Ground-Water Problems of Pennsylvania[1]

By J. B. Graham[2]

Jack Bennett 1913-

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ABSTRACT

Although Pennsylvania's overall supply of ground water is adequate for most present and estimated future needs, serious ground-water problems exist in some heavily populated and industrialized locations. Such problems are largely the result of inadequate hydrologic information, unwise engineering planning, and indifference to practices which result in water pollution.

Large withdrawals for air-conditioning use in Pittsburgh have caused ground-water levels in parts of the Golden Triangle area to decline so much that little additional development appears possible. However, large potential supplies occur in nearby valley deposits along the Allegheny and Ohio Rivers.

In the south part of Philadelphia heavy ground-water pumpage has induced movement of chemically inferior waters into the principal aquifer. The concentration of dissolved minerals has increased so greatly in recent years that continued use of ground water by south Philadelphia's industries and by the United States Naval Base is seriously threatened.

Although about five hundred million gallons of ground water are pumped daily for municipal, industrial, and rural requirements in Pennsylvania, it is believed that extensive supplies of undeveloped ground water are present in the Commonwealth, chiefly in glaciated areas and in valley deposits of streams that once carried glacial meltwater.

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Ground-Water Problems in Pennsylvania

By

Jack B. Graham*

INTRODUCTION

Pennsylvania, the Keystone State, owes its high place in the history and development of our Nation to several factors. Located in the center of colonial development, her streams became arteries of transportation, and her soils and forests supported much of the colonies' requirements for food and timber. And straddling the Appalachians with their great coal resources, with one foot on the Atlantic Coast and the other in the Ohio Valley, the Commonwealth was foreordained to play a stellar role in the country's industrial growth.

Although coal, oil, and gas have been perhaps the most abundant and most valuable of the State's mineral resources, several hundred different types of minerals are known to occur, and some 35 of these have proved to be of great commercial value.

Pennsylvania's mineral wealth is a reflection of the greatly diversified geological conditions found within her borders. Rocks of many ages, representing a large portion of the history of the earth, are found at one place or another within the State and this variety of rocks of different ages is expressed in the diverse topography of the State, adding beauty and contrast to the wealth buried

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beneath the soils. From the fringe of Coastal Plain of the Philadelphia area across the folded Appalachians to the dissected Allegheny Plateau of Erie County, many kinds of industries have sprung up supporting prosperous rural and urban populations.

In the background of Pennsylvania's past and present importance as a center of production is the abundance and ready availability of her water resources. Pennsylvania is blessed with a relatively uniform distribution of precipitation, averaging about 42 inches a year, or 13 inches more than the average for the United States. This abundance of water has resulted in a closely spaced network of perennially flowing streams, making some surface water accessible to practically every community in Pennsylvania. The pore spaces and cracks in the rocks beneath the land surface receive a part of the water of precipitation and transmit generally dependable supplies of ground water to springs and wells.

Thus, early in our national history it was evident that this state's favorable location and abundant natural resources destined Pennsylvania to become a colossus of production. Before 1900, workers in the mineral industries of Pennsylvania produced about half the total mineral wealth of the United States. Then, as population and markets spread westward, other states began to compete, but it was not until 1935 that Texas replaced Pennsylvania as the most important producer of mineral wealth.

The long period of the State's supremacy in production was not without a depleting effect on its resources, and its abundant waters

have suffered with the rest. Each new plant for steel, paper, or other manufactured products tapped the nearby rivers or underground reservoirs for an ever increasing supply of water. Towns and cities were constantly adding to their water facilities, and even on the farms electric power and modern plumbing meant increasing the use of water many fold. Now, it is not uncommon for a large industrial plant to use more than a hundred million gallons of water a day. The present total water use in Pennsylvania can be given only in approximate terms but a conservative computation indicates that if the total average pumpage from wells, rivers, and lakes in the State were distributed equally, there would be more than 700 gallons a day for each Pennsylvania resident. Most of the water used in Pennsylvania is for large industries, and their supply is generally obtained from the larger rivers and lakes. Ground water furnishes the supplies for most rural users and for the majority of the small boroughs.

The use of ground water in Pennsylvania is very large, although as of 1950 it was still less than one-tenth that of surface water. About 80 million gallons a day are needed for rural use. Public supplies require about 100 million gallons a day, and private industry use not less than 300 million gallons a day. The total of nearly half a billion gallons a day is obtained from a great many wells and springs widely spread throughout the State, but there are a few areas of heavily concentrated groundwater pumping. The solution to most problems that have accompained the greatly increasing use of ground water in Pennsylvania requires a knowledge of the principles of occurrence and movement of the water, and

a degree of familiarity of the geology of each problem area.

OCCURRENCE OF GROUND WATER IN PENNSYLVANIA

It is now generally recognized that there is a vast circulation of water from the sea to the land and back to the sea again -- the "hydrologic cycle" -- and that ground water represents a part of the cycle in which some of this water on its way back to the streams or the oceans is stored for a time in the rocks. The direct relation of ground water to the over-all pattern of water movement is vital, for it means that ground water is renewable, and that if the amount of water withdrawn from the ground does not exceed the amount put in, the supply may be depended upon indefinitely. Fortunately, the amount of water stored and in motion beneath the land surface of Pennsylvania is quite large. The streams, sustained during rainless periods by the overflow of the ground-water reservoirs, obtain about 40 percent of their total annual flow from seeps and springs along their water courses.

But it is not the total amount of water moving through the rocks of our State that concerns the individual well owner. He is more interested in how much he can pump out of his well without causing it to go dry, or without jeopardizing his neighbors' supply, and it makes little difference to him to know how much water is beneath his property, if the openings in the rock are too small to result in a satisfactory or perennial well yield. Therefore, ground-water problems are concerned not only with the broad, long-term aspects of demand versus the available supply, but with local features of the geology which may change from one well to the next.

The water-bearing rocks of Pennsylvania range in character from highly productive coarse sand and gravel to almost completely impermeable crystalline rocks such as diabase and granite. In the Piedmont section of southeastern Pennsylvania, and the Ridge and Valley Province of central and south-central Pennsylvania, the rocks have been altered in texture, or folded and faulted so that the character of the surface rocks is seldom the same throughout any large area. In the plateau areas of northeastern and western Pennsylvania, the rocks are generally flat lying and have extensive areas of outcrop, but the deep dissection by streams has exposed narrow bands of older rocks in many of the valleys. All these differences in the kind of rock from place to place are likely to mean differences in the water-bearing properties of the rocks between sites a short distance apart.

The more productive water-bearing rocks constitute only a small percentage of the area of the State, and the pattern of outcrop of such rocks is generally quite irregular. On the basis of present information, the rocks having the highest water yield in the State are the sand and gravel members of Cretaceous formations occurring in parts of Philadelphia and Bucks Counties, and the coarse Pleistocene outwash partially filling some of the valleys of northern and western Pennsylvania. The movement of water through such rocks is controlled by the size and arrangement of the pore spaces between the rock fragments -- that is, the primary porosity.

All other rocks in Pennsylvania, with the possible exception of some sandstone formations, have relatively low primary porosity, and the movement

of ground water is dependent upon the occurrence of cracks in the rock mass. Such secondary openings are characteristically random in size and spacing, so that closer wells adjacent may encounter few or many and therefore differ greatly in yield.

Probably the greatest differences in well yield occur in limestone and dolomite formations in which the rock openings may be enlarged by the dissolving action of ground water. Yields of wells that are side by side may range from dry holes to several thousand gallons a minute. It is generally not possible to determine the occurrence and location of water-bearing openings in such rocks prior to drilling.

Sandstone and conglomerate formations supply relatively good yields to wells, even though throughout much of Pennsylvania these rocks have lost their original high primary porosity. The yields of wells in these formations do not vary as greatly as those in limestone or dolomite.

The red shales and fine-grained sandstones of the Triassic belt of southeastern Pennsylvania provide fairly good yields, and the chances of a complete failure are less than in limestone or dolomite formations. This is due to the relatively numerous, though generally smaller, openings in the brittle shaly rocks, as compared to the larger but more widely scattered openings in more massive rocks.

Other than those enumerated above, the rocks of Pennsylvania are generally unfavorable for supplies greater than needed for domestic or rural uses. Most of these rocks are shaly and have small, irregularly spaced water-bearing openings.

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GROUND-WATER PROBLEMS OF PITTSBURGH AREA

The withdrawal of large quantities of ground water in areas of concentrated population and industry has resulted in several localized but nevertheless serious water problems. One of these area is Pittsburgh and the adjoining river valleys, in which many large manufacturing plants, principally steel, chemical-products, and electric-power, are located. More ground water is used in the Pittsburgh area than in any other locality in the State.

During summer, when the use of ground water for cooling is at a maximum, approximately 100 million gallons of water is pumped daily from sand and gravel deposits in the major river valleys of the Pittsburgh area. Several million gallons a day is pumped from an area of about 0.4 square mile underlying the heart of metropolitan Pittsburgh, the "Golden Triangle." Most of the modern wells produce large yields and many operate continuously throughout the summer. The result has been a decline in water level to the extent that additional supplies cannot be obtained except in the fringe areas of the pumping centers. Any significant further decline in the pumping level of existing wells will expose the upper part of some well screens to aeration, thereby accelerating rusting and incrustation.

The sand and gravel aquifer underlying the "Golden Triangle" is hydraulically connected with the permeable bed of the Allegheny River at Pittsburgh, and probably with the less permeable bed of the adjacent

Monongahela River. Water levels beneath the Triangle have been lowered 17 feet below the normal pool level of both rivers at Pittsburgh, so that water moves from the rivers into the sand and gravel aquifer throughout the year, at rates controlled by the permeability of the aquifer and the seasonal ground-water levels. During winter and spring months the pumping for cooling requirements is small, so that recharge exceeds the rates of withdrawal and ground-water levels recover to approximately the same height year after year. Thus, present pumping rates may be maintained so long as racharge remains effective, but the limit of summertime use appears to have been reached in parts of the area. However, studies by the Pennsylvania Topographic and Geologic Survey and the United States Geological Survey indicate that numerous other localities in the valleys of the Allegheny and Ohio Rivers are favorable for greater ground-water development.

The relation between the sand and gravel aquifers and the rivers of the Pittsburgh area makes possible the sustained withdrawal of a thousand gallons a minute or more from individual wells, but the well water, supplied largely by river infiltration, may have some undesirable temperature and chemical characteristics. Wells located close to the rivers may yield water having a yearly temperature variation of as much as 20° F., and will reflect on a reduced scale the same variations in dissolved-mineral concentration found in the river water. In a few instances, taste-producing chemicals, such as phenols, are not removed in the natural infiltration of the river water, and are contained in the well water. In almost all

cases however, bacteria and sediment in the river water are completely removed during infiltration to the wells.

GROUND-WATER PROBLEMS OF PHILADELPHIA AREA

About 100 million gallons of water is pumped daily from wells in the Philadelphia-Camden area, most of which is obtained from unconsolidated sands and gravels of the Magothy and Raritan formations of Cretaceous age. About a third of this quantity is withdrawn on the Pennsylvania side of the Delaware River, and the remainder from adjacent areas in New Jersey.

The principal water-bearing strata are continuous beneath the river, so that the ground-water problems are interstate in character and therefore make solution more difficult. Pumping from wells on one side of the river at Philadelphia will ultimately lower the water level in wells on the other side of the river. Therefore, it is of interest to each State what the other does in the use and conservation of the water of such interstate aquifers. The first step, of course, is to determine the hydrologic facts and then plan the further development of the resource on some mutually satisfactory basis.

Philadelphia is on the so-called Fall Line, which is the line of contact between the crystalline rocks of the Piedmont province to the northwest and the unconsolidated clay, sand, and gravel strata forming the Atlantic Coastal Plain to the southeast. This contact between the crystalline rocks of the Piedmont and the Coastal Plain sediments extends through central and southwestern Philadelphia in a generally northeast direction. As indicated by the slide (fig. 1), only about a quarter of the city of Philadelphia is

underlain by unconsolidated clays, sands, and gravels of the Coastal Plain. However, they extend beneath all of the adjacent Camden area in New Jersey. The widespread occurrence and greater thickness of these sediments on the New Jersey side of the Delaware River in the Philadelphia-Camden area explains the greater development of the resource on the New Jersey side. The following slide (fig. 2) shows the dip of the Coastal Plain sediments beneath South Philadelphia.

The reservoir volume of the principal aquifer on the Philadelphia side of the river is small in relation to the amount of water being withdrawn at present rates. It is estimated that at the prevailing rate of discharge the Raritan formation underlying Philadelphia and Delaware Counties in Pennsylvania would be dewatered completely within 5 years if there were no recharge. There can be no doubt, however, that recharge of large magnitude is effective, as shown by observations of water-level fluctuations that have been made in south Philadelphia since 1943. These observations indicate no consistent downward trend in the area as a whole to date. In a few small localities, water levels have declined in response to increased pumping.

At present, the conditions of ground-water recharge on the Philadelphia side of the river have not been definitely established. Undoubtedly, the Delaware and Schuylkill Rivers provide much of the recharge, but the location of the chief areas of river infiltration and the amount of such infiltration have not been determined. Very likely, a large part of the infiltrating river water moves first into the shallow Pleistocene sands and gravels and

is then transmitted into the underlying Cretaceous aquifer.

Other sources of ground-water recharge may be leaky and broken sewers and water mains, and several large disposal areas in south Philadelphia where drainage ditches and water-filled pits occur. Throughout much of this area, ground-water levels are somewhat below sea level, thus facilitating recharge wherever surface water is available.

In the Philadelphia area, the chemical quality of ground water obtained from sand and gravel aquifers presents a more serious problem than the over-all quantity of the supply. In recent years, the concentration of dissolved solids has been increasing, particularly iron, calcium, magnesium, bicarbonate and sulfate. In general, chloride has not increased, indicating that brackish water from Delaware Bay is not entering the aquifers. It is more probable that, although fresh water from the Schuylkill and Delaware Rivers supplies most of the recharge, highly concentrated waters from faulty sewers, from waste-disposal areas, and perhaps from a few industrial waste-disposal wells are being added to the river recharge in amounts sufficient to contaminate the whole supply. The chemical concentrations have reached such proportions that some well supplies may have to be abandoned, or expensive treating plants constructed. Water in the shallow Pleistocene sands and gravels of South Philadelphia has the highest concentrations of mineral matter, and will probably continue to pollute the underlying Cretaceous aquifers for years to come, even though most of the recharge is obtained from the better-quality water in the

Delaware and Schuylkill Rivers. The most serious problems of water quality in the Philadelphia area are restricted to south Philadelphia, including the United States Naval Base on League Island. Waters high in iron content are encountered in a few nearby localities. Elsewhere, particularly along the Delaware River in Bucks County just northeast of Philadelphia, conditions appear to be favorable for greatly increased development of ground water having generally satisfactory chemical quality.

POTENTIAL AREAS OF GROUND-WATER DEVELOPMENT

Many other areas in Pennsylvania have good potentialities for additional or new ground-water development. Chief among these are the valleys of streams in northern and northwestern Pennsylvania that contain glacial outwash sands and gravels. In many places these deposits are highly permeable, and wherever conditions are favorable for inducing surface-water infiltration by pumping from wells, large yields can be obtained and sustained more or less indefinitely. At present, these aquifers are being utilized on a substantial scale only in the area around Pittsburgh and at a few scattered localities to the north and east. Much greater use of them can be, and probably will be, made in the future.

GROUND-WATER STUDIES IN PENNSYLVANIA

Ground-water studies in Pennsylvania have been made cooperatively by the Pennsylvania Topographic and Geologic Survey and the United States Geological Survey for about 25 years. During most of the period only broad reconnaissance-type investigations were made, and it has been only since

1943 that detailed attention has been given to local problems or even county-wide areas.

As a result of the cooperative program, a number of ground-water reports have been issued, chiefly by the State Geological Survey, but the adequacy of the present information about this vital resource is lagging far behind the need. The stimulus of the current defense effort, added to the normal expansion of Pennsylvania's population and industry, has resulted in numerous ground-water problems. Statisfactory solutions to many of these problems cannot be readily obtained, owing to the lack of basic hydrologic information. It is apparent that a continuing and accelerated program of research on the ground-water resources of the State will have to be maintained if the further development of our ground-water supplies is to proceed on an intelligent and orderly basis.

FUTURE OF THE GROUND-WATER SUPPLY

Inadequate as our present information is, there is reason to be hopeful about the future of the resource. Observation of water levels in a broad network of wells during the past two decades clearly indicates that there has been no progressive decline in ground-water storage throughout Pennsylvania as a whole. A few areas where new large-scale ground-water developments are possible have been roughly determined. Detailed investigations are under way in the more important areas of heavy ground-water withdrawal and it is believed that, even in these localities, additional ground-water developments are possible, if properly planned.

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