracting mineral resources from the earth's crust.

Fortunately, we have Robert L. Bates, Professor Emeritus at Ohio State University, and, among other things, founder of the annual Forum on the Geology of Industrial Minerals, who has given us tongue-tied professionals books with which we can explain to our children (and curious neighbors) the wonders of the earth's crust and man's ingenuity.

Stone, Clay, Glass—How Building Materials are Found and Used, published by Enslow Publishers, Inc., should be required reading for every intermediate schoolchild in Pennsylvania. In a succinct 60 pages, Bates explains the history, uses, and occurrences of construction materials and their importance in our everyday lives. Although there may be more glamorous mineral commodities, none have played a more significant role in the development of Pennsylvania and the nation. As an example of Bates' humor, skill, and wit, do you know what nummulites and vanity had to do with one of the seven wonders of the world, or how the Romans' thirst for water is related to arches and concrete? Did you know that the quarries that supplied marble for the Parthenon in Greece (Temple of Maidens for you students not yet paying attention) are still in business after 2,000 years, or that a supercooled liquid that we take for granted every day has a case of arrested development but is rich in silica? Do you know

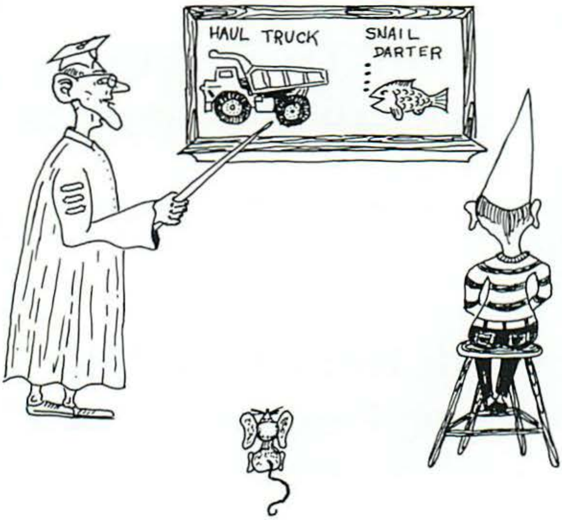

Figure 1. The well-rounded environmental education.

what a plaster sandwich is? What construction material is being used by the chef in the following recipe?

> Take 2 cups crushed limestone; add one-half cup clay or ground-up shale; mix thoroughly and grind fine. Bake in white-hot oven at about 1427°C (2600°F). Cool. Add 1 teaspoon gypsum and grind very fine.

Intermediate-grade science teachers in Pennsylvania will find this book an invaluable teaching aid in the earth science curriculum. Furthermore, Bates' wisdom, gained from many years in the teaching profession, is evident throughout. For example, teachers could find inspiration on what to do with that particularly troublesome student, and every class has one, by creative assignments such as picking out a grain of clay.

Pennsylvania has always been a leading state in the production of industrial minerals as well as building materials; recent values have totaled nearly one billion dollars per year. We should be proud of our mineral heritage and what this industry has accomplished. For those students (young and old) who would like to learn more, we recommend other contributions by Bates and J. A. Jackson such as *Our Modern Stone Age,* published by William Kaufmann, Inc. This well-illustrated book includes such chapters as "Rocks en Route," "The Disassembly Line: Taking Rocks Apart," and "Blast It Out and Break It Up (But Not in My Neighborhood)." A well-rounded environmental education (Figure 1) should include an understanding of our dependence on industrial rocks and minerals and the role of geology and technology in producing them.

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Cumberland County's BIG SPRING

by Michael W. Smith, Pennsylvania Department of Environmental Resources, Bureau of Mining and Reclamation, and William E. Kochanov, Pennsylvania Geological Survey

Big Spring, located approximately 3 miles south of Newville in western Cumberland County, is Pennsylvania's fifth largest spring (Flippo, 1974) (Figure 1). Aside from its large volume discharge (from 11,000 to 16,000 gal/min [gallons per minute]), it has unique hydrogeological characteristics and has played an important role in the history and development of Cumberland County.

Figure 1. Big Spring (photograph from Geyer and Bolles, 1979).

HISTORY, 1700 TO PRESENT. Indians were numerous along Big Spring when Andrew Ralston settled there in 1728. Around 1733, after both banks of the spring had become populated by Scotch-Irish and German settlers, trouble with the Indians began and continued for many years. In a record dated August 17, 1764, an account was given of a young woman, the daughter of James Dysart, who, while "going home from a sermon at Big Spring last Sunday was met with, murdered and scalped and left naked by the enemy. . ." (Rife, 1965). Despite such hair-raising episodes, most of the land around Big Spring was settled by 1750. This was due in part to the large grants of land that were offered to settlers as an incentive to construct and operate grist mills to supply England's army during the French and Indian War. Thus, the spring took on new importance as a source of power for the mills. With such an interest in the Big Spring area, the town of Springfield, located at the head of Big Spring Creek, was at one time considered as a possible county seat.

Due to the plentiful and relatively constant flow of Big Spring Creek, most of which is provided by Big Spring, six mills were spread out along its length (Figure 2). The McCracken Mill was probably the most important because it was located at the head of the spring and could operate at a much greater capacity. The success of this mill stemmed from an incident in 1877 in which the owners of the mill received an order for 50 barrels of flour from a firm in New York. The order was filled promptly because the flour was going to Queen Victoria of England. To the delight of

Figure 2. Locations of the mills along Big Spring Creek (base map dated 1872; photographed from 1985 calendar of the Newville Historical Society, Newville, Pa.).

the Manning Brothers, who were operating the mill at that time, Queen Victoria was so pleased with the quality of the flour that she ordered an additional 100 barrels. The enterprising operators took advantage of this bit of good fortune and were soon advertising, "flour good enough for the Queen should be good enough for anybody" (Kressler, 1965).

Throughout their history, the mills along Big Spring produced flour, timber, paper, and knitted goods and were in operation until the 1930's. All of the mills have since been dismantled, leaving behind remnants of mill dams, ponds, and raceways.

Although the spring is no longer used for milling, its water is still an important resource. Currently, the Pennsylvania Fish Commission pumps from 6 to 10 million gallons of water daily from the spring to raise trout at its Big Spring Hatchery. Due to the nearly constant flow and temperature of the spring, which provide excellent conditions for trout, Big Spring Creek is classified as a "limestone spring wild trout water."

HYDROGEOLOGY. Big Spring discharges from the Stoufferstown Formation, a Lower Ordovician limestone of the Beekmantown Group (Figure 3). Becher and Root (1981) studied the hydrogeology of the area and noted that the apparent groundwater drainage area of Big Spring (approximately 5¼ square miles) was far too small to maintain the large discharge from the spring. They also noted that Yellow Breeches Creek and its tributaries, directly south of Big Spring, lose water and usually are dewatered over this section during the summer and fall months and that the water from the spring exhibits lower specific conductance than groundwater from most wells in the area. The most likely explanation for the large flow of Big Spring, they concluded, was that water on the flank of South Mountain, which enters bedrock solution openings through the colluvium along the mountain flank, flows under Yellow Breeches Creek to Big Spring.

To further examine the hydrologic characteristics of Big Spring and to verify Becher and Root's conclusions, the Pennsylvania Geological Survey installed a continuous-recording stream gage at the former McCrackens Mill Dam, approximately 600 feet downstream from the spring, which includes the flow of several smaller springs discharging a short distance downstream from Big Spring. The flow was measured over a period of one year (April 10, 1986, to April 9, 1987). The hydrograph (Figure 4) shows that the spring flow is fairly constant throughout the year, although highest flows of 38 ft^3/s (cubic feet per second) (17,000 gal/min) occurred in April and lowest flows of 25 ft^3/s (11,000 gal/min) occurred in late September and early October. Some response is shown to individual precipitation events, indicating at least some local recharge to the spring, which is probably facilitated by karst features. Because of evapotranspiration losses, summertime precipitation events generally result in less recharge compared to rainfall or snowmelt during the nongrowing season. Periodic temperature and specific-conductance measurements taken by staff of the Pennsylvania Fish Commission also show little fluctuation. Water temperatures varied little from 11 °C except for a rise of 0.5 °C during the summer months and a decrease of 0.5 °C during January and February.

During the year-long measurement period, Big Spring and associated springs had an average discharge of 30.5 ft^3/s. The average recharge rate for the basin of 17 inches per year can only account for approximately 6.6 ft^3/s, given the apparent size of the groundwater basin. A portion of Yellow Breeches Creek south of Big

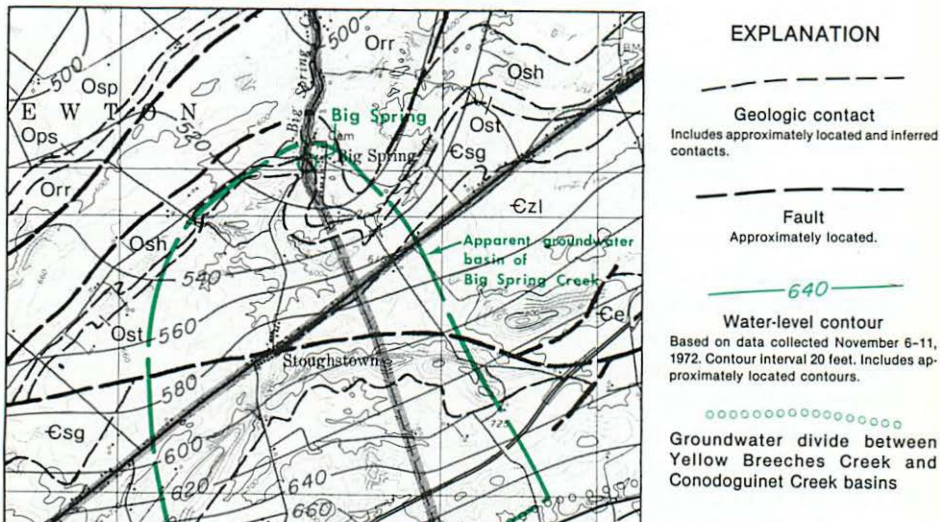

Figure 3. Geologic map of the Big Spring area. Geologic contacts, water-level contours, and groundwater divide from Becher and Root (1981).

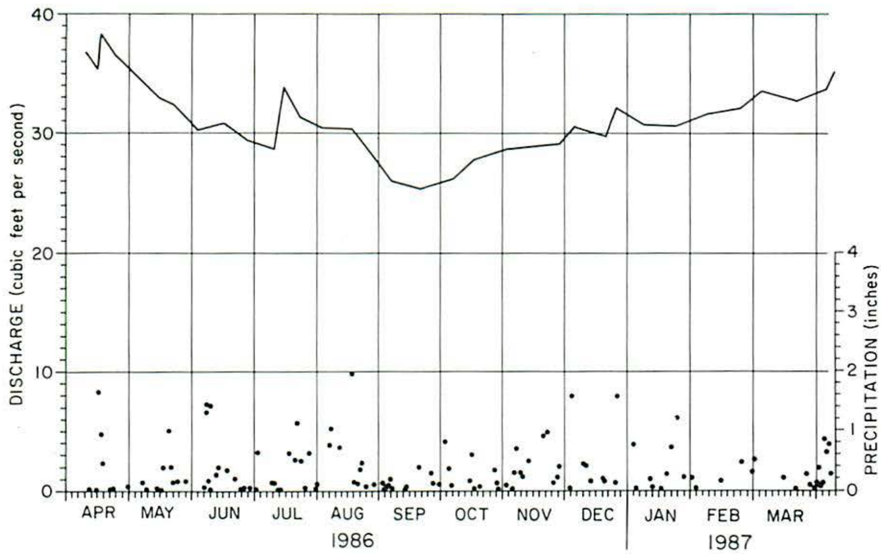

Figure 4. Discharge hydrograph and daily precipitation values at Big Spring for the period April 10, 1986, through April 9, 1987. Precipitation data were supplied by the Pennsylvania Fish Commission.

Spring flows across its own groundwater divide into the Big Spring groundwater basin. Streamflows of Yellow Breeches Creek were measured in this reach of stream, which exhibited losses of approximately 2 ft^3/s, still far less than the quantity that would be required to make up the "extra" flow volume of Big Spring.

It appears, then, that Becher and Root were correct, even though the groundwater flow beneath Yellow Breeches Creek is not manifested in the water-table-elevation contours. Also, a north-south-oriented conduit system may be present which transmits groundwater to the spring. At least one cave, Skelly Cave, that has observable conduit groundwater flow is present near the spring, and additional interconnecting conduits probably exist.

A well-known aspect of carbonate hydrogeology is the difficulty in determining groundwater-flow directions and recharge areas. Through groundwater underflow, Big Spring "steals" water from the Yellow Breeches Creek basin and transfers it to the Conodoguinet Creek basin. As seen with Big Spring, however, groundwater underflow is rarely obvious and can only be detected through extensive geologic and hydrologic investigations.

The authors wish to acknowledge Al Becher of the U.S. Geological Survey, Gene Rozaieski and David Bierly of the Pennsylvania Fish

Commission, and Georgia Rife of the Newville Historical Society for their assistance and contributions to this article.

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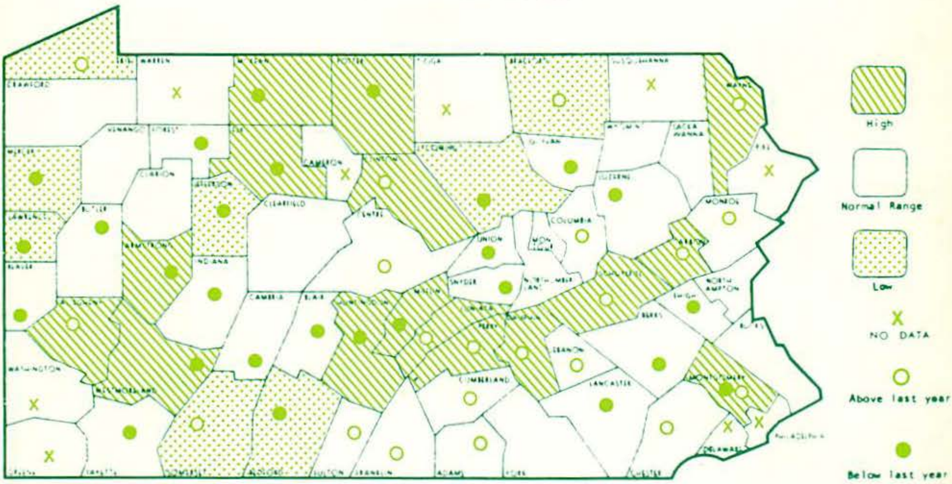

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